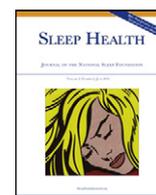




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## Sleep-deprived motor vehicle operators are unfit to drive: a multidisciplinary expert consensus statement on drowsy driving<sup>☆</sup>



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### ABSTRACT

**Objectives:** This article presents the consensus findings of the National Sleep Foundation Drowsy Driving Consensus Working Group, which was an expert panel assembled to establish a consensus statement regarding sleep-related driving impairment.

**Methods:** The National Sleep Foundation assembled an expert panel comprised of experts from the sleep community and experts appointed by stakeholder organizations. A systematic literature review identified 346 studies that were abstracted and provided to the panelists for review. A modified Delphi RAND/UCLA Appropriateness Method with 2 rounds of voting was used to reach consensus.

**Results:** A final consensus was reached that sleep deprivation renders motorists unfit to drive a motor vehicle. After reviewing growing evidence of impairment and increased crash risk among drivers who obtained less than optimal sleep duration in the preceding 24 hours, the panelists recognized the need for public policy guidance as to when it is certainly unsafe to drive. Toward this end, the panelists agreed upon the following expert consensus statement: "Drivers who have slept for two hours or less in the preceding 24 hours are not fit to operate a motor vehicle." Panelists further agreed that most healthy drivers would likely be impaired with only 3 to 5 hours of sleep during the prior 24 hours.

**Conclusions:** There is consensus among experts that healthy individuals who have slept for 2 hours or less in the preceding 24 hours are too impaired to safely operate a motor vehicle. Prevention of drowsy driving will

<sup>☆</sup> Endorsed by the National Sleep Foundation, AAA Foundation for Traffic Safety, American College of Chest Physicians, American College of Occupational and Environmental Medicine, and Society for Research on Biological Rhythms.

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require sustained and collaborative effort from multiple stakeholders. Implications and limitations of the consensus recommendations are discussed.

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## Introduction

More than 1 in 4 Americans report obtaining insufficient sleep on most nights, and less than 1 in 3 Americans report consistently obtaining sufficient sleep,<sup>1</sup> adversely affecting health, performance, and safety.<sup>2</sup> Insufficient sleep impairs neurobehavioral performance<sup>3,4</sup> and diminishes a driver's ability to safely operate a motor vehicle.<sup>5,6</sup> Drowsy individuals demonstrate diminished neurocognitive performance across virtually all domains related to performing an overlearned task such as driving. These performance decrements include delayed reaction time;<sup>7–10</sup> impaired visual-perceptual ability;<sup>10–16</sup> increased distractibility;<sup>10,17</sup> reduced ability to focus attention;<sup>10,18</sup> increased probability of eyelid closure and the risk of loss of situational awareness, even when the eyes remain open;<sup>10</sup> slowed cognitive processing;<sup>19–22</sup> memory impairment;<sup>18</sup> and deterioration in vigilance with time-on-task.<sup>6,23</sup> Indeed, the degree of impairment from sleep loss can be comparable to that of alcohol intoxication,<sup>3,5,24</sup> with 24 hours of continuous wakefulness resulting in impairments in neurobehavioral performance<sup>7,25,26</sup> similar to that induced by a blood alcohol concentration of 0.10 g/dL,<sup>3,5,27–30</sup> which is beyond the legal limit in all 50 US states. Just as with alcohol, sleep deprivation impairs judgment<sup>31–33</sup> and decision making,<sup>34</sup> such that sleep-deprived individuals often underestimate the impact that sleep deprivation is having on their performance. Ironically, instead of slowing response times to preserve accuracy, sleep-deprived individuals often increase speed at the expense of making more mistakes (ie, become “fast and sloppy”) and take greater risks.<sup>12,35,36</sup>

