Sleep, Health, and Society

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KEY POINTS

• Insufficient sleep and sleep disorders are highly prevalent in the population and are associated with significant morbidity and mortality.

• Adverse outcomes of insufficient sleep and/or sleep disorders are weight gain and obesity, cardiovascular disease, diabetes, accidents and injuries, stress, pain, neurocognitive dysfunction, psychiatric symptoms, and mortality.

• Exposure to sleep difficulties varies by age, sex, race/ethnicity, and socioeconomic status; significant sleep health disparities exist in the population.

• Societal influences, such as globalization, technology, and public policy, affect sleep at a population level.

CONCEPTUALIZING SLEEP IN A SOCIAL CONTEXT

Sleep represents an emergent set of many physiologic processes under primarily neurobiological regulation that impact many physiologic systems. As such, many advances have been made over the past several decades that have shed light on these neurobiologic mechanisms of sleep- wake,[1-4] with especially exciting work in the area of functional genetics/genomics[5,6] and molecular mechanisms of sleep-related regulation.[7-9] Still, the phenomenon of sleep exists outside the nucleus and the cell membrane—sleep is experienced phenomenologically. Sleep is a biological requirement for human life, alongside food, water, and air. Like consumption of food and unlike breathing air, achieving this biological need requires the individual to engage in volitional behaviors. Although many of these behaviors are genetically and intrapersonally driven (eg, it is not a coincidence that most people prefer to sleep at night, and that most humans sleep in a stereotypical posturally recumbent manner), there is still much variability in sleep behaviors and practices. Because of this, sleep is also socially driven, dictated by the environment, and subject to interpersonal and societal factors.

Sleep in most humans occupies between 20% and 40% of the day. Even prehistoric evidence suggests the importance of sleep in human life[10]; this is consistent with archaeological and historical accounts of sleep having a prominent and important role in even early human society. Sleep was a universal phenomenon that was inescapable and thus was incorporated in social structures. In this way, sleep became not just a set of physiologic processes, but one represented in sociocultural structures. Thus, the timing, environment, and constraints surrounding sleep across human societies began to differ between rich and poor, powerful and powerless, rural and urban, and so forth. As sociologist, Simon Williams, writes, "Where we sleep, when we sleep, and with whom we sleep are all important markers or indicators of social status, privilege, and prevailing power relations."[11]

Conceptualizing Downstream Consequences

The downstream consequences of insufficient sleep duration and/or inadequate sleep quality (including sleep disorders and circadian misalignment of sleep) are varied and impact many physiologic systems. Conceptualizing these is therefore difficult. One way to do so is to acknowledge domains of outcomes and recognize the overlaps and relationships among those domains. The recent position statement from the American Academy of Sleep Medicine and Sleep Research Society[12-15] broadly categorizes effects of insufficient sleep as pertaining to the following categories: general health, cardiovascular health, metabolic health, mental health, immunologic health, human performance, cancer, pain, and mortality.

Conceptualizing Upstream Influences: Social Ecological Models

Upstream social and environmental influences on sleep are also complex and overlapping and implicate many potential pathways. With this in mind, a social-ecological framework may be best suited to describe this relationship. The social-ecological model was originally developed to describe the complex ways that an individual's behavior related to their health is a product of influences at the individual level, but that the individual operates in the context of social structures that they are a member of, but these structures exist outside of the individual.[16] For example, an individual has genetic, psychological, and other reasons for consuming a healthy diet, but social structures that they are a part of but exist outside of that individual (like their neighborhood, which may have healthy food; their job, which may or may not have a cafeteria; their family, which may have other food restrictions, and so forth) play a role in that individual's behavior.

This model may also be appropriate for understanding sleep. At the individual level, factors that influence a person's sleep include that person's genetics, knowledge, beliefs, and attitudes about sleep, their overall health, and so forth. The individual level is embedded, though, within a social level, which includes the home (family, bedroom, and so forth), neighborhood, work/ school, socioeconomics, religion, culture, race/ ethnicity, and other factors. All of these factors influence sleep through the individual. Still, this social level is embedded within a societal level, which includes social forces that exist outside of things like work, family, and neighborhood, including globalization, geography, technology, public policy. These factors, at this high of a level, filter through the social structures that eventually come to bear on the individual. For example, as society embraced the Internet, it caused changes in jobs and families, which led to individual changes that play a role in sleep (such as social networking in bed or browsing the Internet late at night). **Fig. 1** displays a social-ecological model of sleep, illustrating of sleep duration and quality are influenced by factors at the individual level, which is embedded within a social level, which itself is embedded within a societal level. **Fig. 2** brings these models together, with sleep as the fulcrum (shown in **Fig. 1)** at the interface of upstream social-environmental influences (shown in more detail in **Fig. 3)** and downstream health and functional outcomes (shown in more detail in **Fig. 2).** This model brings all of these concepts together to describe how sleep is influenced by these societal factors and how those influences, through sleep, may play a role in health. The first version of this model was published in 2010,[17] and it has appeared in several other publications since then.[14,18-20] It may serve as a useful framework for conceptualizing the physiologic processes of sleep in a social context.

Fig. 1. Social ecological model of sleep.

POPULATION PREVALENCE OF SLEEP DURATION AND SLEEP DISTURBANCES *Sleep Duration*

Population estimates of habitual sleep duration are variable, because few studies used identical methods to derive estimates. The best populationlevel estimates come from 1 of 3 sources: (1) self- reported time use data, (2) self-reported typical weeknight/work-night sleep, and (3) self-reported average sleep within 24 hours. For US-based data, the primary sources of these estimates come from the American Time Use Survey (ATUS) for time use data, the National Health Interview Survey or National Health and Nutrition Examination Survey (NHANES) for weeknight sleep, and the Behavioral Risk Factor Surveillance System (BRFSS) for 24-hour sleep.

Longitudinal analysis of time-use diaries by Knutson and colleagues[21] found that the proportion of Americans reporting short (<6 hours) sleep was 7.6% in 1975 and 9.3% in 2006. Bin and colleagues[22] examined similar time use data from several countries and showed that, in the United States, sleep duration has generally declined since the 1960s, if only by a small amount. The most comprehensive analysis of time use data related to sleep was recently undertaken by Basner and colleagues.[23] They report that the age group that receives the most sleep is young adults (8.86 hours on weeknights and 10.02 hours on weekends) and that those aged 25 to 64 report about 0.70 to 0.99 fewer hours on weeknights and 0.62 to 1.16 fewer hours on weekends. Prevalence of sleep duration by hour is not reported, though.

