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REVIEW

The Effect of Air Pollution and Climate Change on Sleep

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ABSTRACT

Research has shown that air pollution and climate change affect both the duration and quality of sleep; threatens physical and mental health especially through respiratory, cardiovascular, and nervous systems; and shortens life expectancy. This review will begin with overall information on air pollution, climate change and sleep. Then, it will proceed with the effects of these two environmental issues on sleep, in the light of previous research.

Keywords: Air pollution, climate change, particulate matter, sleep, sleep disturbances, sleep quality

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INTRODUCTION

Air Pollution

Air pollution and specifically one of its components called the "particulate matter", create serious health problems for the human body especially with the respiratory, cardiovascular, and nervous systems; along with shortening life expectancy (1). A research has shown that air pollution is responsible for 19% of deaths caused by cardiovascular diseases (2). The underlying biological mechanism of particulate matter's negative effect on health is partially understood. However, epigenetic mechanisms and increased systemic inflammatory response are considered to play a central role (3–5).

The most threatening compounds of air pollution are particulate matter (PM) with a diameter of 10 micrometers (µm) or less (e.g., PM10, PM2.5), and the complex mixture of gasses such as nitrogen oxide and ozone (6). Particulate matter consists of carbon, heavy metals, inorganic ions, polycyclic aromatic hydrocarbons (PAH), and elements found on earth.

Particulate matter with a diameter between 2.5 and 10 µm are called "coarse", those between 0.1 and 2.5 µm are called "fine"; and those smaller than 0.1 µm are called "ultrafine" particulate matter. These harmful substances cause inflammation in the nose and upper respiratory tracts as well as the lungs. Additionally, it has been shown that fine and ultrafine particulate matter can travel through the alveoli and enter the bloodstream (3).

Sleep

Sleep is vital for the functioning of a healthy human being. The fact that one thirds of adults report sleep related problems, indicates insufficient sleep is a public health issue (7). The sleep duration being too short increases chronic diseases and susceptibility to illnesses, and damages physiological and cognitive functions (8). Regular and sufficient sleep plays an integral role in the maintenance and restoration of the human body. Lack of sleep can interfere with neural consolidation of new information, muscle repair, and efficient removal of waste from the brain (9,10). Insufficient sleep can also hinder the immune system and metabolism functions, and increase systemic inflammation in the body (11). Having too little sleep can increase the risk of cardiovascular diseases, diabetes and obesity. From a neuropsychiatric perspective, the sudden sleep deprivation is linked to negative changes in mood, and may play a role in developing depression and suicidal ideation (12,13). It also negatively affects cognitive performance by causing decline in memory, attention and processing speed (14).

The normal sleep-wake cycle is controlled by the circadian rhythm, the 24 hour clock of the body. Temperature is one of the fundamental factors that affect sleep (15). Both the temperature of the body and the ambient temperature are critical determinants of falling and staying asleep. While the body prepares for sleep, blood vessels in the skin dilate and facilitate loss of heat. Thus, core body temperature decreases, which is a critical signal for the state of sleep. Once the core body temperature drops low enough to initiate sleep, it stays low throughout the night, and rises again near waking time (16). Increase in ambient temperature can disrupt normal sleep physiology by affecting circadian thermoregulation (17).

Highlights

- **Extreme weather events and rising temperatures lead to sleep disorders.**
- **Particular matter affect sleep also by directly entering the central nervous system.**
- **Researchers sholud also contribute to environmental health policies.**

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Climate Change

Climate change poses a threat for the health of living beings. Around the world, the increase in temperature associated with climate change is leading to diseases, extreme heat events, and deaths (18,19). Food and waterborne diseases such as salmonella and campylobacteriosis are becoming more common since they occur more in higher temperatures (20). Vector-borne diseases such as Lyme are also seen more frequently in recent years due to climate change. In addition to people losing their lives because of the increasing number of hurricanes, tornadoes, and other severe weather conditions; these events cause displacement of vulnerable individuals and affect their mental health. Independently of being exposed to such events, some individuals also experience anxiety on the grounds of the impending threat of climate change (21).