Multiple lines of evidence indicate that sleep-related impairment places drivers at increased risk for motor vehicle crashes and harm to others, causing about 20% of motor vehicle crashes and serious crash injuries.<sup>37–41</sup> In the United States, methodologically rigorous analyses of a nationally representative sample of crashes involving a passenger vehicle towed from the scene found sleepiness to be associated with 21% of all motor vehicle crashes in which a person was killed and 13% of those requiring hospitalization, causing 328,000 police-reported crashes, 109,000 injuries, and 6,400 deaths in the United States annually.<sup>39</sup> Given that these analyses did not include single-vehicle, fatal-to-the-driver truck crashes, an estimated one-third of which are fatigue related, the injury and death toll from drowsy driving crashes is likely much higher. Although robust evidence clearly establishes risks of drowsy driving, no expert consensus panel has previously been assembled to review the evidence and provide guidance to policy makers as to whether or not sleep deprivation alone can render an individual unfit to drive and, if so, the point at which sleep-related driving impairment categorically renders an individual unfit to operate a motor vehicle. This lack of a clear definition of when an individual is categorically too sleep deprived to drive has contributed to insufficient public awareness regarding the risks of this preventable behavior. Furthermore, in the absence of an easily quantifiable threshold for sleep-related driving impairment, drowsy driving as a factor in crash assessment or litigation can be argued to be a relative rather than absolute risk, despite the robust biological evidence that lack of sleep adversely affects driver neurocognitive performance. To advance education and prevention initiatives, clear direction is needed from the scientific community on what quantity

of sleep deprivation would categorically result in healthy drivers being too sleep deficient to operate a motor vehicle safely. Hence, the purpose of the current effort has been to review the evidence and develop such an expert consensus statements from the National Sleep Foundation's Drowsy Driving Consensus Working Group.

## Methods

### Participants

In order to ensure a wide range of perspectives regarding the impact of sleep deprivation on driving fitness, the National Sleep Foundation assembled an expert panel comprised of sleep experts as well as experts in other areas of science and medicine. The 16-member panel included representatives selected by stakeholder organizations (n = 9) as well as sleep experts selected by the National Sleep Foundation (n = 7). Stakeholder organizations that appointed representatives included the AAA Foundation for Traffic Safety, American Academy of Sleep Medicine, American College of Occupational and Environmental Medicine, American College of Preventive Medicine, American College of Chest Physicians, American Thoracic Society, Sleep Research Society, and Society for Research on Biological Rhythms.

### Procedures

#### Literature review

The National Sleep Foundation performed a systematic review of peer-reviewed literature from the years 2005 to 2015 using PubMed, Web of Science, and EBSCO CINAHL Plus databases. Search terms were agreed upon by the panel (see Table 1). Inclusion criteria for individual studies included English language and human participants of legal driving age (ie, > 15 years). Because the objective was to define drowsy driving in the general population, studies of individuals with sleep, medical, or psychiatric disorders were excluded. Study data (ie, sample characteristics, driver age, country, study design, measures, and results) were extracted and summarized in alphabetical tables. These tables and the corresponding full-text articles were distributed to panelists for review.

#### Panel deliberations and consensus voting

Panelists were first tasked with the question of whether acute sleep deprivation, when extended for long enough, would definitively render an individual unfit to drive. If this question were answered affirmatively, panelists were to be tasked with answering the question, “When considering the past 24 hours, how appropriate is it to say an individual is too impaired to drive if they only slept ‘X’ hours?” To answer these questions, panelists reviewed the assembled scientific literature, met a total of 4 times over a 3-month interval to discuss scientific findings, and participated in 2 rounds of voting. The first round of voting took place independently. The second round took place at a subsequent in-person meeting. During the in-person meeting, panelists heard presentations from nonpanelist experts in highway safety and law enforcement and reviewed the results from the first round of voting, which formed the basis for discussion.

**Table 1**  
Search terms used in the systematic review.

Sleep term	Outcome term
Sleep deprivation	Loss of function
Sleepiness	Cognitive ability
Drowsiness	Car/Motor vehicle crashes
Fatigue	Reaction time
Sleep extension	Accidents
	Driving
	Performance

Following deliberations, panelists participated in the second round of voting and built consensus for the recommendations.

Panelists voted on 7 possible sleep durations (ie, each possible hour from 0 to 6) for appropriateness and quality of evidence. Appropriateness was rated from 1 (ie, extremely inappropriate—many people will not be too impaired to drive at this level of sleep deprivation) to 9 (ie, extremely appropriate—the vast majority of people will be too impaired to drive at this level of sleep deprivation). Quality of evidence was rated from A to D (A, convincing scientific evidence; B, weaker scientific evidence; C, expert opinion; D, your own experience/opinion).

