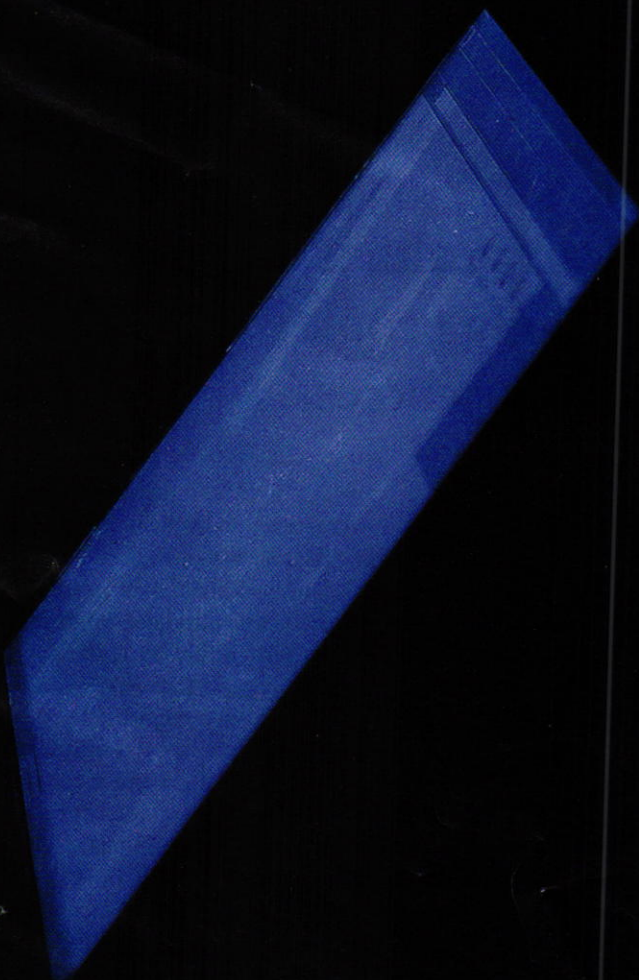


The waking wounded



Tempted to read just one more email before you sleep? Don't. New research finds that not getting enough sleep — whether because of our insatiable desire for digital media or more traditional sleep disturbances — has far-reaching effects on physical and psychological health.

BY DR. SIRI CARPENTER



Orfeu Buxton, PhD, has just pulled his first all-nighter in six years, and he is tired. Earlier in the week, he stayed up all night for the final push on a grant application to the National Institute on Aging, coordinating a small crew who worked past dawn. Two days later, he's still exhausted and says he feels "ghostlike." He may also be a little embarrassed. As a sleep researcher, he should know better. "Maybe next time the irony will be too powerful," says Buxton, a neuroscientist in the Harvard University School of Medicine and the Division of Sleep Medicine of Brigham and Women's Hospital in Boston.

Buxton has plenty of company in his sleeplessness. Technology keeps serving up ever more enticing ways to put off bedtime — whether for entertainment or work — and in this era of economic uncertainty, job and financial stress keeps millions of Americans from getting a good night's sleep. Data on just how much the nation sleeps are imprecise, but among scientists, the consensus is that it's not enough. According to the Centers for Disease Control and Prevention (CDC), a quarter of U.S. adults say they don't get enough sleep at least half of the time. Research indicates that a quarter of teens get no more than 6.5 hours, far short of the nine or so hours most need. And a 2012 study from the CDC's National Institute for Occupational Safety and Health found that 41 million workers get fewer than six hours of sleep a night — significantly less than the seven to nine hours that experts recommend.

Researchers are unlocking the unsettling and far-reaching health consequences of losing all of this sleep. Some are obvious: According to the National Highway Traffic Safety Administration, for example, driver fatigue results in 100,000 crashes annually, leading to 1,550 deaths and more than 70,000 injuries.

More subtly, a large body of research now shows that chronically getting too little sleep disrupts many aspects of physical health, including hormone regulation, glucose metabolism, insulin resistance, inflammation processes, pain perception and immune function, to name a few.

