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The Interplay of Climate Change and Health: Addressing Physical and Mental Well-Being

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Abstract

Climate change has been recognized as one of the most significant global challenges with far-reaching implications for human health, particularly in the domain of chronic diseases and mental health. This paper aims to explore the relationship between chronic diseases and climate change, explaining how recent academic research relates global changes in the climate to human health, including mental well-being. An in-depth review of literature has been carried out to explore the links between climate change and chronic diseases, its underpinning mechanisms explaining these relationships, identification of vulnerable populations, and interpretation of findings in the public health contexts of policy and intervention. The paper also provides a comprehensive theoretical framework addressing aspects of chronic diseases, mental health, and climate change. Overall, findings show that climate change has drastic impacts on the burden, distribution, and incidence in the management and progression of chronic diseases, along with significant implications for mental health. This overview therefore emphasizes that climate change is, without doubt, an issue of great importance and needs to be at the forefront for interventions among healthcare providers, policymakers, and researchers in efforts to manage the arising burden of chronic diseases and improve general health. This paper points out the high necessity of interdisciplinary collaboration in the development of adaptive strategies, improving health resilience, and applying preventive measures that can effectively support responses to the health challenges emanating from climate change, particularly in the context of mental health. It also emphasizes the importance of mainstreaming consideration of climate into the public health planning process, medical education, and response to chronic illness so that healthcare systems are well-prepared for the new health environment occurring in a changing climate.

Keywords: Chronic Diseases – Climate Change – Mental Health

1- Introduction

One of the most serious global challenges of the 21st century, climate change is characterized by extreme changes in temperature and precipitation patterns, coupled with an increased frequency and severity of consequential weather events. The consequences of this change have wide-ranging repercussions, extending beyond environmental degradation to pose serious threats to human life and well-being. These chronic and acute changes to the Earth can cause drastic direct and indirect effects on the health of humans, including mental health challenges (Liu et al., 2015, as cited in Pettitt et al., 2022).

The interaction between climate change and health has become one of the most important research fields today, with implications of changes in climate manifesting through the incidence, prevalence, distribution, and alteration of various forms of diseases, primarily chronic diseases. Chronic diseases, including cardiovascular and respiratory diseases, and diabetes, are the leading causes of morbidity and mortality worldwide. Traditionally associated with lifestyle factors and genetics, these conditions are increasingly linked with physical environment-related factors, including climate change. The relation that climate change has with chronic diseases is multifaceted and complex, involving direct and indirect pathways through which climatic changes can aggravate health outcomes, including mental health.

The direct health impact of climate change includes mortality and morbidity associated with extreme temperatures and changing patterns of respiratory and cardiovascular diseases, which may also lead to heightened levels of psychological stress and anxiety in affected populations as a result of more frequent and severe extreme temperature events (Chan, 2019).

Indirectly, the impacts of climate change on health are mediated through its effects on ecosystems and human systems, leading to health impacts from vector-borne, foodborne, and waterborne diseases, respiratory illnesses, occupational health and safety challenges, undernutrition, and negative impacts on mental health and wellness (Woodward et al., 2014 as cited in Wang, 2015; Cunsolo & Harper, 2019). Mental health issues, such as anxiety and depression, may arise from the stressors associated with climate-related disasters, loss of livelihood, and changes in social dynamics. Figure 1 illustrates the structure of the review and the association between climate change, chronic diseases, and mental health.

Chronic diseases are conditions that impact individuals over an extended duration, influencing one or multiple bodily functional systems, ultimately impacting the individual's health status and necessitating ongoing medical attention. Examples of chronic diseases include diabetes, hematologic disorders, musculoskeletal conditions, and cardiovascular diseases. Chronic diseases affect all age groups and, in the contemporary period, are widely regarded as a public health crisis impacting individuals, posing a significant threat to their well-being, shaping their destiny and prospects, regulating the trajectory of their lifestyles, and compelling adherence to a prescribed regimen concerning healthcare, dietary practices, therapeutic interventions, and other aspects.