A modified Delphi RAND/UCLA Appropriateness Method<sup>42</sup> was used to synthesize scientific evidence and expert opinion. In this approach, expert consensus recommendations are defined as appropriate (panel median of 7–9, without disagreement), uncertain (panel median of 4–6 or any median with disagreement), or inappropriate (panel median of 1–3, without disagreement). Agreement occurs when at least 80% of votes fall within any 3-point range (ie, 1–3, 4–6, or 7–9). Disagreement takes place when more than 20% of votes fall outside any 3-point range.

## Results

### Literature review

One hundred eight searches, 36 in each database, produced a total of 4,859 nonredundant articles. Five hundred sixty-six were identified for full-text review, and 346 met inclusion criteria. A majority used an experimental ( $n = 302$ ) or observational ( $n = 36$ ) design. The most common research questions pertained to effects of drowsiness or sleep loss on driving ( $n = 102$ ), effects of sleep loss on neurocognitive performance ( $n = 80$ ), or drowsy driving detection mechanisms ( $n = 54$ ). Separate summary tables were developed for each topic area. A flowchart of literature search results is depicted in Fig. 1.

### Panel deliberations and consensus voting

In discussions that preceded the 2 rounds of voting, panelists were unanimous in concluding that acute sleep deprivation, when extended for long enough, would definitively render an otherwise healthy individual unfit to drive. Thus, panelists were tasked with answering the question, “When considering the past 24 hours, how appropriate is it to say an individual is too impaired to drive if they only slept ‘X’ hours?” As depicted in Table 2, the expert panel achieved consensus that a history of no sleep during the previous 24 hours, 1 hour or less of sleep during the previous 24 hours, or 2 hours or less of sleep during the previous 24 hours would render a healthy individual unfit to operate a motor vehicle. The expert panel also reached consensus that it would be inappropriate to conclude that a history of 6 hours of sleep in the prior 24 hours would render the vast majority of otherwise healthy, well-rested individuals unfit to operate a motor vehicle. Although the median Appropriateness rating for the 3-hour threshold was in the Appropriate range with a score of 7, with most panel members scoring in this range, 80% consensus among panel members was not quite reached for that threshold.

The median Appropriateness rating was in the uncertain range and there was disagreement (ie, 80% consensus was not reached) regarding the 4-, and 5-hour thresholds, principally because of the paucity of epidemiologic motor vehicle crash data available at those sleep durations. Although many panelists concluded from laboratory data that drivers would be too impaired by sleep loss to drive with only 3, 4, or 5 hours of sleep in the prior 24 hours, more than 20% of the panelists concluded that there were insufficient data from published epidemiologic studies of motor vehicle crashes to draw a conclusion as to whether or not the vast majority of drivers would be impaired if they had obtained only 3, 4, or 5 hours of sleep in the prior 24 hours. Concerns were raised about individual variability in factors such as physiological sleep need,<sup>43</sup> time of day,<sup>44–46</sup> and deployment of fatigue countermeasures such as light,<sup>47–49</sup> caffeine,<sup>50,51</sup> and other wake-promoting therapeutics.<sup>52–54</sup> Based on a review of currently available published epidemiologic data on sleep, performance, and motor vehicle crashes, the members of the expert panel established the following final consensus conclusion: “Drivers who have slept for two hours or less in the preceding 24 hours are not fit to operate a motor vehicle.”

## Discussion

Scientific investigations spanning more than a century confirm that sleep deprivation degrades human performance and is a leading, preventable cause of motor vehicle crashes. Yet to date, there has been no expert consensus as to whether sleep deprivation, *per se*, renders an individual unfit to drive, and if so, the sleep duration threshold below which an otherwise healthy individual could be deemed too sleep-deprived to drive safely. The National Sleep Foundation was concerned that the absence of formal expert consensus guidance regarding sleep deficiency and driving could impede the development of appropriate public awareness initiatives and policies designed to reduce the risks of an increasingly common and hazardous behavior that causes so many preventable fatalities and debilitating injuries. Therefore, the National Sleep Foundation conducted a systematic literature review, convened an expert panel, and used a modified Delphi RAND/UCLA Appropriateness Model to summarize expert opinion regarding these questions. Consensus was achieved that—even among otherwise healthy, well-rested individuals without a sleep disorder or other medical or psychiatric disease—individuals who have slept no more than 2 of the past 24 hours are too impaired to drive safely.