In a guest editorial for *Sleep Medicine Reviews*, clinical psychologist Michael Grandner, PhD, of the Center for Sleep and Respiratory Neurobiology at the University of Pennsylvania, argued that along with diet and exercise, "sleep should be considered a key domain of healthy behavior." The same sort of public health resources devoted to education and interventions promoting activity and healthy eating, he and others argue, should also be directed at promoting healthy sleep.

With the mounting evidence that normal variations in sleep

can lead to poorer health, both the public health community and the media now seem to be waking up to the importance of sleep in our overall health. Fixing some sleep problems may seem as simple as following a few key "sleep hygiene" guidelines, but there is still a disconnect. The temptation to check one more message, read one more article or watch one more episode is powerful and insidious.

Every hour counts

In 1938, University of Chicago physiologist Nathaniel Kleitman, PhD, and a colleague sequestered themselves for 32 days in the bowels of Kentucky's Mammoth Cave to reset their bodies to a 28-hour clock and track the physical and psychological consequences of doing so. Kleitman, whose first paper on sleep deprivation was published in 1923, is considered the founder of sleep research in the United States. His research on circadian processes and his co-discovery of the rapid-eye movement, or REM, stage of sleep in the early 1950s were foundational developments. (Kleitman's

willingness to tamper with his own sleep seems, paradoxically, not to have harmed his health — he lived to the age of 104.)

Throughout Kleitman's life and since, the University of Chicago (UC) remained a center of sleep research. In 1963, Kleitman's colleague Allan Rechtschaffen, PhD, described the first sleep disorder, narcolepsy. In another influential series of studies conducted during the 1980s, Rechtschaffen showed that sleep-

deprived rats eventually died from the collapse of their thermoregulatory systems.

But despite such striking demonstrations of sleep's importance to basic physiological functioning, sleep science struggled for recognition. Sure, most people understood that you might not be your sharpest after a poor night's sleep. And for sleep researchers, it seemed obvious that anything we did for a third of our lives was probably important. But for the most part, popular culture and academia alike just yawned and declared: "It's only a quarter [of your life] if you're tough." And researchers didn't have much of a comeback.

But they were on the trail. In 1991, UC sleep medicine specialist Eve Van Cauter, PhD, reported in the *Journal of Clinical Investigation* that subjecting healthy people to total sleep deprivation threw off their glucose tolerance and insulin resistance and that these issues resolved after recovery sleep. Since then, dozens of studies have elaborated on that finding.

For years, laboratory sleep research focused on extreme kinds of sleep loss — the kind of total deprivation that Buxton experienced when he pulled his all-nighter. But outside

One way sleep may thwart health is by skewing people's dietary choices.

the nation's sleep labs, far more common than total sleep deprivation is what researchers variously call *partial sleep loss*, *sleep restriction* or *short sleep*. Whatever they call it, they're referring to chronically cutting one's sleep short by just an hour or two a night. The first study to look closely at the health effects of partial sleep was published in *The Lancet* in 1999. In that study, Van Cauter's team found that levels of leptin, a hormone that regulates hunger and appetite, dropped 19 percent during a period of partial sleep deprivation.

The cardiometabolic trap

Subsequent studies have confirmed the effects of partial sleep loss on hormone regulation and have led to a burgeoning of research on the role of sleep in obesity, diabetes and cardiovascular disease — a tangled triumvirate of sickness and mortality that are key elements of what researchers sometimes refer to as cardiometabolic disease. In a 2012 article published in the *American Journal of Human Biology*, UC biomedical anthropologist Kristen Knutson, PhD, reviewed research on sleep and cardiometabolic health and concluded that sleep restriction leads to “substantial and clinically significant changes in appetite regulation, hunger, food intake, glucose metabolism and blood pressure control.” Knutson also found a significant association between short sleep duration (less than six hours per night, in most studies) and either more obesity or a higher body mass index. Adolescents and children showed a stronger association, suggesting they may be especially vulnerable to the effects of lost sleep.