Adverse effects on cardiopulmonary health have been linked to climate change. Air pollution is correlated with an increased risk of myocardial infarctions and the aggravation of symptoms related to asthma and chronic obstructive pulmonary disorder. The psychological impacts of these physical health conditions can lead to a decreased quality of life, contributing to mental health disorders such as anxiety and depression. The lengthening of the pollination season due to warmer weather, a consequence of climate change, has led to an increase in allergy-related rhinitis and asthma, which can further exacerbate mental health issues through increased stress and reduced overall well-being (Pettitt et al., 2022). Adaptation and mitigation are the two main approaches adopted to alleviate and manage the health risks of climate change to achieve climate-resilient pathways for sustainable development (Chan, 2019).

Understanding the association between chronic diseases and climate change is crucial to formulating appropriate public health strategies and policies. Addressing this association calls for integrated analysis between the science of climate change, epidemiology, public health, and health management, including mental health considerations. A full range of mitigation strategies is an imperative complement to a comprehensive set of

adaptation measures to enhance resilience to the impacts as required by an appropriate health response to climate change.

In connection to the aforementioned issue, this paper elaborates on the relationship existing between climate change and chronic diseases and explores the pathways through which climatic changes influence disease patterns and health outcomes, including mental health impacts. The study attempts to prioritize the urgent need for mitigation and adaptation efforts concerning climate change to safeguard public health by carefully considering the current evidence and highlighting the mechanisms of interaction.

The literature review in the last five years exemplifies the increased research pertaining to climate change and its impact on human health concerning chronic diseases and mental health. Studies show the various pathways of impact of climate variations on health through changes in air quality, temperature extremes, alterations in disease vectors, and food systems. Moreover, the mental health consequences arising from these changes highlight the necessity for interdisciplinary approaches to address such challenges and safeguard public health against continuous climate change.

In 2019, Poole et al. conducted a study titled *Impact of Weather and Climate Change with Indoor and Outdoor Air Quality in Asthma: A Work Group Report of the AAAAI Environmental Exposure and Respiratory Health Committee*. The research aimed to examine the impact of weather and climate change on air quality, both indoors and outdoors, and how it affects asthma. The study found a strong relationship between air pollution and climate change, with air pollutants contributing to rising atmospheric temperatures. Increased temperatures, in turn, lead to a rise in natural volatile organic compound emissions. The study highlighted that CO2 emissions from fossil fuels not only drive climate change but are also a major source of air pollution. The researchers further noted that larger and more frequent wildfires, associated with climate change, could significantly worsen air quality and consequently increase anxiety and stress levels in affected populations.

Another study from 2019, led by Cunsolo and Harper, explored *Climate Change and Health: A Grand Challenge and Grand Opportunity for Public Health in Canada*. The research delved into the challenges and opportunities posed by climate change for public health in Canada. The study underscored the direct impact of climate change on human health, primarily through changes in extreme weather events such as heatwaves, droughts, and heavy rainfall. These extreme events result in various adverse health outcomes, including heat- and cold-related morbidity and mortality, unintentional injury and death, and mental health issues arising from trauma and stress associated with these events. Additionally, the study identified indirect health impacts from climate change, such as the spread of vector-borne, foodborne, and waterborne diseases, respiratory illnesses, occupational health risks, undernutrition, and negative effects on mental health and well-being.

In a more recent study from 2022, Perera and Nadeau examined *Climate Change, Fossil-Fuel Pollution, and Children's Health*. Their research aimed to investigate the impact of fossil fuel pollution and climate change on the health of children. The findings revealed that fossil fuel combustion is a leading source of both air pollution and greenhouse gas emissions, which drive climate change. Children were found to be particularly vulnerable to these environmental hazards, with risks that include respiratory illnesses, mental health issues, and developmental problems. The study further showed how climate change, manifested through extreme weather events like heatwaves and wildfire smoke, exacerbates these health risks for children, including increased anxiety and stress. It also highlighted the existence of disparities, with socially and economically disadvantaged children being disproportionately affected.