RESULTS

Compared to the more well-known effects of climate change on health, its effects on sleep are far less studied. It is possible to foresee that climate change will have many effects on inadequate sleep and other sleep problems. Extreme weather conditions caused by global temperature rise might cause trauma by raising the physical and emotional stress levels (22). The high temperature levels sustained throughout the day results in continued high temperatures at night, especially in urban cities. In a study conducted in the United States, Obradovich, Migliroini and colleagues have shown a relationship between high temperatures and decrease in sleep quality (23). In this study, the data from a total of 765,000 participants who have completed the Behavioral Risk Factor Surveillance Survey (BRFSS) at the Centers for Disease Control and Prevention between the years of 2002 and 2011 have been used to assess whether abnormally high night-time temperatures affect sleep quality. The answers participants gave to the question of "During the past 30 days, for about how many days have you felt you did not get enough rest or sleep?" have been investigated in combination with the interview date and the geolocation of the city. Temperature, precipitation and climate data were taken from meteorological stations and the relationships were investigated based on theoretical parameters. Results show that for every 100 people per month, a +1°C difference in overnight temperatures causes an increase of three nights of inadequate sleep. This strong relationship between atypical night time temperatures and insufficient sleep is especially salient during summer, for elderly people, and for those with low socio-economic status. The researchers emphasized that these findings are in line with the expanding literature indicating the close relationship between climate change and human health (21), and with recent studies demonstrating the effects of increasing temperatures on mortality and morbidity, as well as on crime and violence tendency (22). A literature review points out that 6 different empirical studies have reported that increased temperatures negatively affect sleep duration and quality (24). Another literature review indicates a relationship between high ambient temperatures and the increased intensity of obstructive sleep apnea (25). The consequences of untreated obstructive sleep apnea include chronic diseases such as hypertension, cardiac diseases, diabetes and stroke; drowsiness and sleepiness during the day due to sleep disruptions and thus decrease in productivity and quality of life (26,27).

It is well known that climate change leads to increases in extreme weather events such as hurricanes and tornadoes. A study conducted with a small group after Hurricane Andrew (1992) showed for the first time that the subjective sleep complaints increase after natural disasters (28). In this research, Pittsburgh Sleep Quality Index (PSQI) was administered to 54 individuals, 6–12 months after the hurricane. The greatest increase in subjective sleep complaints were seen in participants with comorbid psychiatric disorders. It was also emphasized that sleep disturbances, such as frequent waking and bad dreams and worsening in daily functioning, were common in these individuals.

An investigation of research on the effects of floods and forest fires on sleep has shown that exposure to these events also increase sleep disturbances as a result (29–31). More than 900 people who have been exposed to the flood in Brisbane, Australia in 2011, especially those individuals whose homes were directly affected by flooding, showed a greater decrease in sleep quality (29). Another research conducted with those who have been affected by the floods in China revealed that in addition to sleep problems caused directly by trauma; fear and depression were also indirect contributors to sleep disturbances (30). In a recent research conducted in 2018 with female victims of forest fires in Greece, higher proportions of insomnia were revealed due to the fear of feeling the imminence of death (31).

Increasing number of epidemiological and experimental findings shows that exposure to air pollutants such as particulate matter and mixtures of gasses (nitrogen dioxide [NO_2], ozone [O_3]) negatively affect sleep quality. In a review article analyzing 15 different studies, including 133,695 participants from 10 countries such as Turkey, Mexico, Iran, Brazil, USA, and Egypt; the main findings were emphasized (32). Firstly, air pollutants could be triggering poor sleep quality via the central respiratory control center, central nervous system and allergic and non-allergic mechanisms. Secondly, investigating the relationship between some diseases (e.g., mental and cardiovascular), some behaviors (e.g., impulsivity) and air pollution can give us important clues on the relationship between sleep quality and ambient air pollution.

In a study examining the relationship between PM and sleep disorders, data on air pollution, demographics and other associated factors were collected from the UK Biobank (33). Using the data of 5976 patients and a control group of 97,160 people, the odds ratio (the effect of risk factors to dependent variables) were calculated using single- and four-pollutant models and univariate analysis. Results showed that PM2.5 was a risk factor for sleep disorders and both PM2.5 and PM10 decreased the duration of sleep. Researchers emphasized that decreasing exposure to PM can increase the duration of sleep and decrease the risks of sleep disorders.

Another study conducted in a city in China called Ningbo with high levels of air pollution and a growing population of the elderly employed data from the local health records of 395,561 people aged 60 or higher (34). Information on the hospital visits between the years of 2008–2017 and values of daily air pollutants (NO_2, O_3, SO_2, PM10 and PM2.5) were obtained from seven stations measuring environmental air quality in the city. Relationship between the date of hospital visits and exposure to air pollution in the previous 7 days were analyzed. Results showed that there is a positive relationship between short term exposure to air pollutants and hospital admissions for sleep problems which is a common comorbid issue of mental and neurological problems in elderly.

In a study conducted in Chile among the parents of 546 school-aged children between the ages of 5–9, Pediatric Sleep Questionnaire (PSQ) was administered to gather information such as the frequency of snoring, observed apneas, difficulty in breathing during sleep, daytime sleepiness and familial risk factors (35). Additionally, air pollution and meteorological data were gathered from the air quality database. This research showed that air pollutants such as ozone and sulfur dioxide had a significant relationship between respiratory sleep problems including snoring and wheezing and these pollutants can worsen Sleep Disordered Breathing (SDB) similar to other respiratory problems.

