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Review Article

Impact on human health of climate changes

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ABSTRACT

There is increasing evidence that climate is rapidly changing. These changes, which are mainly driven by the dramatic increase of greenhouse gas emissions from anthropogenic activities, have the potential to affect human health in several ways. These include a global rise in average temperature, an increased frequency of heat waves, of weather events such as hurricanes, cyclones and drought periods, plus an altered distribution of allergens and vector-borne infectious diseases. The cardiopulmonary system and the gastrointestinal tract are particularly vulnerable to the adverse effects of global warming. Moreover, some infectious diseases and their animal vectors are influenced by climate changes, resulting in higher risk of typhus, cholera, malaria, dengue and West Nile virus infection. On the other hand, at mid latitudes warming may reduce the rate of diseases related to cold temperatures (such as pneumonia, bronchitis and arthritis), but these benefits are unlikely to rebalance the risks associated to warming.

1. Introduction

Climate change, defined by significant variations of regional or global climates over long periods, includes major changes in average and peak temperature, humidity, atmospheric pressure, precipitations, wind patterns and water salinity, as well as a decrease in the size of mountain and polar glaciers [1]. The supply of safe water is also endangered by climate changes. Although the average climate conditions have been relatively stable for millennia, the last 50 years have witnessed an acceleration of changes [2,3], so that the average global temperature has increased by 0.7 °C and is expected to further increase between 1.8 and 4.0 °C by the year 2100 [4–6]. The main cause of the ongoing warming of the earth must be sought in the increasing emissions into the lower atmosphere of carbon dioxide (CO_2) and other greenhouse gases resulting from human activities (mainly methane and nitrous oxide) [6]. Greenhouse gases absorb some of the radiation emitted from the earth, trapping more heat in the lower atmosphere and thereby increasing temperatures [6]. Climate experts strongly believe that climate changes will lead to increasingly frequent and severe heat waves and extreme weather events, as well as to a rise in sea levels [6]. Accordingly, it is becoming clearer and clearer that climate changes over relatively short time periods pose serious threats to human well-being and health [7]. This narrative review summarizes the most relevant actual and potential effects on human health of climate changes.

2. Methods

We performed an electronic search on PubMed using the following terms without time limits: “climate change”, “climate variability”, “global warming”, “meteorological factors”, “weather”, “atmosphere”, “heat waves”, “extreme weather”, “ambient air pollution”, “outdoor”, “particulate matter”, “PM”, “air pollutants”, “mortality”, “human health”, “health effects”, “infectious disease”, “diarrheal disease”, “cardiovascular disease”, “ischemic heart disease”, “cancer”, and “respiratory disease”. The date of the last search was November 30, 2014. The references of all retrieved original articles and reviews were assessed for additional relevant items. We also reviewed recent reports on the relationship between climate and human health from non-biomedical journals, as well as from regulatory documents produced by environmental and health agencies.

3. Climate effects on health

Effects of global climate change on human health may be direct or indirect. Until now investigators were mainly focused on the direct effects of extreme weather events, such as heat waves, droughts, cyclones and tropical storms, for which empirical data are readily available and correlations are easily demonstrable [8]. Secondary effects related to climate changes, such as the worsening of ambient air quality and the

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impact on infectious disease diffusion are also relevant for human health [9,10].

3.1. Extreme weather events

The contribution of climatic conditions on the clinical manifestations of cardiopulmonary disorders has been recognized by several studies indicating a seasonal variation of acute coronary syndromes, myocardial infarction and related morbidity and mortality rates, acute events consistently peaking in winter with troughs in summer [11–15]. On the other hand climate changes, at least in the earlier stages, may bring some health benefits. For instance, if winter in mid-latitude temperate countries becomes milder, morbidity and mortality from respiratory and cardiovascular disease should decrease [1]. Common conditions such as arthritis and related chronic pain may also improve. However, the negative effects of global climate changes far outweigh the potentially positive ones, because warmer temperatures will lead to more frequent, intense and longer heat waves, which are well-documented to be associated with adverse effects on health [16]. Climate models project up to a 50% increase in the frequency and intensity of the hottest days in Europe and North America in the second half of the 21st century [17,18]. Extreme heat markedly increases the number of related illnesses and deaths, children and elderly patients with chronic respiratory or cardiovascular disease being more susceptible [19]. For example, the 2003 European heat wave caused a higher mortality peak (more than 22,000 people died) [20], involving particularly the older citizens of Northern European countries not adapted to heat. Each year in the USA approximately 400 people die from heat-related illness (heat exhaustion and heat stroke) [21].