Jones, in 2022, authored *The Health Impacts of Climate Change: Why Climate Action is Essential to Protect Health*, a study aimed at emphasizing the reasons why climate change is the greatest global health threat of the 21st century. Jones argued for the need for urgent climate action, examining the significant role health professionals can play in addressing these issues. The research provided unequivocal evidence of the detrimental impacts of human-induced climate change on planetary and human health, including the psychological burden. While no geographical

region will escape these consequences, the study stressed that the most severe effects fall on those who have contributed the least to climate change. The health threats identified include increased exposure to extreme heat, flooding, and other hazardous environmental conditions related to climate change, as well as negative effects on mental health, which need to be integrated into health policies and climate action strategies.

Also, Pettitt et al. (2022) explored the role of physicians in mitigating the health impacts of climate change in their study, **The Impact of Climate Change on Our Patients' Health and the Family Physician's Role**. The researchers sought to understand how climate change affects patient health and the role that family physicians can play in addressing these impacts. The study found that climate change adversely affects cardiopulmonary health, with air pollution linked to a heightened risk of myocardial infarctions and exacerbation of asthma and chronic obstructive pulmonary disorder (COPD) symptoms. The research also noted that the warming climate has prolonged the pollination season, increasing the prevalence of allergy-related conditions such as rhinitis and asthma. Additionally, the lengthened transmission season for infectious diseases, especially vector- and water-borne illnesses, was identified as another significant consequence of climate change.

Moreover, the psychological and mental health implications of climate change are increasingly recognized, as exposure to environmental stressors can lead to heightened anxiety, depression, and other mental health disorders. The direct correlation between climate change-related disasters and mental health issues emphasizes the necessity for healthcare professionals to be vigilant about the emotional well-being of their patients, especially in vulnerable populations.

More recently, Lee et al. (2023) focused on how climate change and public health interact, specifically examining **The Effects of Global Warming on the Risk of Allergies and Autoimmune Diseases**. Their study highlighted that climate change may lead to increased pollen production, longer pollen seasons, and altered plant distribution, potentially heightening the risk of allergies. Furthermore, the study discussed how environmental factors linked to climate change could influence the risk of autoimmune diseases, revealing complex interactions between climate change and public health.

Overall, research on climate change impacts on health, particularly in relation to chronic diseases, is limited. There is a scarcity of studies in vulnerable regions, especially in non-OECD countries, examining how climate variables affect disease incidence and mortality (Verner et al., 2016; Khader et al., 2015). Additionally, limited information exists on how changes in meteorological parameters influence these health outcomes (Khader et al., 2015). Certain health impacts, such as non-communicable diseases, malnutrition, and mental health disorders, remain significantly understudied (Verner et al., 2016).

There are also notable research gaps in understanding the effects of climate change on chronic non-communicable diseases, particularly cardiovascular and kidney diseases (Kjellstrom et al., 2010). Moreover, many existing studies face statistical limitations, including inappropriate study designs, poor exposure and outcome assessments, and inadequate statistical modeling (Khader et al., 2015). The uncertainty surrounding climate change projections, the complexity of the relationship between climate and health, and the challenges of accounting for future socioeconomic changes further hinder efforts to estimate disease burden accurately. This uncertainty, coupled with limited studies, complicates the assessment of these health impacts (Gholami-Borujen et al., 2018; Ebi et al., 2018).

Additionally, conventional health monitoring methods are insufficient for tracking climate-related health risks, creating a need for improved indicators that account for vulnerability, current impacts, projected risks, and adaptation processes (Ebi et al., 2018). Geographic scope also presents a limitation, as most research on climate change and disease burden has been conducted in wealthier nations, leaving gaps in understanding for other regions, particularly marginalized communities most at risk (Gholami-Borujen et al., 2018; Dellaripa et al., 2024). Furthermore, access to recent government reports with accurate information on climate change's impact on human diseases is often restricted due to unavailability or security concerns, and economic constraints further limit access to

relevant databases (Khan et al., 2019). These limitations highlight the need for improved indicators and collaborative research to enhance understanding of climate change impacts on chronic diseases, particularly as they relate to mental health.