Fig. 2. Social ecological model of sleep and health.

Fig. 3. Health belief model.

Regarding weekday sleep duration, Grandner and colleagues[24] reported census-weighted estimates of sleep duration using the 2007 to 2008 wave of the NHANES. They report that 6.2% of the population reports less than 5 hours of sleep, 33.78% reports 5 to 6 hours of sleep, 52.68% report 7 to 8 hours of sleep, and 7.38% report at least 9 hours of sleep per typical weeknight. These values from NHANES is similar to values reported from Krueger and Friedman,[25] who assessed similar data from the NHIS using data from 2004 to 2007. They report prevalence of 5 hours or less being 7.8%, 6 hours being 20.5%, 7 hours being 30.8%, 8 hours being 32.5%, and 9 or more hours being 8.5%.

Regarding typical 24-hour sleep, which presumably includes napping, recent data from the Centers for Disease Control and Prevention (CDC) released data from the 2014 BRFSS, which included data from 444,306 American adults. Based on the recently published guidelines,[12,15] the CDC calculated the prevalence of less than 7 hours of sleep duration across all 50 states.[26] The median prevalence of less than 7 hours of sleep was 35.1%, with a range of 28.4% (South Dakota) to 43.9% (Hawaii). This report also documents that the prevalence of 5 hours or less was 11.8%, with prevalence of 6, 7, 8, 9, and 10 or more hours being 23.0%, 29.5%, 27.7%, 4.4%, and 3.6%, respectively.

Taken together, the time diaries generally show more sleep than other retrospective reports, perhaps because they may better capture time in bed but not actual sleep. Indeed, most retrospective sleep reports have this issue,[27] although perhaps it is particularly problematic for time diaries. In general, though, at least one-third of the population seems to be reporting habitual sleep of 6 hours or less. The proportion of those with 6 hours or less is salient, given the risk factors associated with sleep duration described in more detail in later discussion.

Sleep Disturbances

Sleep disturbances are difficult to measure at the population level. Often, population-level assessments of general sleep disturbances subsume insufficient sleep duration and/or sleep disorders that may not expressly fit into this category. The 2006 BRFSS asked the following question to more than 150,000 residents of 36 US states/territories: "Over the last 2 weeks, how many days have you had trouble falling asleep or staying asleep or sleeping too much?" In an analysis of these responses, values were coded in whole numbers ranging from 0 to 14, but responses aggregated at 0 and 14; therefore, responses were dichotomized as either endorsing or not endorsing "sleep disturbance."[28,29] For men, the prevalence of sleep disturbance ranged from 13.7% (ages 70-74) to 18.1% (ages 18-24), and for women, the prevalence ranged from 17.7% (ages 80 or older) to 25.1% (ages 18-24).[29] Interestingly, reports of sleep disturbance generally declined with age. This finding was recently replicated using data from the 2009 BRFSS, which showed a similar pattern of declining self-report of insufficient sleep with age.[30]

Regarding sleep symptoms, data from the 2007 to 2008 NHANES were examined with regards to prevalence of various sleep symptoms.[31] Long sleep latency (more than 30 minutes) was reported by 18.8% of Americans. Self-reported difficulty falling asleep was reported at a rate of 11.71% for mild symptoms (1-3 times per week) and 7.7% for moderate-severe symptoms (at least half of nights). Similarly, sleep maintenance difficulties were reported by 13.21% endorsing mild and 7.7% endorsing moderate-severe symptoms, and early morning awakenings were reported at a rate of 10.7% for mild and 5.8% for moderate-severe symptoms. Daytime sleepiness and non- restorative sleep were reported at a rate of 13.0% and 17.8% for mild symptoms, respectively, and 5.8% and 10.9% for moderate-severe symptoms, respectively. Frequent snoring was reported by 31.5% of adults and snorting/gasping during sleep was reported by 6.6% "occasionally" and 5.8% "frequently."

SLEEP EFFECTS ON HEALTH AND LONGEVITY

Because sleep is involved with many physiologic systems, insufficient sleep duration and poor sleep quality have been associated with several adverse health outcomes. Separate literature texts have emerged describing some of the negative effects of insufficient sleep duration, sleep apnea, and insomnia.

Mortality

The first report documenting the relationship between sleep duration and mortality risk was published more than 50 years ago.[32] This first study, an analysis of data from the American Cancer Society's first Cancer Prevention Study of more than one million US adults, found that increased mortality risk was associated with both short (6 hours or less) and long (9 hours or more) sleep duration. Since that time, many other studies have been published, from both large and small cohorts, covering both short and long follow-up periods, from 6 continents. Taken together, this overall pattern of findings, that both short and long sleep are associated with mortality risk, has generally remained consistent across studies, although not all studies found this pattern.[17] Two meta-analyses have been published, using slightly different methods and controls.[33,34] Still, their findings were highly consistent, indicating a 10% to 12% increased risk for short sleep and a 30% to 38% increased risk associated with long sleep duration. Much controversy remains, though, regarding this issue. For example, the precision of measurement of sleep in these studies is often poor.[17,27,35] Self-reported sleep time may better approximate time in bed, and although an actigraphic study found a similar pattern,[36] the cutoffs for short and long sleep indicated an overestimate among self-reports. Also, there is still a lack of clarity on the biological plausibility of the long sleep relationship, although some ideas have been proposed.[37,38] For this reason, most of the attention has been focused on risks associated with short sleep duration, which may be far more prevalent.

Weight Gain and Obesity

Many studies have found associations between sleep duration and adiposity and obesity.[39-41] Although most of these studies are cross- sectional, precluding causality, several other studies have longitudinally examined this relationship, demonstrating that short sleep duration is associated with increased weight gain over time.[42-46] These studies include individuals with otherwise low obesity risk, diverse community samples, and samples where effectiveness of weight loss interventions was mitigated by sleep and circadian factors. Several important caveats seem to be present in this relationship. First, this relationship is dependent on age, with the strongest relationships among younger adults and U-shaped relationships more common in middle- aged adults.[47] Also, this relationship may be moderated by race/ethnicity, with stronger relationships between sleep and obesity among non- Hispanic white and black/African American adults.[24]

Diabetes and Metabolism

Several studies have documented a cross- sectional relationship between insufficient sleepand diabetes risk.[40,48-51] A recent meta-analysis showed that insufficient sleep is associated with a 33% increased risk of incident diabetes.[52] These studies are supported by laboratory findings that show that physiologic sleep loss is associated with diabetes risk factors, including insulin resistance,[53-56] and other diabetes risk factors, such as increased consumption of unhealthy foods.[57-59] Physiologic studies also show that sleep loss can influence metabolism through changes in metabolic hormones,[60,61] adipocyte function,[62] and beta-cell function.[63]