Extreme heat events are associated with exacerbations of preexisting respiratory and cardiovascular diseases. For instance, a recent study found an association between environmental temperature, humidity and hospital admissions for angina pectoris [22]. Hot and humid days may also trigger asthma symptoms: studies in the USA have associated acute increases in temperature and humidity with more visits to emergency departments and hospitalizations for asthma, both in children and adults [23,24]. Furthermore, a recent observational study conducted in the USA Medicare elderly population provided strong evidence for an association between outdoor heat and respiratory disease hospitalization [25]. A case-crossover study in England and Wales examining the relationship between hourly temperature and incidence of acute myocardial infarction found that increasing ambient temperatures above a threshold of 20 °C were associated with a higher risk of myocardial infarction occurring as early as 1 to 6 h after exposure [26]. The close link between a higher incidence of myocardial infarction and higher temperatures has been confirmed in a recent systematic review [27]. There is also evidence that extreme heat may trigger exacerbations of congestive heart failure [28].

Heat and drought greatly contribute to the occurrence of wildfire, which has dramatically increased in frequency in the USA, Russia and Mediterranean areas [7]. Smoke emissions can travel hundred of kilometers downwind of fire areas, exposing many people to a noxious mixture of particulate matter (PM), ozone and other harmful compounds [29,30]. According to a recent estimate as many as 339,000 deaths may be attributed annually worldwide to landscape fire smoke [31]. Respiratory and cardiovascular hospital admissions and emergency room visits increase in response to wildfire smoke exposure [29,32].

3.2. Impact on food production

Desertification and droughts related to climate changes are major public health issues, especially regarding the ability of low-income countries to maintain sufficient food production as well as adequate supplies of safe water [33]. The World Health Organization ranked malnutrition as the largest global health problem associated with climate change [34]. In a recent analysis, malnutrition was found to be responsible for a large proportion of global deaths due to pneumonia in children under the age of 5 years [35]. It has been estimated that sub-Saharan Africa and South Asia, whose food supplies are already limited, will have the largest reductions in food supply as a result of climate changes [36].

3.3. Diarrheal diseases

Diarrheal diseases are still a global health problem, particularly in children from low-income countries. Good hygiene and a reliable access to adequate sanitation and a safe water supply are the requisites for prevention. Climate warming and related changes, such as periods of droughts but also of massive rainfall and floods, are likely to reduce the availability of safe water. It is well demonstrated that low rainfalls are associated with the prevalence of diarrheal diseases in children. A number of studies have convincingly demonstrated that diarrheal diseases increase as temperatures increase, ranging from a 3% to 11% increased risk per 1 °C of temperature increase. On the other hand, the intense rainfalls that are associated with hurricanes and floods are damaging the safety of drinking water supply. For instance, salted water from the sea may leak into the aqueducts, with the resulting risk of excessive salt intake by the population. All in all, these data show that the impact of global warming on diarrheal diseases is likely to be an important component of the overall effect on health of climate changes, particularly in children and in such areas such as South Asia and Eastern Africa. This effect of climate changes is driven mainly by that on safe water supply.

3.4. Ambient air pollution

Warmer temperatures increase the concentrations of air pollutants, mainly ozone and particulate matter (PM) (coarse particle < 10 μm, fine particles < 2.5 μm, ultrafine particles < 0.1 μm), that are of particular relevance for cardiopulmonary health [37]. A review published in 2007 by the US Environmental Protection Agency (EPA) concluded that high ozone exposure owing to heat waves was associated with a reduction in lung function and exacerbation of respiratory symptoms (including aggravation of asthma) in patients with preexisting respiratory diseases, contributing to more premature deaths in people with heart and lung disease [38]. A meta-analysis of 39 studies by Bell and colleagues [39] found a positive association between mortality and short-term exposure to ozone, particularly cardiovascular and respiratory mortality. Such association was also reported between ozone levels and hospital admissions for cardiovascular disease in an Australian study [40]. Short-term elevations in ozone have been associated with increases in all-cause mortality in Western Europe and America [41, 42]. A study of mortality rates in French cities during the 2003 heat wave found that the associated high levels of ozone contributed to higher short-term mortality [43].

There is also a strong evidence for the negative impact on health of PM, especially on the cardiovascular system [44–46]. Fine and ultrafine particles, which penetrate deeper into the lung alveoli and may pass into the bloodstream, are the most dangerous [47,48]. Their effect seems to be more pronounced than that caused by ozone: $PM_{2.5}$-induced premature mortality is about 15 times higher than that due to ozone [49]. In addition, there is evidence that high temperatures and PM interact to cause greater mortality than expected for the same PM levels at cooler temperatures [50,51]. Overall, the percentage relative risk increase for all-cause mortality related to short-term PM exposure has been estimated to range from 0.4–1.5% per 20 $\mu g/m^3$ increase in PM_{10} and 0.6–1.2% per 10 $\mu g/m^3$ increase in $PM_{2.5}$ [52]. These associations are much stronger in East Asian countries, especially in China and India, where owing to rapidly developing economies dense populations are exposed to very high levels of outdoor and indoor air pollution [53,54]. In the APHEA 2 study, air pollutants also had an effect on hospital admissions, i.e. a 10 $\mu g/m^3$ increase of PM_{10} was associated with a 1%