1. Chronic Diseases

Chronic health conditions, including chronic illnesses as well as physical disabilities, are generally considered as those conditions that last longer than 12 months and are severe enough to limit the patient's usual activity (Alharbi et al., 2022). Living with a chronic illness requires individuals and their families to adjust to a 'new normal' (Revenson et al., 2016). Chronic diseases may exert a significant impact on an individual's mental health. In turn, the mental health condition of an individual influences their capacity to engage in the process of treatment and rehabilitation.

A study conducted by Daré et al. (2019) found that mental disorders have a 36.6% prevalence in patients with chronic physical diseases. In addition to the physical severity and symptoms of the illness, individuals with chronic diseases experience mental distress, cognitive and emotional symptoms such as worry, rumination, and melancholy, along with heightened stress and tension, all attributed to their chronic condition. Consequently, this gives rise to a diminished sense of life satisfaction, heightened levels of turmoil and sorrow, anticipation of negative outcomes, feelings of powerlessness and exhaustion, ultimately culminating in the development of mental disorders such as depression and anxiety.

The interplay between chronic illness and mental health conditions can create a vicious cycle where the physical symptoms exacerbate psychological distress and vice versa. A chronic illness can affect the ability to participate in work or leisure activities, leading to social isolation, which is associated with increased rates of anxiety and depression (Gürhan et al., 2019). Furthermore, individuals with chronic diseases are often subjected to societal stigma, which can further deteriorate their mental health, creating additional barriers to treatment and recovery.

2. Characteristics of Chronic Diseases

Chronic diseases are conditions that impact individuals over an extended duration and impact one or multiple functional systems within the body, consequently impacting the individual's health and necessitating ongoing medical attention, including conditions such as diabetes, blood disorders, musculoskeletal disorders, and cardiovascular diseases (De Lemos & Omland, 2018). According to the Centers for Disease Control and Prevention (2022), chronic diseases are defined broadly as conditions that last 1 year or more and require ongoing medical attention or limit activities of daily living or both.

According to Huard (2018), chronic disease is characterized by: the presence of a long-lasting physical, psychological, or cognitive pathologic condition, a duration of several months, and an impact on daily life including at least one of the three following elements: (a) functional limitation of activities or social participation, (b) dependence on a medicine, scheme, medical technology, device, or personal assistance, and (c) the need for medical or paramedical care, psychological aid, adjustment, monitoring, or a specific prevention that can be part of a medico-social care pathway.

In the long term, the patient's situation is not stable; evolutions are usually negative. These complications can be numerous and varied, worsen over time while not being fully predictable, and become debilitating, greatly deteriorating the patient's quality of life. The Australian Institute of Health and Welfare (2023) similarly highlights that chronic diseases share common features: complex causality, with multiple factors leading to their onset, a long development period, for which there may be no symptoms, a prolonged course of illness, perhaps leading to other health complications, and an associated functional impairment or disability.

3. Climate Change

The United Nations Development Program defines climate change as the long-term changes in the Earth's climate that are warming the atmosphere, ocean, and land. Climate change is affecting the balance of ecosystems that support life and biodiversity, impacting health. It also causes more extreme weather events, such as more intense and/or frequent hurricanes, floods, heat waves, and droughts,

and leads to sea level rise and coastal erosion as a result of ocean warming, melting of glaciers, and loss of ice sheets (United Nations Development Program, 2023).

The magnitude of recent changes to the earth's climate is unprecedented over hundreds and thousands of years. Human influences on the earth's climatic systems through the emission of greenhouse gases (GHGs) are now unequivocally accepted as the cause of these effects. Climate change has been defined as human-induced change in the earth's climate—distinct from climate variability, which is due to natural causes. The surface temperature of the earth is currently around 1.2°C warmer than it was in pre-industrial times, and the last decade, 2011–2020, was the hottest on record (Jones, 2022).

Climate change poses one of the biggest public health threats in the twenty-first century. According to estimates by the World Health Organization, climate change will lead to excess annual deaths of 250,000 between 2030 and 2050. The direct health impacts of climate change include changing patterns of respiratory and cardiovascular diseases and morbidity and mortality as a result of more frequent and severe extreme temperatures (Chan, 2019).