One way in which lack of sleep may thwart cardiometabolic health is by skewing people's dietary choices. In a 2011 study published in the *American Journal of Clinical Nutrition* by a large multicenter team, healthy men and women who were restricted to just four hours of sleep per night over six nights took in significantly more calories, particularly from fat, than their well-rested counterparts — and they didn't make up for it by burning more energy.

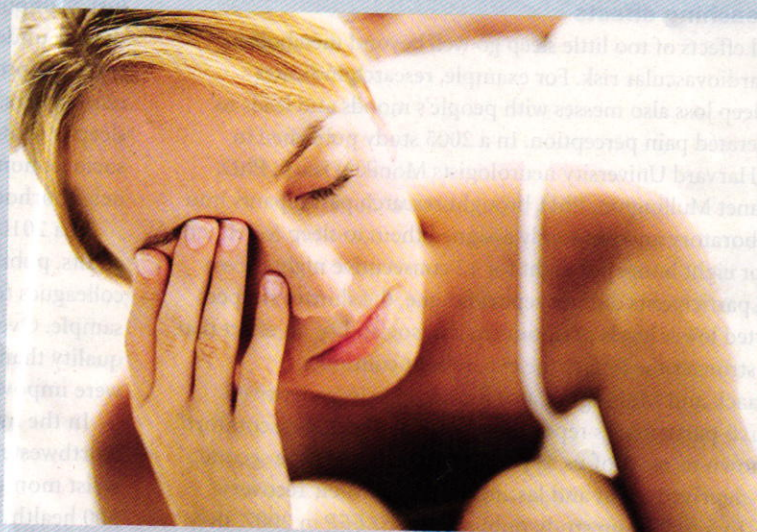
Another study, conducted by Arlet Nedeltcheva, MD, and colleagues at UC and published in the *American Journal of Clinical Nutrition* in 2009, found that adults who were allowed to sleep only 5.5 hours per night for two weeks indulged in more snacks than their counterparts who enjoyed 8.5 hours of sleep each night. Likewise, in a 2012 yet-to-be-published study that drew on data from the CDC's 2007–08 National Health and Nutrition Examination Survey, Knutson, Grandner and colleagues mapped dietary patterns to

sleep complaints including difficulty falling asleep, difficulty staying asleep, non-restorative sleep and daytime sleepiness. Every complaint, they found, was significantly associated with greater total caloric intake.

In a 2012 study published in the *Annals of Internal Medicine*, a team of UC researchers uncovered a molecular clue to how lack of sleep might promote diabetes: Fat cells in people who don't get enough sleep have a 30 percent reduced ability to respond to insulin. Fortunately, the biochemical processes that sleep loss sets in motion may be reversible, at least if skipping sleep doesn't become a lifelong habit. In September, psychologist Karen Matthews, PhD, of the University of Pittsburgh, reported in *SLEEP* that if teens who normally got six hours of sleep per night were allowed just one extra hour of sleep, their insulin resistance improved by 9 percent.

Now, Till Roenneberg, PhD, of the University of Munich's Institute of Medical Psychology, has introduced a new wrinkle to the sleep literature: The physiological chaos that ensues when the body's internal clock, which is set by our exposure to sunlight and night-time darkness, is out of sync with our “social clocks,” which are set by the demands and temptations of modern life, from early-morning alarms to the late lure of “The Daily Show.” Roenneberg calls this familiar brand of circadian disruption “social jet lag,” noting that staying up later and sleeping later on weekends, then wrenching one's schedule back in time at the beginning of

Less money, less sleep



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To learn more about the link between socioeconomic status and sleep, visit our digital edition at www.apa.org/monitor/digital/sleep-and-ses.aspx.

each workweek, is akin to traveling from New York to Denver every Friday night, then returning every Monday morning.