This project focused on sleep duration within the past 24 hours as a modifiable target to reduce the number of excessively sleepy drivers on the road. Insufficient sleep duration was selected because it is the most likely cause of observed sleepiness in the general population.<sup>55</sup> The 2-hour recommendation serves as a threshold for when the vast majority of healthy drivers will be too impaired to safely operate a motor vehicle. Panelists further agreed that most healthy drivers would likely be impaired with only 3 to 5 hours of sleep during the past 24 hours,<sup>38,56,57</sup> but insufficient epidemiologic data at each of the hourly time points together with concerns about individual variability in sleep need, time of day, and use of fatigue countermeasures precluded panelists from reaching 80% consensus at those values.<sup>43,44,48–54</sup>

It is important to realize that insufficient sleep duration is only one of many factors that influence sleep-related driving impairment. Other factors include physiological sleep need, cumulative sleep debt, biological time of day (ie, circadian phase), duration of wakefulness, sleep quality, the recency of the last sleep episode (ie, sleep inertia), time on task, environmental stimulation, the level of physical activity, age, use of agents with stimulant or hypnotic properties, light exposure, sleep disorders, and other medical and psychiatric conditions.<sup>58,59</sup> Untreated sleep disorders are a major contributor to drowsy driving, as most of the 50 to 70 million Americans estimated to suffer a sleep