High levels of air pollution increases the risk of respiratory tract infection requiring hospitalization in children and heightens mortality in the elderly by disrupting the immune response of the lungs (36,37). An experimental study conducted with mice showed that ambient air pollution causes edema, inflammation and irritation in the upper respiratory tract; and thus, results in airway obstruction during sleep (38). It has been detected that PM2.5 stimulates the inflammatory response in epithelial cells in the inner part of the human nose (39); whereas fine PMs (those with a diameter below 2.5 µm) and NO_2 are related with chronic rhinosinusitis, allergic and non-allergic rhinitis (40). Chronic upper respiratory tract inflammation and irritation due to air pollution can increase adenoid and tonsillar hypertrophy, and consequently narrowing of the upper airway. This information reveals that environmental factors (climate change, air pollution) can cause sleep health problems by increasing the risk of obstructive sleep apnea (OSA).

In a study conducted in the USA, a total of 1974 people from different ethnic groups participated in both Sleep and Air Studies of the Multi-Ethnic Study of Atherosclerosis (MESA). The study estimated the average yearly and 5-year levels of exposure to nitrogen dioxide (NO_2) and PM2.5 based on the monitoring completed at the homes of participants and using spatiotemporal models (41). For the measurement, participants underwent full polysomnography and wore wrist actigraphy for 7 days in their homes. To investigate the possible association between air pollution and sleep apnea (apnea-hypopnea index ≥15) as well as sleep efficiency measured by actigraphy, multivariate models were utilized. Results showed that exposure to high levels of NO_2 and PM2.5 throughout the year increased the risks of sleep apnea.

Fine particulate matter and nitrogen dioxide, which represent traffic-related pollutants, can directly enter the central nervous system and cause neurotoxicity and neuroinflammation. Thus, they affect the regions that regulate sleep and those that control respiration. Long-term exposure to air pollution has been shown to be associated with cognitive impairment and neurodegeneration (42).

CONCLUSION

While studies examining the negative consequences of climate change and air pollution on general human health are abundant, these environmental issues' effect on sleep has received more limited attention. The information conveyed throughout this article, supported by studies from the field, shows that climate change and air pollution affect both sleep duration and quality. Although the exact underlying mechanisms of their effect are not fully understood, current literature points to different possible explanations of their relationship.

Research discussed in this article suggests two main pathways underlying the relationship between climate change and sleep. The first mechanism effecting sleep is increased temperatures especially during the night, which can be regarded as the most prominent outcome of climate change. Studies have shown that increased nighttime temperatures result in inadequate sleep both in duration and quality (23,24), in addition to more specific sleep problems such as obstructive sleep apnea (OSA) (25). The second mechanism through which climate change seems to negatively affect sleep is the psychological problems caused by extreme weather conditions. Studies conducted after such extreme events (e.g., hurricanes, forest fires) reveal higher levels of subjective sleep complaints (28,29), increases in sleep disturbances such as waking up frequently (28) and elevated levels of insomnia (31). As the authors of these studies also emphasize, psychological disturbances after extreme weather events could be the moderating factor on this relationship; in other words, extreme weather events might disrupt psychological well-being, which contributes to further problems regarding sleep quality. This relationship is also supported by evidence such as the fact that higher proportions of sleep problems are observed among people who have been affected by these events more profoundly (30).

The mechanisms through which air pollution negatively affect sleep quality appears to rely predominantly on respiratory systems. Despite the varying effects of different components of air pollution (such as coarse/fine/ultrafine particulate matter, nitrogen dioxide, ozone, and sulfur dioxide) on sleep, a shared factor is the increased rates of edema, inflammation, or irritation in the upper respiratory tract (38). More specifically, air pollutants have been found to be a causal factor in inflammation in the epithelial cells of the inner part of the nose (39), increased snoring and wheezing (Sleep Disordered Breathing) (35), obstructive sleep apnea (OSA) (41), and chronic rhinosinusitis (40). Besides inducing problems in the upper respiratory tract, air pollutants can also disrupt the immune response of the lungs via lower respiratory tract infections (36,37). However, research shows air pollutants could detrimentally affect sleep not only through respiratory systems, but by directly entering the central nervous system. Specifically, fine PM and nitrogen dioxide have been shown to cause neurotoxicity in the brain, potentially leading to cognitive impairment in the long term (42). Recent research examining the pathways through which this effect occurs suggests that inhaled particles could enter the brain directly through the cribriform plate and be detected by the olfactory bulb, resulting in inflammatory biomarkers which could potentially reach the brain (43).

While existing research shed light on the negative effects of climate change and air pollution on sleep, gaps in literature explaining the underlying mechanisms still exist. Some limitations are due to the fact that most studies are cross-sectional and exclude more vulnerable populations such as children. Another factor is a lack of standardized measurements including operationalization of definitions of climate change and air pollution, and reliance of subjective measurements such as verbal complaints of sleep problems. Future research can utilize longitudinal designs which would provide powerful insights on the cumulative effects of environmental factors on sleep outcomes. Furthermore, as the weight of climate change continues to grow, it wouldn't be wrong to anticipate increasingly harmful effects on sleep as well as general health. In order to overcome this global crisis, multidimensional approaches in the form of interventions and policies should be undertaken. Thus, researchers' role should go beyond descriptive findings related to sleep and general well-being but aim towards research that can help with policy-making on a broader context to alleviate the detrimental effects posed by climate change and air pollution.

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