In a study in *Current Biology* in 2012, Roenneberg and colleagues in Germany and the Netherlands surveyed 65,000 European adults to understand their sleep habits, health behavior and physical health. They found that 69 percent of respondents suffered from at least an hour of social jet lag each week, and a third of participants regularly suffered at least two hours of social jet lag. Like short sleep, social jet lag appears to be a significant health hazard. Even after the researchers accounted for sleep duration and other characteristics that affect health, people who suffered social jet lag were more likely to be overweight than those whose social and biological clocks were more in sync. And among people who were overweight, more extreme social jet lag was associated with much greater risk of obesity.

The importance of considering both the duration and the timing of sleep is further bolstered by a study by Buxton and colleagues, which showed that disrupting people's internal clocks as well as partially restricting their sleep could increase risk of both diabetes and obesity. In the research, reported in *Science Translational Medicine* in 2012, Buxton's group controlled the sleep and diet of 21 participants for six weeks, cutting their sleep by about two hours per night and subjecting them to an artificial 28-hour circadian day for three weeks. The participants' pancreatic function went "haywire," Buxton says, causing hyperglycemia after a breakfast meal, which over time leads to increased risk of diabetes. The circadian and sleep disruption also caused a metabolic slowdown that, if not counteracted, would cause a weight gain of about 10 pounds a year.

Far-reaching effects

The ill effects of too little sleep go well beyond metabolism and cardiovascular risk. For example, research indicates that sleep loss also messes with people's moods and leads to exaggerated pain perception. In a 2005 study published in *Pain*, Harvard University neurologists Monika Haack, PhD, and Janet Mullington, PhD, brought research participants into the laboratory and randomly assigned them to sleep for either four or eight hours per night for 12 consecutive nights. Even when participants did not report fatigue, the shorter sleepers reported lower levels of optimism and sociability, an effect that grew stronger the longer the experiment continued.

Haack and Mullington also found that sleep-deprived research participants reported increasing "bodily discomfort" — known to most of us as pain — starting after the second sleep-deprived night and lasting until after their recovery sleep. In a follow-up study published in *SLEEP* in 2007, they found that sleep deprivation caused increases in blood plasma levels of interleukin-6 (IL-6), a signaling molecule that contributes to pain sensitivity. The more bodily discomfort that participants reported in Haack and Mullington's study, the more their IL-6 levels were elevated. Even though the

increases in IL-6 were typically small, the researchers argued that they may play an important role in exacerbating pain.

Sleep's importance is now felt across more areas of medicine. In a 2012 study in the *American Journal of Geriatric Psychiatry*, psychologist Kathi Heffner, PhD, of the University of Rochester Medical Center, and colleagues reported that when healthy men and women age 50 and older were given stressful cognitive tasks, those who were poor sleepers showed a larger IL-6 response — a marker of inflammation — than did good sleepers.

Other research shows that sleep apnea and other sleep-disordered breathing (SDB) conditions are associated with higher cancer incidence as well as more deaths from cancer. In a study published in the *American Journal of Respiratory and Critical Care Medicine* in 2012, the University of Wisconsin's F. Javier Nieto, MPH, MD, PhD, and colleagues found that the incidence of cancer deaths in patients with severe SDB was five times higher than in those without the disorder.

Even the body's immune response to vaccines is weaker if the recipient is short on sleep, according to a recent study in *SLEEP* led by University of California, San Francisco, health psychologist Aric Prather, PhD. The researchers gave 125 healthy adults a three-dose series of hepatitis B shots, monitoring their sleep duration and quality for a week before and after each shot. Results showed that people who slept less during the study had lower antibody response to the vaccine, potentially increasing their susceptibility to hepatitis infection.

Who lacks sleep?

Just as important as understanding the effects of insufficient sleep is understanding who is most at risk, so that efforts to fix the problem can be concentrated most effectively. In recent years, sleep researchers have found that insufficient sleep is related to a constellation of social factors, including socioeconomic status, race and ethnicity, and workplace and neighborhood conditions.

In a 2010 survey of 9,714 randomly selected Pennsylvania adults, published in *BMC Public Health*, Grandner and colleagues found a significant "sleep disparity" within the sample. Overall, minority respondents had poorer sleep quality than white respondents. However, among those who were impoverished, whites unexpectedly fared worse.