Inflammation

Laboratory studies have shown that physiologic sleep restriction is associated with a proinflammatory state, including elevations in inflammatory cytokines, such as interleukin 1B (IL-1B),[64,65] IL-6,[64],[66-68] IL-17,[64] [69] tumor necrosis factor-a,[64],[68],[70-72] and C-reactive protein.[64],[69],[73-76] Findings at the population level have been more difficult to assess,[64] but similar relationships were found. A recent meta-analysis found no consistent relationship between sleep duration and inflammation,[77] but this may be because it did not include some studies that were more generalizable and with larger samples (eg, Ref.[76]). Also, it is plausible that population-level samples did not optimally measure these markers, because relationships with sleep vary across 24 hours and single time-point blood draws may miss the window of difference.[68]

Cardiovascular Disease

In addition to increased likelihood of obesity, diabetes, and inflammation, insufficient sleep is associated with increased risk of cardiovascular disease. Many studies have found that short sleep duration is associated with hypertension.[24,78-80] Although directionality is difficult to ascertain, several of these studies were longitudinal in nature. A meta-analysis of these longitudinal studies indicated that habitual short-sleep duration is associated with a 20% increased likelihood of hypertension, relative to normal sleep duration.[81] Other studies have supported this association, showing increased 24-hour blood pressure in short sleepers.[82] Other studies have also shown short sleep to be associated with hypercholesterolemia[24,79] and atherosclerosis risk.[83] Regarding cardiovascular endpoints, there is some evidence that habitual short sleep increases likelihood of cardiovascular events,[84] although meta-analyses do not generally show short sleep to be associated with increased cardiovascular mortality.[33,34,85]

Neurocognitive Functioning

Many studies have examined the relationship between laboratory-induced sleep loss and neurocognitive function. The domain that is most often studied is vigilant attention,[86,87] most often operationalized with the psychomotor vigilance task.[87,88] These studies show that as sleep time declines, attentional lapses increase in a somewhat dose-dependent manner.[86,89] Furthermore, these impairments often become cumulative over time[90] and do not seem to level off even after weeks in a laboratory. Other domains of neurocognitive function have also been assessed. For example, reduced sleep duration has been shown to cause impairments in working memory,[91] executive function,[92] processing speed,[93-95] and cognitive throughput.[96] Although some of these effects may be rescued with stimulants such as caffeine, the effects on executive function particularly do not seem to be rescued.[92] Although studies of this phenomenon in the general population are scarce, some studies show that reduced sleep time is associated with drowsy driving[97] and occupational accidents.[98-100]

Mental Health

Many studies have shown that short sleep duration is associated with poor mental health. Sleep disruptions are a common diagnostic feature of many mental health disorders.[101] Patients with mood disorders and anxiety disorders frequently experience short sleep duration. Sleep duration has also been identified as a suicide risk factor.[102] In the general population, overall mental health has been identified as the leading predictor of self- reported insufficient sleep.[30]

BELIEFS AND ATTITUDES ABOUT SLEEP

Real-world sleep may be driven by many of the same factors that drive other health-related behaviors, such as diet and exercise. With this in mind, previous literature from health behavior researchers has identified several models that explain healthy behavior, identifying the roles of beliefs and attitudes.

The Health Belief Model and Application to Sleep

The Health Belief Model was originally developed in the 1960s,[103,104] but has since been used in the study of many health-related behaviors. See **Fig. 3** for a schematic of this model. This model can be applied to sleep behaviors. For example, a person will engage in healthy sleep behaviors (eg, making time for sufficient sleep or adhering to treatment) if they (1) believe that they are susceptible to the adverse effects of insufficient/ poor sleep, (2) believe that the adverse effects are severe enough to warrant action, (3) believe that the action will mitigate the adverse effects, (4) believe that barriers to performing the action are sufficiently reduced, (5) are reminded to engage in the action, and (6) believe that performing the action is under their control. According to the health belief model, all of these are required for action. Therefore, just educating patients about the severity of outcomes of inaction, for example, is not sufficient to motivate behavior.

The Integrated Behavioral Model and Application to Sleep

The Integrated Behavioral Model arose from the Theory of Planned Behavior and Theory of Reasoned Action[105] to describe why people engage in behaviors. A schematic for this model is presented in **Fig. 4.** According to this model, attitudes, norms, and agency need to be addressed. Regarding attitudes, this would involve leading individuals to not only endorse helpful beliefs and attitudes about healthy sleep but also associate healthy sleep with positive feelings. Regarding norms, more research is needed to understand how the sleep of a person's (perceived) peers and those to which that individual wishes to conform influences individual sleep behaviors.

Beliefs and Attitudes About Sleep

Across segments of society, sleep practices and beliefs can vary to a great extent. For example, bed-sharing with infants and other family members differentially exists across cultures.[106-111] The cultural impact of dreaming also varies widely across cultures.[112] As globalization and technology penetrate society, sleep-related beliefs and practices can change, including the provision of longer working hours,[113-120] shift work,[121-124] and discouraging otherwise culturally appropriate naps.[125-127] There have been a few studies that examined beliefs and attitudes about sleep. In a sample from Brooklyn, New York, blacks/African Americans who were at high risk of obstructive sleep apnea had higher scores on the Dysfunctional Beliefs and Attitudes about Sleep scale, compared with those who were not at high risk.[128] In a study in the Philadelphia area among older black and white women,[129] participants were administered a questionnaire to evaluate sleep-related beliefs and practices. Black women were more likely to endorse incorrect and unhelpful statements. Sell and colleagues[130] examined sleep knowledge among Mexican Americans in San Diego. Non-Hispanic whites were more likely than Mexican Americans to know what sleep apnea was, but when describing the symptoms, both groups had similar knowledge that such a problem existed. Taken together, the role of sleep and health in society is driven by healthy behavior choices. These behavioral decisions, as described in the models above, are largely influenced by beliefs and attitudes about sleep. These beliefs and attitudes, though, are differentially endorsed by racial/ethnic groups, which may underlie sleep difficulties in those populations.