Elevated surface temperatures have altered global weather patterns and the frequency and severity of extreme weather events, including heat waves, droughts, sandstorms, wildfires, floods, and tropical storms. Wildfires release large amounts of toxic pollutants into the atmosphere that heighten the risk of pulmonary diseases and allergies (Intergovernmental Panel on Climate Change, 2023).

4. Impact of Climate Change on Health

There appears to be a general agreement that climate change has a profound impact on human health, although scientists do not agree on the precise mechanisms involved. For example, some scientific research results suggest that extreme weather events appear to have the greatest influence on health. With the current alarming climate change rate, humanity will face more injuries, diseases, and deaths due to natural disasters such as heat waves, floods, high rates of waterborne illnesses, as well as premature deaths and diseases related to air pollution (Alhassan, 2017).

While everyone is vulnerable to the health impacts associated with climate change, children are disproportionately affected because of their physical, physiological, and cognitive immaturity (Etzel & Balk, 2018). This vulnerability extends to various aspects of mental health, as children may struggle with anxiety, depression, and other psychological disorders exacerbated by climate-related stressors.

In 2009, the **Lancet Countdown on health and climate change** concluded that "anthropogenic climate change threatens to undermine the past 50 years of public health gain" and described climate change as "the biggest global health threat of the 21st century," with associated impacts on health being experienced around the globe (Costello et al., 2009, as cited in Jones, 2022). The threats that climate change presents to health are usually categorized as direct and indirect impacts on health (Jones, 2022).

Directly, climate change impacts human health most often via changes in extreme events (e.g., heat waves, drought, heavy rain), resulting in heat- and cold-related morbidity and mortality, unintentional injury and death, and other adverse health outcomes. The psychological toll of such extreme weather events can lead to an increase in mental health disorders, including post-traumatic stress disorder (PTSD), depression, and anxiety, as individuals grapple with loss, displacement, and uncertainty about the future. Indirectly, the impacts of climate change on health are mediated through climate change impacts on ecosystems and human systems, with health impacts from vector-borne, foodborne, and waterborne diseases, respiratory illnesses, occupational health and safety challenges, undernutrition, and negative impacts on mental health and wellness (Smith et al., 2014).

Global climate change may also affect microbial evolution and their stress response, as well as the emergence of new pathogens. Over a long period of time, many bacteria have developed mechanisms allowing them to survive and even grow in unfavorable stress conditions. This has been well proven in the case of **Escherichia coli O157**

, which can survive in acidic conditions at pH

2, in contrast to its former survival at pH 5 (Mirski et al., 2011).
At high temperatures, displacement of blood to the surface of the body may lead to circulatory collapse. Indoor thermal conditions, including ventilation, humidity, radiation from walls or ceilings, and the presence or absence of air conditioning, are important in determining whether adverse events occur, but these variables are seldom well measured in epidemiological studies (Anderson et al., 2012). These increasing temperatures lead to extreme heat-related events, such as heat strokes, which is the most prominent cause of weather-related deaths (Poole et al., 2019).

Higher levels of CO2 and ozone (O3), along with a warmer climate, can expand the geographic spread of plants and lengthen their flowering season, thereby prolonging the pollen season. Pollen exposure elicits nasal congestion in people with allergic rhinitis and has been found to enhance susceptibility to respiratory viral infections such as COVID-19, regardless of allergy status (Perera & Nadeau, 2022). The stress of dealing with worsening allergies and respiratory conditions can further contribute to anxiety and depressive symptoms in affected individuals.

Of the many implications of climate change, its effect on food resources is a topic gaining immense traction. Due to climate change's correlation with increased temperatures, rainfall, and CO2 levels, this poses problems with agriculture, potentially impacting nutrition. Many effects of climate change can alter crop yield, nutrient value, protein content, and even livestock (Pettitt et al., 2022). The lack of access to nutritious food can lead to mental health challenges, including anxiety and depression, particularly in vulnerable populations such as children and low-income families.