In the most refined look at sleep and race to date, Northwestern University's Mercedes Carnethon, PhD, used wrist monitors to study sleep patterns in a random sample of 500 healthy U.S. adults. Results showed that after accounting for potentially confounding cardiovascular disease risk factors and education levels, black adults slept an average of only 6.8 hours per night, compared with 7.4 hours, on average, for whites. Asians and Hispanics didn't fare much better — they slept an average of 6.9 hours per night.

Workplace conditions also appear to exert power over one's sleep — or lack thereof. In a 2010 study in the *Journal of Occupational Health Psychology* that looked at sleep duration and cardiovascular disease risk in 393 health-care workers, Buxton and colleagues found that workers with less-supportive managers — as defined by their “openness and creativity in dealing with employee work-family needs” — got 29 minutes less sleep daily and were twice as likely as those with more supportive bosses to have two or more risk factors for cardiovascular disease. “That’s a powerful effect of a supervisor on their low-wage employees,” Buxton says.

Where one lays one's head is another important risk factor, says Lauren Hale, PhD, of Stony Brook University School of Medicine. She suspects that people in low-income neighborhoods can't sleep as well due to a constellation of physical and psychological hazards — from high-traffic streets and inadequate heating and cooling to food insecurity and landlord hassles. In a study published in *Social Science & Medicine* in 2012, Hale and colleagues examined the associations among neighborhood conditions, sleep quality and health in using data from the Survey of the Health of Wisconsin. People who reported they lived in neighborhoods with more physical and social disorder tended also to report poorer sleep quality, perceive their health as poorer and experience more symptoms of depression.

By statistically controlling for numerous demographic and health factors, Hale's team found that people's sleep quality accounted for about 20 percent of the association between neighborhood quality and both self-rated health and depression. “The determinants of poor sleep fall along lines of social disadvantage,” Hale concludes. “My hunch is that it's bigger than just A/C and noise. It's more about autonomy. If people have choices and control over their lives, they have more ability to shut down at night and sleep when they need to sleep and wake up when they need to wake up.”

Findings that link sleep deficiencies to social factors signal a need for a more sophisticated public health approach to promoting healthy sleep, sleep researchers believe. “We have to understand the social and environmental context of health behaviors before we can intervene on them,” Grandner says.

For some people, simple changes to “sleep hygiene” can go a long way toward ensuring a good night's sleep. But it would be naïve to believe that across the board, simply educating people about the importance of healthy sleep habits — avoiding caffeine late at night, having a consistent bedtime routine, eschewing the seductive blue light of the laptop late at night — will be sufficient to correct endemic problems that lead to insufficient sleep.

Strength in sleep

“I'll sleep when I'm dead.”

You've no doubt heard it said, and possibly even said it yourself. You were joking, and projecting a certain brio, the notion that sleep is a luxury.

Buxton doesn't see the humor, and he has a quick retort. “If you want [death] to come sooner,” he responds. Sleep, he argues, can be an incredibly strong indication “of things going well or things going wrong.”

Even as the causes and consequences of insufficient sleep become better understood, developing and implementing behavioral interventions to improve sleep are likely

to be major challenges. Grandner speculates that doing so will require a community-based behavioral strategy, similar to campaigns used to improve diets and promote regular exercise.

Can we change health at a societal level by changing sleep patterns?

“I think it's possible,” Hale says. “Do I think it's easy? No.” But she does think it's important to try to tackle the deteriorating length and quality of sleep wrought by new devices, new media and new societal pressures. Recently, she came across a disturbing video in which a motivational speaker tells teens, “If you're going to be successful, you've got to be willing to give up sleep. ... You've got to be willing to work off of three hours of sleep, two hours ... because if you go to sleep, you might miss the opportunity to be successful.”

“I hate the ethos that sleep is for the weak,” she says. “That's very shortsighted, and the wrong message to be sending adolescents. In the long run, everybody is better off if they go to bed at a reasonable hour.” ■

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