GENDER AND AGE IMPACTS SLEEP IN THE POPULATION

Sleep Changes with Normal Aging in the Population

Physiologic changes in sleep have been well- documented. In a landmark meta-analysis by Ohayon and colleagues,[131] polysomnographic sleep characteristics across the lifespan were examined across 65 studies spanning more than 40 years. This analysis found that with age, polysomnographic total sleep time, sleep efficiency, slow-wave sleep, rapid eye movement (REM) sleep, and REM latency decline, whereas sleep latency, wake after sleep onset, stage 1 sleep, and stage 2 sleep increase. This finding suggests a phenomenon of more disturbed and lighter sleep. In addition to these changes, melatonin secretion declines with age, which may also impact sleep consolidation in older adults.[132] Risk for many sleep disorders also increases with age.[133-135] In particular, sleep disorders, such as insomnia,[136] restless legs syndrome,[137,138] sleep apnea,[139] and REM behavior disorder,[140] include older age as a risk factor. However, a paradox exists, which was highlighted in a large, international cohort study by Soldatos and colleagues.[141] In this study, older adults were more likely to report difficulties initiating and maintaining sleep. However, they did not endorse a greater level of dissatisfaction with their sleep. A lack of dissatisfaction is similar to results reported in Italy by Zilli and colleagues,[142] who found that younger adults were more likely to report dissatisfaction with sleep than older adults. In the US population, general dissatisfaction with sleep associated with age was examined using the 2006 BRFSS. In a study of more than 150,000 US adults, general sleep disturbance (general difficulties with sleep) was most frequently reported in young adults, and rates generally declined with age.[29] In controlled analyses, no age groups were statistically less likely to report sleep disturbances than the oldest adults, aged 80 or older, although many of the younger groups reported higher levels. These results were replicated using the 2009 BRFSS, which examined self-reported perceived insufficient sleep among greater than 350,000 US adults and found a decline in general sleep insufficiency associated with age.[30] Thus, it appears that sleep objectively worsens with age, but that subjective dissatisfaction with sleep is not associated with normal aging. In fact, this may be a sign of illness or depression.[143]

Population-Level Differences in Sleep Between Men and Women

Differences in sleep between men and women have been widely reported in the literature for decades.[144-149] Overall, in the general population, women report shorter sleep duration,[150] more sleep symptoms,[31] greater rates of insomnia,[151] and lower rates of sleep apnea.[152] In an analysis of sleep disturbances reported in the 2006 BRFSS, it was found that women reported more nighttime sleep disturbances and daytime tiredness than men. Across all age groups, sleep disturbance was reported by between 13.7% and 18.1% of men, depending on age group, and between 17.7% and 25.1% of women.[29] Similarly, for daytime tiredness, rates were 16.4% to 22.9% of men and 20.5% to 29.9% of women, depending on age. In all age groups, women reported nominally more disturbances than men. Statistically, after adjusting for demographics, socioeconomics, health variables, and depression, rates of sleep disturbances were more prevalent among women for all age groups between 25 and 69 years old and rates of daytime tiredness were more common in women for all age groups from 18 to 59 and 75 to 79.

Fig. 4. Integrated behavior model.

Other issues regarding sleep differences exist between men and women. For example, sleep disturbances are common in pregnancy,[153-155] especially the first and third trimesters. These sleep disturbances can include insomnia, short sleep duration, sleep fragmentation, and gestational sleep apnea. Sleep disturbance in pregnant women can result in adverse outcomes for both the mother and the fetus.[156,157] Sleep in new parents (especially mothers) is also frequently disturbed,[158,159] especially in the first few months after birth. Sleep disturbances among parents of infants are associated with increased postpartum depression,[160-162] increased sleep disturbances among infants, and other adverse outcomes. Women also experience sleep disturbances around menopause. Sleep during the menopausal transition is often characterized by insomnia symptoms and increased sleep fragmentation.[163] Hot flashes are also a common source of sleep disturbance around the menopausal transition.[164]

Some sleep disturbances are disproportionately experienced by men. For example, men are more likely to have obstructive sleep apnea,[139] are more likely to have difficulty adhering to sleep apnea treatment,[165,166] and are more likely to die as a result of complications or consequences of sleep apnea.[167] In addition, men are more likely to be diagnosed with REM Behavior Disorder, which is typically diagnosed among older adults and likely predates neurodegenerative disorders.[168] During the aging process, men are also more likely to demonstrate a steeper decline in slow-wave sleep generation,[131] with lower amounts of slow-wave sleep among older man versus older women.

RACE, ETHNICITY, AND CULTURE ASSOCIATED WITH SLEEP

Insufficient Sleep Associated with Race/ Ethnicity

Many studies have documented a "sleep disparity" in the population,[19,39] such that racial/ethnic minorities, especially in the context of socioeconomic disadvantage, achieve less quality sleep. Most studies in this area have shown that, overall, blacks/African Americans are more likely to experience short sleep duration compared with non- Hispanic whites.[19,39] One nationally representative study found that this pattern is robust even after adjustment for a large number of other demographic and socioeconomic covariates, such that the rate of very short sleep (<4 hours) was 2.5 times those of non-Hispanic whites and the rate of short (5-6 hours) sleep was about twice as high.[150] A similar pattern was seen for Asians/others, who reported very short sleep at a rate of 4 times that seen in non-Hispanic whites and a short sleep about twice as frequently. Among Hispanics/Latinos, there is less clear evidence of habitual short sleep, especially among Mexican Americans. In addition to epidemiologic studies, some laboratory studies have also examined this issue. For example, blacks/African Americans have been shown to sleep less in the laboratory.[169-171] Also, this group has been shown to demonstrate less slow-wave sleep, compensated by increased stage 2 sleep. Other studies have shown similar patterns for sleep duration in other samples that included minority groups,[172,173] and this topic was the subject of multiple recent reviews.[19,174,175]

Sleep Disturbances Associated with Race/ Ethnicity in the Population

Less work has been done to characterize rates of sleep disturbances in racial/ethnic minorities. One previous study showed that racial/ethnic minorities demonstrated a lower sleep efficiency based on actigraphy.[176] A study in the Philadelphia area found that race differences in poor sleep quality largely depended on socioeconomic status.[177] A nationally representative study found that black/African Americans were 60% more likely than non-Hispanic whites to report sleep latency more than 30 minutes, although they (along with Hispanics/Latinos) were less likely to report "difficulty falling asleep."[31] This discrepancy between self-reported "problems" and computed long sleep latency suggests that symptom reports may vary based on the question asked. Overall, minority groups were less likely to report insomnia symptoms, nonrestorative sleep, and daytime sleepiness, although non-Mexican Hispanics/Latinos were more likely to endorse sleep apnea symptoms such as snoring.