Droughts, storms, and sandstorms also release large amounts of fine particulate matter (PM) into the atmosphere, which again can elevate the risk of respiratory diseases and allergies. In summary, by increasing exposure to novel pollutants, allergens, and disease vectors, climate change may play a role in the development of allergic and autoimmune diseases (Lee et al., 2023).

Cardiopulmonary systems are affected by climate change through air pollution, extreme temperatures, sand dust storms, and wildfires (Pettitt et al., 2022). Due to industrialization, increasing fossil fuel consumption has led to high levels of CO2. High CO2, coupled with warmer temperatures, contributes to the promotion of plant growth and elongation of the pollen season. This is due to plants flowering earlier in the spring with warmer weather and surviving longer into fall with a delayed first frost (Glaser et al., 2016).

Climate change is projected to harm human health by increasing ground-level ozone and/or particulate matter air pollution. Ground-level ozone (a key component of smog) is associated with many health problems, such as diminished lung function, increased hospital admissions and emergency room visits for asthma, and increases in premature deaths (World Health Organization, 2010; World Health Organization, 2014). This air quality deterioration may also exacerbate mental health issues, including stress and anxiety, as individuals cope with worsening health conditions.

Climate change is increasing the vulnerability of many forests to wildfires. Wildfire smoke contains particulate matter, carbon monoxide, nitrogen oxides, and various volatile organic compounds (which are ozone precursors) and can significantly reduce air quality, both locally and in areas downwind of fires (Costello et al., 2009). Similarly, Cotty and Jaime-Garcia (2007) assert that smoke exposure increases respiratory and cardiovascular hospitalizations; emergency department visits; medication dispensations for asthma, bronchitis, chest pain, chronic obstructive pulmonary disease (commonly known by its acronym, COPD), and respiratory infections; and medical visits for lung illnesses.

5. Impact of Climate Change on Chronic Disease

Chronic diseases such as diabetes and ischemic heart disease magnify the risk of death or severe illness associated with high ambient temperatures (Basu and Ostro, 2008; Sokolnicki et al., 2009 as cited in Smith et al., 2014). Mental health disorders, including

depression and anxiety, are also more prevalent in individuals with chronic diseases, compounding the negative health impacts of climate change.

5.1. Respiratory and Allergic Diseases

A body of evidence suggests that major changes involving the atmosphere and climate have an impact on the biosphere and human environment. Increased concentrations of greenhouse gases, especially carbon dioxide, in the earth's atmosphere have already substantially warmed the planet, causing more severe and prolonged heat waves, temperature variability, increased length and severity of the pollen season, air pollution, forest fires, droughts, and heavy precipitation events and floods, all of which put respiratory health at risk (Ayres et al., 2009). The psychological impact of respiratory diseases, particularly among vulnerable populations such as children and the elderly, can lead to increased anxiety, stress, and depression.

Climate change-related events may increase the risk of mortality and morbidity of respiratory and allergic diseases. Increasing exposure to risk factors may introduce or exacerbate pre-existing medical conditions (D'Amato et al., 2014). The risk of respiratory and allergic diseases is related to reduced outdoor air quality as climate change may: (i) increase concentrations of air pollutants, such as ozone, particulate matter, and dust; (ii) alter production patterns and allergenicity of allergens such as pollen and mould spores; (iii) increase dust in the air; and (iv) increase the frequencies of wildfires and wildfire smoke consisting of air pollutants (Friel et al., 2011).

With more people using air-conditioning equipment in hot weather and increased air particulates, outdoor and indoor air pollution (coupled with poor ventilation) are likely to increase the incidence rate of respiratory tract diseases. Strong sunshine also increases the intensity of ozone at ground level and may potentially affect the respiratory system and people with underlying health risks such as asthma and chronic obstructive pulmonary disease. In addition, as the temperature increases, some comparatively cold regions become warm, and the habitat range of mosquitoes expands toward high-latitude areas (Chan, 2019). The mental health consequences of respiratory diseases and allergic reactions may include heightened levels of distress, anxiety, and reduced quality of life.