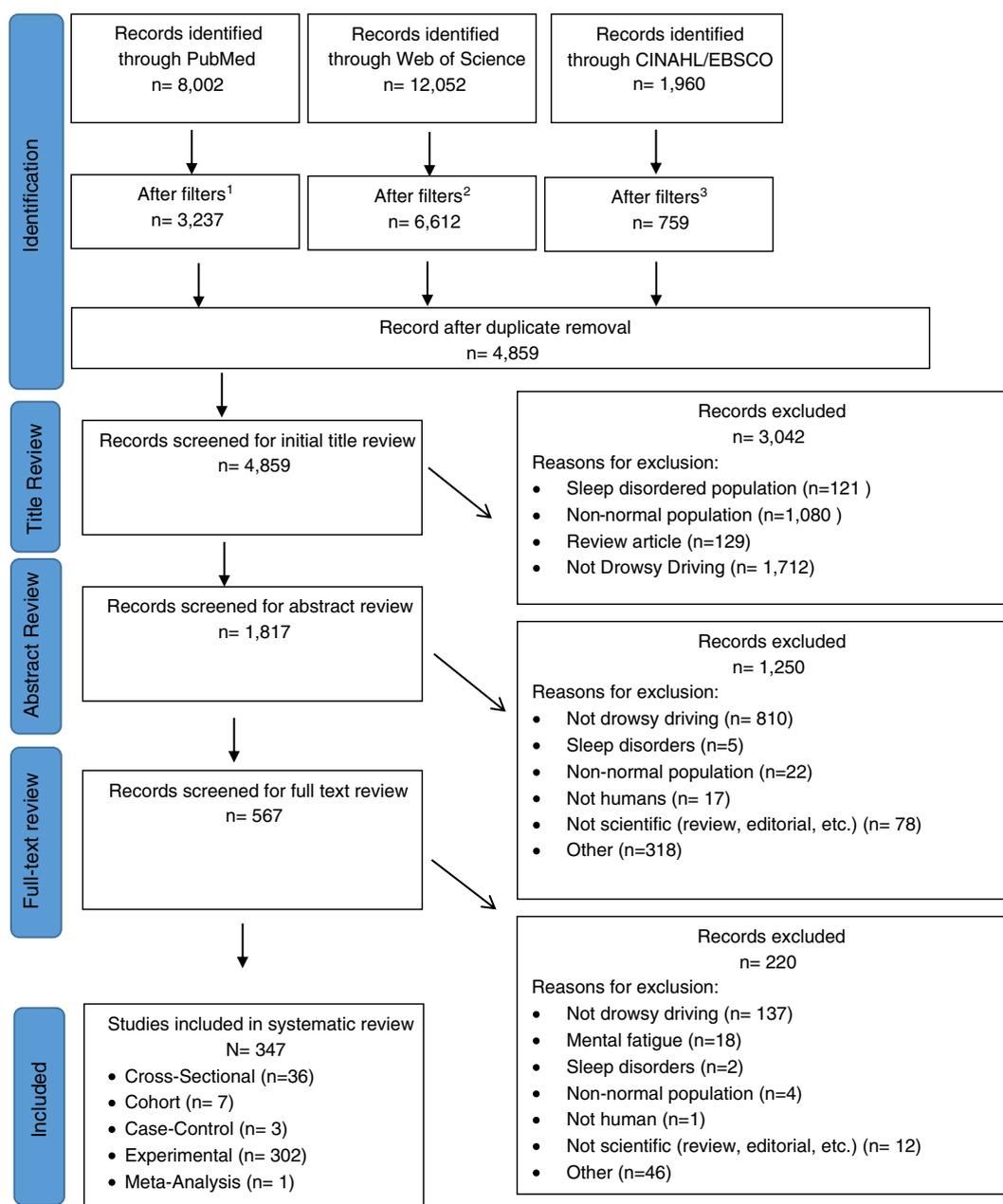


Fig. 1. Flowchart of literature search results.

**Table 2**  
Results of expert panel voting.

Sleep duration (h)	Median Appropriateness rating	Agreement threshold (80%)	Decision
0	9	Agree	Appropriate
1	9	Agree	Appropriate
2	8.5	Agree	Appropriate
3	7	Disagree	Uncertain
4	5.5	Disagree	Uncertain
5	3	Disagree	Uncertain
6	1.5	Agree	Inappropriate

disorder remain undiagnosed and untreated.<sup>60</sup> Sleep disorders along with many medical and psychiatric disorders can result in drowsiness and fatigue, and it must be emphasized that these consensus recommendations apply only to healthy individuals. Individuals with such disorders are even more vulnerable to the effects of sleep deprivation.<sup>61</sup> Furthermore, medication side effects, particularly residual grogginess from sedative hypnotics, can cause drowsiness and impair the ability to drive. Nontraditional work schedules (eg, night shift work) result in worsened sleep quality and shortened sleep duration, increasing risk for sleep-related driving impairment for the 12 million working US adults who work on the night shift or on irregular or rotating shift schedules.<sup>59</sup> Finally, situational factors such as driving for an

extended period of time, driving long distances, and driving at night also increase the risk for sleep-related motor vehicle crashes.

Prevention of drowsy driving crashes will require the collaborative effort of multiple stakeholders, including both public and private institutions and employers. At the policy, regulatory, and judiciary levels, the current expert consensus recommendations provide needed guidance that—like alcohol intoxication—sleep deprivation (operationally defined as 2 hours or less of sleep in the prior 24 hours) impairs driving performance, rendering sleep-deprived individuals unfit to operate a motor vehicle. This conclusion has important public policy implications and supports model legislation that was previously endorsed by the Boards of Directors of the National Sleep Foundation, the Sleep Research Society, and the American Academy of Sleep Medicine, adding sleep deficiency (less than 2 hours of sleep in the prior 24 hours) to the list of conditions (ie, operating under the influence of intoxicating liquors, narcotics, vapors of glue, etc) considered negligent in the operation of a motor vehicle.<sup>62</sup> At the level of individual drivers, these recommendations can serve as a cornerstone for public and employee awareness and education campaigns regarding the dangers of driving while sleep deprived. Drivers should be responsible for ensuring that they have the opportunity to obtain adequate sleep and then use that opportunity to do so before getting behind the wheel of a car or truck. Establishment of the firm principle that a sleep-deprived driver is unfit to drive is an important foundational step toward achieving a much needed “collective efficacy” regarding drowsy driving, wherein all drivers and society as a whole find this behavior unacceptable and police themselves from driving while sleep deprived.

The current findings also suggest several areas for future research. First, it is essential to delineate more clearly the relative risk of crash involvement associated with varying levels of acute and chronic sleep loss in healthy individuals and in individuals with sleep and medical disorders. This will require both controlled experiments and real-world observations, including enhanced governmental acquisition of driver sleep histories in representative subsamples of crashes. Second, improved ability to detect and record drowsy driving is needed. Finally, there is an urgent need for the development, dissemination, implementation, and evaluation of evidence-based drowsy driving education and prevention interventions, including legislation specifically designed to improve drowsy driving education and prevent sleep-related crashes.<sup>63</sup>

Scientists and policymakers are often required to make decisions based on the best available evidence. The RAND/UCLA appropriateness method is a well-recognized technique for systematically analyzing experts' interpretations of extant research. This systematic process enables conclusions to be derived by experts based on a review of the extensive evidence. In the current project, expert panels advanced scientific understanding by reviewing the literature, deliberating, and voting on the appropriate threshold for when healthy individuals are categorically too sleep-deprived to drive safely. Consensus was reached that drivers who have slept for 2 hours or less in the preceding 24 hours are not fit to operate a motor vehicle. This represents the first scientific expert consensus determination that sleep deprivation, *per se*, can render an otherwise healthy individual unfit to drive a motor vehicle.