Several studies have examined the role of racial discrimination as a unique stressor that impacts sleep. A study of residents in Michigan and Wisconsin found that exposure to racial discrimination was associated with sleep disturbances, above the effects of race, sociodemographics, and even depressed mood.[178] This finding, that sleep disturbance is associated with exposure to racism was consistent with other findings that showed that exposure to discrimination was associated with shorter sleep and more sleep difficulties[179] and that these findings are also seen in objective sleep assessments.[169,170] Interestingly, polysomnography differences in slow-wave sleep between black/African American and non-Hispanic white individuals (ie, reduced slow-wave sleep) were mediated by exposure to discrimination.

Sleep, Acculturation, and Immigration

Few studies have examined sleep related to acculturation. Sell and colleagues[130] found that Mexican Americans who were more acculturated to American lifestyle were more familiar with information about sleep disorders. Also, in a nationally representative sample, speaking only Spanish at home was associated with a decreased likelihood of sleep duration in the short (5-6 hours) and very short (<4 hours) categories compared with 7 to 8 hours. In this same sample, being born in Mexico (but not any other country) was associated with decreased likelihood of both short and very short sleep duration, but these effects were not significant after adjusting for other demographic and socioeconomic factors, which likely explain this finding.[129]

EMPLOYMENT, NEIGHBORHOOD, AND SOCIOECONOMICS

Although sleep is an important factor in overall health, society has incentivized insufficient sleep. Many of these incentives involve finances and employment. Because of this, there is evidence that one of the strongest societal determinants of sleep is work. The relationship between work and sleep is especially important for safety-sensitive occupations that not only incentivize insufficient sleep but also for which the associated fatigue also jeopardizes the public safety.

Trading Sleep for Work Hours

Replicating and extending prior work in this area, Basner and colleagues[23] examined data from greater than 100,000 Americans over a 9-year period who participated in the ATUS, which is performed annually by the US Bureau of Labor Statistics and uses time diaries to determine work and other activities across 24 hours.[180] In a recent report, Basner and colleagues[23] show that work time, including actual work and other related activities (such as commuting), was the primary determinant of sleep duration. In addition, later start times of school and work were associated with longer sleep, such that each hour of delayed work or training start time was associated with 20 more minutes of sleep. Also, those holding multiple jobs were at greater risk for short sleep duration compared with those only working one job at a time. Although work is a strong determinant of sleep duration, other studies show that employed individuals report the lowest rates of self-reported sleep disturbance.[28] Unemployment, on the other hand, is associated with more sleep problems.[28,30]

Sleep Deprivation and Sleep Disorders in Occupational Settings

Recognition of the role of sleep disorders and sleep deprivation in occupational settings is gaining increased attention. Rosekind and colleagues[181] showed that the typical well-rested worker costs an employer about $1300 per year in lost sleep-related productivity, and this number increases to about $3000 for those with insomnia or insufficient sleep. Furthermore, the loss to productivity permeates many areas of functioning, including time management, mental and interpersonal demands, output demands, and physical job demands. Hui and Grandner[182] show that not only is self-reported poor sleep quality associated with decreased work performance but also worsening sleep longitudinally predicts worsening performance over time. In addition, difficulty sleeping is associated with increased health care costs. Those with difficulty sleeping “often” or “always” were associated with additional health care costs of $3600 to $5200 per person per year more than those who “never” have sleep problems, and these costs increased over time if sleep became worse. Additional analyses from this dataset also showed that poor sleep may motivate employees to make healthy changes as part of a workplace wellness program, but it may also limit those employees' ability to maintain healthy change.[183]

Regarding safety-sensitive occupations such as medicine, law enforcement, and transportation, sleep plays a critical role in safety. For example, sleep apnea occurs at high rates among commercial drivers[184-186] and impairs their ability to drive safely. Accordingly, workplace programs to increase screening and treatment of sleep apnea may have financial benefits for companies.[184] Similar efforts may show effectiveness in rail workers as well.[187,188] Airline pilots face similar challenges, in addition to challenges presented by crossing many time zones. To address these concerns, sleep disorders screening in addition to circadian approaches and scheduled napping have shown effectiveness in improving safety.[189-197] Among law enforcement and first responders, several studies have shown that sleep disturbances are common among police officers[198-203] and firefighters.[204,205] In particular, issues such as sleep apnea, insomnia, and shift work are the most common problems.[206] In a landmark study by Rajaratnam and colleagues,[198] police officers who were at greatest risk of sleep disorders were also more likely to be at risk for job-related problems, such as falling asleep at meetings and using unnecessary violence against citizens. Studies have shown that sleep disturbances in police officers and firefighters are associated with reduced ability to maintain job performance and safety.[198,203,207]

Several studies have been conducted among medical residents and nurses. For nurses, shift work and long work hours have been shown to be related to adverse health outcomes and indicators of reduced functioning.[208-217] Among medical residents, long work hours and shift work have been shown to lead to insufficient sleep duration.[218-221] Furthermore, longer work hours in medical residents have been associated with markers of reduced work performance, although impacts on actual work performance are more inconsistent.[115,222] In a landmark study that compared 2 groups of residency programs, those that gave more time off for sleep did not show measurable changes in work performance.[223] Paradoxically, residents given more time to sleep were more worried about decreases in their quality of work as a result of working less, yet they were more satisfied with the quality of their life and social functioning.

Sleep, Poverty, and Neighborhood Factors

Several studies have shown that poverty is associated with both shorter sleep duration and worse sleep quality.[30] However, once the benefits of income are accounted for (by statistically co- varying education, access to health care, and so forth), associations with income are often nonexistent and may go in the opposite direction. For example, in an analysis of data from greater than 350,000 US adults, insufficient sleep was associated with poverty before adjusting for covariates, but after adjustment, the opposite relationship was seen.[30] A positive relationship between income and insufficient sleep after adjusting for covariates suggests that money may not buy sleep, but many of the benefits of income may contribute to healthy sleep. One aspect of this relationship is neighborhood quality. Several studies have investigated the role of the neighborhood in an individual's sleep quality, showing that neighborhoods that are crime-ridden, not socially cohesive, and dirty, are associated with worse sleep quality.[224 227] Furthermore, sleep quality may partially mediate the relationship between neighborhood quality and both mental[227] and physical[225] health. One way that a neighborhood may directly influence sleep would be via the physical environment. There is substantial literature showing that environmental noise[228,229] and light[230-233] can adversely impact sleep and that neighborhoods that are active at night may directly impact sleep through these.