There has been great progress in understanding mechanisms by which the environment can mediate immune reactions and allergy risks. These pathways generally begin with environmental assaults that lead to epithelial barrier dysfunction and penetration of both allergens and pollutants into underlying tissue. In the human gut, the loss of epithelial integrity, sometimes referred to as leaky gut syndrome, can permit the entry of endotoxins into the intestinal lumen. In the respiratory tract, a disrupted epithelium may increase the risk of infections by facilitating the passage of respiratory pathogens. For instance, the loss of barrier integrity in atopic dermatitis has been associated with greater concentrations of *Staphylococcus aureus* (Lee et al., 2023).

Air pollutants can also stimulate immune cells through pathways involving toll-like receptors, reactive oxygen species, or aryl hydrocarbon receptors to activate proinflammatory signals and support the inflammatory response through synergistic effects (Lee et al., 2023). An in vitro cell culture study showed that stimulation with pollutant extracts of bronchial epithelial cells increased the production of proinflammatory cytokines (for instance, IL-1α, IL-1β, IL-6, and IL-8), while particulate matter stimulated proinflammatory cytokine production with macrophages (Mitschik et al., 2008).

Wildfires contribute significantly to air pollution by releasing PM and CO2, carbon monoxide (CO), complex hydrocarbons, NOx, trace minerals, heavy metals, and other toxic and carcinogenic compounds (European Environment Agency, 2022). These pollutants can exacerbate mental health issues, particularly in individuals already predisposed to anxiety and depression.

Increased human activities and high levels of industrialization lead to the emission of pollutants such as particulate matter, nitrogen dioxide, sulfur dioxide, and ozone. Climate change can enhance allergic diseases and respiratory disorders by increasing the frequency and severity of air pollution, allergen exposure, and vector-borne diseases

(Baumgartner et al., 2011). Such heightened exposure contributes to increased anxiety and distress, especially among vulnerable populations, including children, the elderly, and individuals with pre-existing mental health conditions.

Increased human activities and high-density urban living may lead to more air pollutants (such as ozone, fine particles, and dust) entering the air, which may raise the incidence of respiratory illnesses, such as asthma and COPD. The health impact of air pollutants is more apparent with high temperatures (Chan, 2019). Moreover, the psychological effects of these respiratory illnesses can exacerbate mental health issues, leading to increased anxiety and depression among affected individuals.

Anthropogenic climate change has also exacerbated the frequency of sand and dust storms, primarily in Northern Africa and Asia, that release particulate matter. A study conducted in Nicosia, Cyprus, reported significantly elevated cardiovascular hospital admissions during Saharan dust storms. Another study in Madrid, Spain, found that daily mean concentrations of PM2.5 were 1.4 times higher and 1.9 times higher for PM10–2.5 on days of Saharan dust storms (Tobías et al., 2011). The psychological burden associated with these environmental changes can lead to heightened stress and mental distress among populations living in these affected areas.

The most susceptible population groups for respiratory and allergic diseases exacerbated by climate change are those suffering from chronic respiratory diseases, people with pre-existing medical conditions such as asthma and cardiovascular problems, and vulnerable population groups such as children and older people (Friel et al., 2011). Mental health variables, such as resilience and coping strategies, play a significant role in how these groups manage the stressors associated with their conditions.

5.2. Cardiovascular Diseases and Cerebrovascular Diseases

Climate change may directly or indirectly increase CVD risks through three main pathways: (i) air pollution; (ii) extreme temperatures; and (iii) changes in dietary options (Friel et al., 2011). Increased exposure to air pollutants may increase CVD-related hospitalization and deaths by triggering heart attacks, strokes, and irregular heart rhythms, particularly in people with pre-existing medical conditions (Gold and Samet, 2013). The psychological stress associated with these health challenges may further exacerbate mental health conditions, including anxiety and depression.

When extreme heat is combined with high pollution, the CVD risk in susceptible populations may be increased, as the August 2003 heatwave in Europe showed (D'Amato et al., 2014). Additionally, the mental health consequences of such events can lead to an increase in psychological distress among individuals, particularly those with existing vulnerabilities.