## Disclosures

C.A.C. has received consulting fees from or served as a paid member of scientific advisory boards for Amazon.com, Inc; A2Z Development Center, Inc; Bose Corporation; Boston Celtics; Boston Red Sox; Cleveland Browns; Institute of Digital Media and Child Development; Jazz Pharmaceuticals, Inc; Merck Sharpe and Dohme; Purdue Pharma; Quest Diagnostics; Samsung Electronics; Teva Pharmaceutical Industries Ltd.; Koninklijke Philips Electronics, N.V.; Novartis; and

Vanda Pharmaceuticals, Inc. C.A.C. owns an equity interest in Somnus Therapeutics, Inc, and Vanda Pharmaceuticals, Inc, and has received research/education support from Cephalon, Inc; Jazz Pharmaceuticals; Mary Ann and Stanley Snider through Combined Jewish Philanthropies; National Football League Charities; Optum; ResMed; Philips Respironics; the San Francisco Bar Pilots; Simmons; Schneider, Inc; Sysco; and Vanda Pharmaceuticals. C.A.C. has received royalties from McGraw Hill, Penguin Press/Houghton Mifflin Harcourt, and Philips Respironics, Inc, for the Actiwatch 2 and Actiwatch Spectrum devices. C.A.C.'s interests were reviewed and are managed by Brigham & Women's Hospital and Partners HealthCare in accordance with their conflict of interest policies. C.A.C. has received lecture fees from Harvard School of Public Health; National Institute of Diabetes and Digestive and Kidney Diseases, National Sleep Foundation, and the New England College of Optometry. The Sleep and Health Education Program of the Harvard Medical School Division of Sleep Medicine (which C.A.C. directs) has received Educational Grant funding from Cephalon, Inc; Jazz Pharmaceuticals; Takeda Pharmaceuticals; Teva Pharmaceuticals Industries Ltd; Sanofi-Aventis, Inc; Sepracor, Inc; and Wake Up Narcolepsy. C.A.C. is the incumbent of an endowed professorship provided to Harvard University by Cephalon, Inc, and holds a number of process patents in the field of sleep/circadian rhythms (eg, photic resetting of the human circadian pacemaker). Since 1985, C.A.C. has also served as an expert witness on various legal cases related to sleep and circadian rhythms, including those involving the following commercial entities: Bombardier, Inc; Continental Airlines; Greyhound; and Purdue Pharma, L.P., as well as matters related to commercial drivers used by Celadon, Crete Carrier Corporation, FedEx, United Parcel Service, and other commercial carriers. E.M.W. has moderated noncommercial scientific discussion for Merck and is an equity stakeholder in WellTap, which provides online patient screening and education. L.B. has served as a consultant for Tovec, Sysco Trucking, and San Jose State University Foundation. W.D. is a shareholder of ResMed, Inc. S.W.R. reports that he has served as a consultant through his institution to Vanda Pharmaceuticals, Philips Respironics, EdanSafe, National Transport Commission, Rail, Bus and Train Union, Australian Workers' Union, Tontine Group, Transport Accident Commission, Meda Consumer Healthcare, and New South Wales Department of Education & Communities, and has through his institution received research grants from Vanda Pharmaceuticals and Philips Respironics, and reimbursements for conference travel expenses from Vanda Pharmaceuticals. He serves as a consultant to, and is a Program Leader for, the Cooperative Research Centre for Alertness, Safety, and Productivity. His institution has received equipment donations or other support from Optalert, Compumedics, Philips Lighting, and Tyco Healthcare. He was President and a Director of the Australasian Sleep Association. He has also served as an expert witness and/or consultant to shift work organizations. R.P. has served on an advisory board for Jazz Pharmaceuticals. B.P. is the president of American College of Chest Physicians and is on the advisory board for the Sleep Board Review and SEEK, a study product for the pulmonary medicine board subspecialty examination.

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