INFLUENCES OF HOME, FAMILY, AND SCHOOL ENVIRONMENT

The home, family, and school environments also likely play important roles in an individual's sleep. For example, household size is negatively associated with sleep, such that more crowded homes are more likely to foster insufficient sleep.[30] Also, as mentioned above, the physical sleep environment can also play a role. Bedrooms that have levels of light, noise, and temperature that are not conducive to sleep may contribute to insufficient sleep.[234-236]

Although data on beds and other sleeping surfaces are relatively scarce, an uncomfortable sleeping environment may also reduce sleep ability.[237-239]

Another key issue of the home and family environment on sleep regards the marital relationship. Although most sleep research is performed on individuals sleeping alone in a laboratory, most adults do not sleep alone most nights.[240,241] With this in mind, several studies have explored the important role of marital and relationship quality in sleep quality and how this relates to health. For example, relationship quality has been shown to be an important predictor of sleep health, especially among women, and relationship quality may be an important moderator between sleep quality and health.[241-244]

TECHNOLOGY IN AND OUT OF THE BEDROOM

In 2011, the National Sleep Foundation polled Americans regarding their use of technology in the bedroom. In a report of the findings of this survey, Gradisar and colleagues[245] note that 90% of Americans use some sort of electronic device in the hour before bed. Also, more than two-thirds of adolescents and young adults used a Smartphone in the hour before bed, compared with approximately one-third of middle-aged adults and about one-fifth of older adults. Furthermore, the more engaging the technology application, the more the electronic device use was associated with difficulties falling asleep and nonrestorative sleep. This finding is supported by other work that shows that not only is electronic media use near bedtime prevalent[246] but also the light emitted by the devices[247] as well as the mental engagement[248] can interfere with sleep. Growing awareness of the influence of mobile electronic device use on sleep is a key example of a societal-level change (use of technology) impacting an individual's sleep.

GLOBALIZATION AND 24/7 SOCIETY

Another societal-level factor that impacts sleep is the advent of globalization and a 24/7 society. In the past, social interactions, commercial activities, and work responsibilities were dictated by more local factors. Now, though, the advent of globalization and 24/7 operations often impinge on sleep. Regarding globalization, individuals and organizations are connected across the globe. In combination with a society that institutes shift work and 24-hour operations, entire segments of the population are awake across all hours of the 24-hour day, and access to individuals across time zones is easier than ever. Because of this, social interactions (such as interactions with friends, family, and even online groups), commercial activities (such as eCommerce and availability of entertainment around the clock on demand), and work responsibilities (such as e-mails outside of business hours and business conducted across the globe) can impinge on sleep. The influence of globalization and 24/7 society on sleep behaviors is particularly relevant, because shift work has been repeatedly shown in both laboratory and field studies to be related to adverse health outcomes.

PUBLIC SAFETY AND PUBLIC POLICY

As mentioned above, many safety-sensitive occupations, such as those in transportation, law enforcement, and medicine, require healthy sleep for optimal performance. The problem is that these professions often institute policies that make healthy sleep difficult. As a result, the sleep of an individual in one of those occupations may have ramifications for others in the public. For example, when a large commercial truck crashes, it causes more damage and a greater likelihood of fatal injury.[249,250] For this reason, several policy approaches to sleep and public safety have been proposed. The Accreditation Council for Graduate Medical

Education has already instituted duty hour restrictions on medical residents, based on results from a report by the Institute of Medicine.[218] These restrictions, although controversial,[115,251-253] are likely resulting in increased sleep among medical residents.[222] In the transportation industry, recommendations by the National Highway Transportation and Safety Administration address the need for sleep disorders screening and fatigue mitigation among commercial drivers,[250] although formal regulations have notyet been passed. The Federal Aviation Administration also recently issued guidelines to address sleep issues in pilots.[254] More work is needed in this area, and although regulations to ensure public safety have been proposed, they still have not yet been passed.

Another domain of public safety is drowsy driving. Even among non-commercial drivers, drowsy driving is an important public safety issue. Drowsy driving is prevalent, reported among about 5% of the US population over a 6-month period.[255] Population-level data suggest that short sleep duration is an independent risk factor for drowsy driving, even if respondents believe that they are completely well rested.[97]

Another area of public policy related to sleep involves school start times. Existing evidence suggests that most US schools, especially high schools, start too early for most adolescents.[256-259] Earlier start times not only promote shorter sleep duration among adolescents (who need more sleep than adults) but also do not take into account natural circadian delays that occur in adolescence.[260] It has been proposed that delaying school start times can improve academic performance, improve mental health, and improve overall health in students.[261-266]

Other public policy initiatives have addressed the issue of environmental light and noise in neighborhoods. There are several policies in place, and more being proposed, that limit the brightness of street lights in neighborhoods, increase “quiet time” regulations at night, direct airplanes to avoid some residential areas at night, reduce traffic and train noise at night, and so forth. These approaches are usually regional, and many efforts are ongoing.

One more public policy implication relevant to sleep would be health policy legislation. For example, improving mental health parity laws will do much to intervene on perhaps the most important determinant of sleep health at the population level[30] and will facilitate treatment of insomnia with the most well supported therapy.[267] In addition, health equity legislation may help to address some of the disparities seen in sleep in the population.[20]

These and other future approaches may better promote healthy sleep from a policy standpoint.

IMPORTANT LIMITATIONS OF THE EXISTING LITERATURE

There are several important limitations to the existing literature, which constrain interpretations and generalizations of the data. The most important limitation is that there is a lack of consistency in sleep assessment methods across studies, and this is a problem for several reasons. First, retrospective self-report (eg, survey), prospective self-report (eg, diary), laboratory-based objective (eg, polysomnography), and field-based objective (eg, actigraphy) estimates of sleep tend to disagree with each other, because they capture different elements of sleep well. It is likely that physiologic sleep is substantially less than that which is self-reported.[27] Even among survey methods, there seems to be systematic variation.[35] Second, because there is still no nationally representative dataset that includes any well-validated estimate of sleep duration or quality, generalizability from one dataset to the next is limited. Third, cutoffs and categories used to describe sleep are often inconsistent across studies; for example, the cutoff for the shortest sleep duration category can be as low as 4 hours or less or as high as 7 hours.

Another important limitation is a general lack of physiologic sleep measures at the societal level. Because these measures are typically more expensive and require more infrastructure to implement, they are often infeasible for large studies that require assessment of thousands of people. Until sleep assessment becomes more of a priority, otherwise rich datasets will continue to have just a few nonvalidated survey items measuring sleep. Suboptimal measurement of sleep will make data interpretation difficult, because it is unclear the degree to which associations are referring to physiologic sleep or other factors that become subsumed in self-reported sleep experience.

A third important limitation regards the complexity of social environments. As shown in the Social-Ecological Model, the influences that may play a role in sleep are many, varied, and exist at several levels. Still, most studies do not address the complex nature of social-environmental influences on health. Also, future studies that will examine epigenetic effects will need to better account for gene-environment interactions, and this will require a better operationalization of environmental variables in many cases. An example of one study that brought these methodologies together is cited by Watson and colleagues,[268] who combined geospatial neighborhood analyses with sleep genetic information to characterize a social-environmental influence on sleep duration.

Afourth important limitation to the existing literature is a lack of interventional studies. If, for example, sleep represents a modifiable factor in health disparities, it is plausible that improvements in sleep at the community level could reduce effects of health disparities. However, there is a lack of interventional studies that can demonstrate this; rather, the best examples of investigations in this area use mediational analysis to show that changes in sleep account for changes in health outcomes across groups, such as blood pressure.[269] More sleep interventions at the community level are going to be needed in order to understand the causal role of sleep in these outcomes. Also, there is a general lack of empirically supported interventions for sleep health. Although many interventions exist to promote healthy diet, physical activity, and substance cessation, a lack of standardized sleep health interventions limits knowledge in this area.

FUTURE RESEARCH DIRECTIONS

Several potential future research directions may help advance knowledge in this area. First, expanded epigenetic studies are needed to explore gene-environment interactions. As the science of human sleep genetics develops, more research into how genetic vulnerabilities interact with environmental influences is needed. For example, although it is unlikely that genetics explains racial disparities in sleep, it is plausible that some genetic adaptations to one geographic region may confer risk in another region (eg, less sunlight, different food availability). Also, it may be possible that certain genetic vulnerabilities (eg, airway collapse) may differentially affect groups because body mass indexes increase in the presence of increasing obesity rates due to westernized diets.

Another important direction in research will be to clarify the sleep phenotypes and endophenotypes. Currently, typing of sleep at the community and population level is frequently based on broad sleep duration groups (eg, “short sleepers”) or sleep symptoms (“difficulty falling asleep”), although these groups can be highly heterogeneous. Genetic studies are limited by this limited clarity in sleep phenotypes. Short sleepers, for example, may comprise individuals who are “true” short sleepers and need less sleep, those who need more sleep but are able to tolerate less sleep for an extended period of time ("resilient"), and those who are insufficient sleepers. Still, insufficient sleepers may belong to groups that demonstrate neurocognitive and metabolic impairments at variable rates (eg, some individuals may demonstrate more metabolic impairments and some more cognitive). Perhaps more clarity regarding phenotypes will help move forward an agenda of better human sleep genetics.

More intervention studies are also needed at the laboratory, clinical, and community levels that address real-world sleep concerns. As mentioned above, there is a lack of healthy sleep interventions, relative to healthy diet or physical activity recommendations. Without these data, it is difficult to make recommendations in addition to just stating a problem. Also, interventions need to address issues that have generally been ignored yet carry real-world significance For example, despite many adults sleeping between 6 and 7 hours per night, this sleep duration is almost never included in the literature, either because epidemiologic studies categorize at the hour (including them in either 6- or 7-hour groups) or because laboratory studies try to maximize difference between groups (usually comparing 8-6, 5, or 4 hours but not between 6 and 7).[14] These and other real-world issues need to be better captured in intervention studies.

Finally, intervention studies are needed that identify real-world approaches to increasing sleep time among chronically sleep-deprived individuals. Unlike traditional intervention study designs, where changing sleep is the intervention and some health marker is the outcome (which would address the question of whether changing sleep impacts health), study designs are needed whereby changing sleep itself is the outcome. For example, it is known that smoking cessation can positively impact health. However, how does one quit smoking? Just recommending that someone quit is not enough, and literature has emerged that proposes novel ways to achieve this difficult behavioral change. Likewise, changing sleep duration in a real-world setting (with home, work, and other societal pressures) may be difficult, and useful strategies besides simply making recommendations need to be explored.

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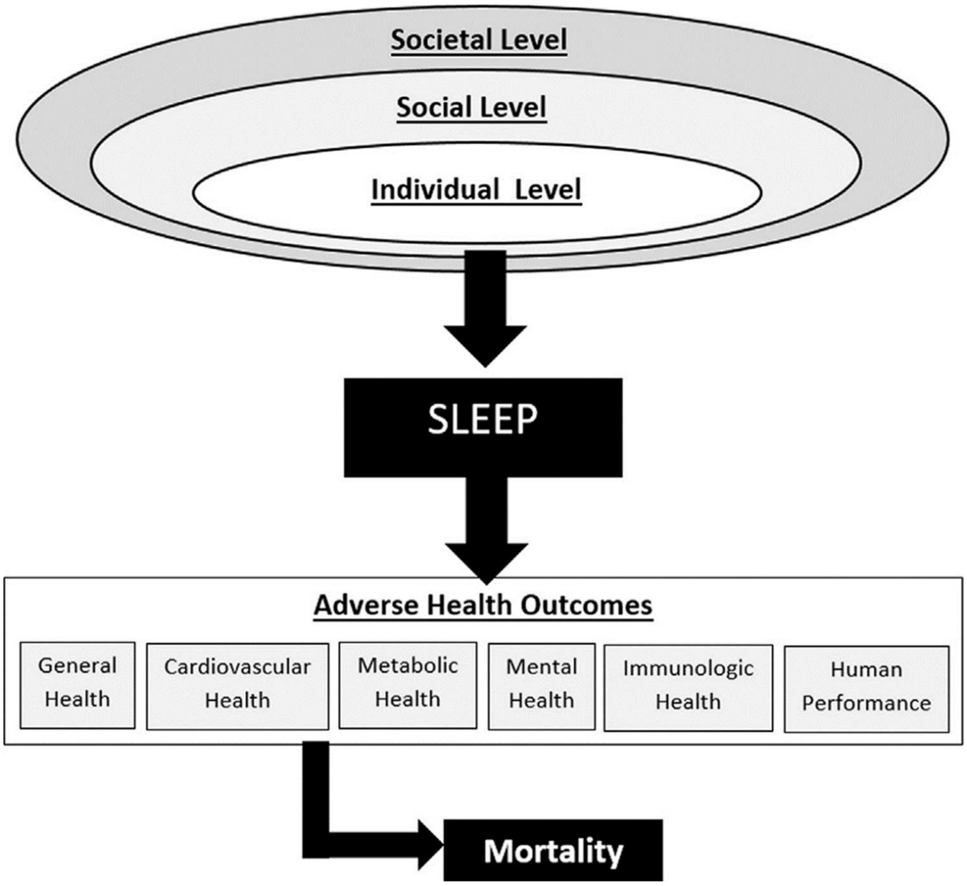

Fig. 2. Social ecological model of sleep and health.

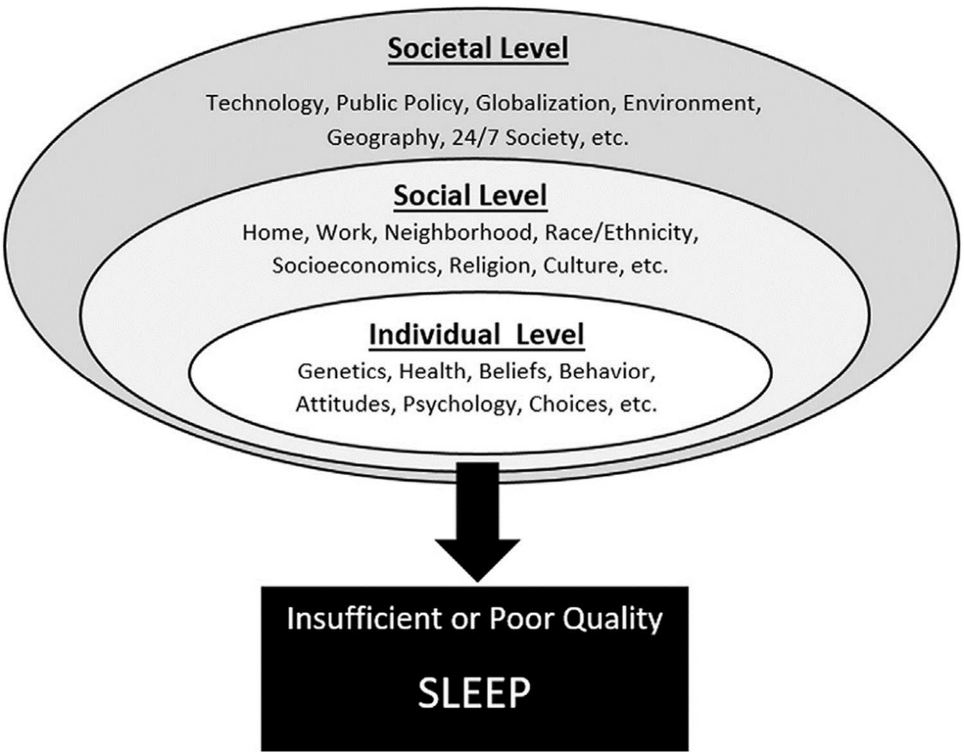

Fig. 1. Social ecological model of sleep.

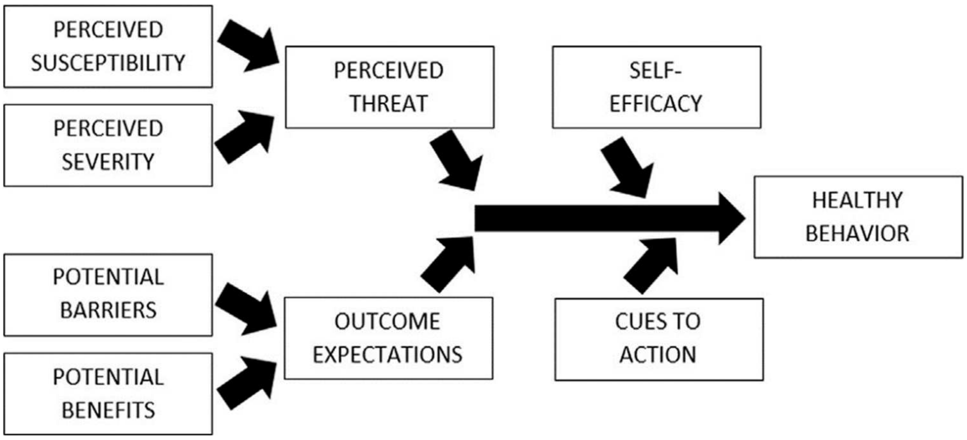

Fig. 3. Health belief model.

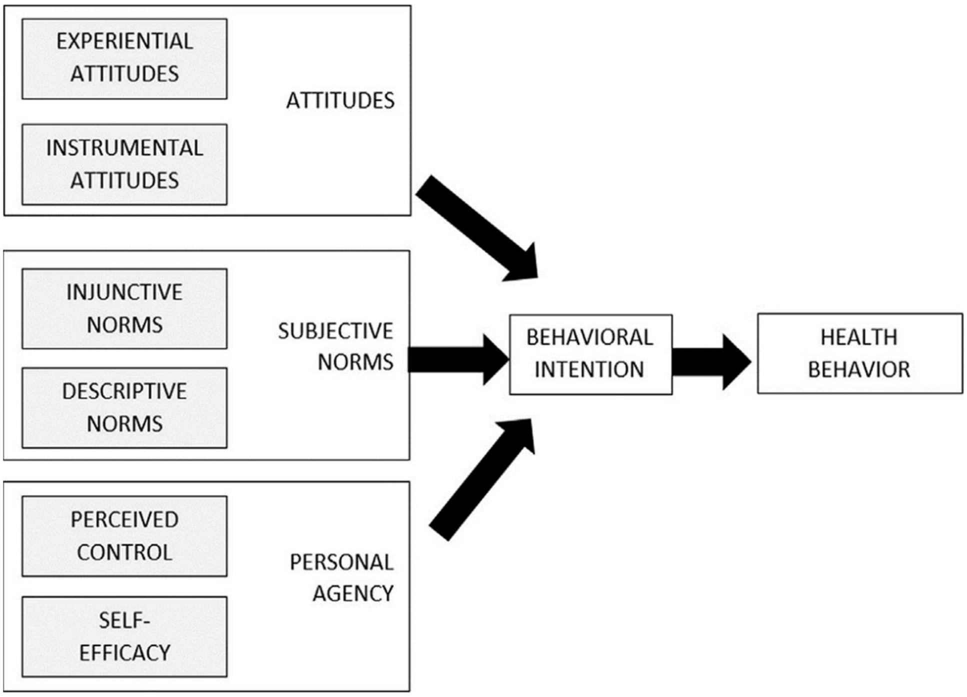

Fig. 4. Integrated behavior model.