With more intense and longer duration of heatwaves due to climate change, deaths and hospitalizations of CVD patients are expected to increase (De Blois et al., 2015). Changes in dietary options and lifestyles as a result of the environmental impact of climate change may increase the risks of CVD indirectly (Chan, 2019). For example, the Inuit communities in the Arctic region had to change their traditional lifestyle due to the loss of sea ice and permafrost. This adjustment has reduced physical mobility and increased reliance on imported energy-dense processed food, increasing the risk of obesity, diabetes, and CVDs (Dixon et al., 2009).

People with a history of heart attacks, strokes, and pre-existing cardiac diseases such as angina or irregular heart rhythm, as well as those who perform heavy physical labor, are at higher risk of CVDs (De Blois et al., 2015). Furthermore, age, lifestyle habits, and genetics may also contribute to higher risks, for example smoking, family history of hypertension, or people over 65 years old (Gold and Samet, 2013). The psychological strain of managing these chronic diseases can result in increased mental health issues, further complicating their physical health challenges.

5.3. Cancer

Climate change can influence UV radiation levels at the Earth's surface and increase skin cancer risk in at least three ways (Arblaster et

al., 2014): (i) while climate change is not the cause of stratospheric ozone depletion, warming temperatures may slow down the recovery of the ozone layer; (ii) altered precipitation patterns and cloud coverage may change UV levels, with UV levels highest under cloudless skies; and (iii) a warmer climate may change behavioral patterns, such as increased outdoor activities.

In addition to the physical health risks associated with increased UV exposure, there are significant mental health implications. The fear of developing skin cancer can lead to heightened anxiety and stress among vulnerable populations, particularly those with a family history of cancer.

6. Vulnerable Population

Children, the elderly, and communities living in poverty are among the most vulnerable to the harmful effects of climate change (Kim et al., 2014). Vulnerable populations to chronic diseases due to climate change include children, pregnant women, older adults, impoverished populations, people with chronic conditions, and those with mobility and cognitive constraints. Factors such as age, gender, socio-economic status, and other health conditions contribute to this vulnerability (Sharma, 2021).

The impacts of climate change disproportionately affect low-income countries and poor people, threatening their human rights and social justice (Levy, 2015). In particular, long-term care facility occupants, who are often elderly and have chronic diseases, are highly sensitive to climate change impacts (Wollschlaeger, 2021). The intersection of these vulnerabilities also extends to mental health, as economic stress and lack of resources exacerbate mental health conditions within these populations.

7. Responses to Climate Change

Responses can be categorized into mitigation and adaptation—the former involving efforts to reduce greenhouse gas emissions, and the latter involving strategies to adapt to predicted changes (Ingwersen et al., 2013). Adaptation refers to the process of adjustment made according to the actual and expected climate and its effects to moderate harm or exploit beneficial opportunities (Lavell et al., 2012).

A successful adaptation plan requires cooperation and coordination between health departments and non-health departments. Although measures taken by non-health departments are not directly connected to health, these efforts may reduce the risk of a community's exposure to threats and reduce injuries and health vulnerability, such as setting up an early warning system and building flood protection (Chan, 2019).

Mitigation refers to basic prevention measures to relieve or stabilize the adverse impact of climate change on the human living environment. Two main mitigation approaches include: (i) promoting low-carbon development to reduce the emission of greenhouse gases from the source, by reducing the demand for activities with high emissions; and (ii) strengthening the absorption of greenhouse gases by protecting natural carbon sinks (e.g., forests and oceans) or creating new carbon sinks to facilitate carbon dioxide re-absorption (Lavell et al., 2012).

Adaptation and mitigation approaches should support and complement one another to combat climate change. Not only may these measures reduce the health risks brought about by climate change, but well-coordinated and planned mitigation and adaptation measures are likely to be more cost-effective (Chan, 2019).

8. Conclusion and Future Outlook

The paper confirms the profound impacts that climate change is having on chronic diseases, hereby epitomizing a relationship that creates major public health challenges, as well as multifaceted interlinkages. The direct and indirect mechanisms through which climate change exacerbates the prevalence and severity of various chronic diseases are disproportionately borne by vulnerable populations. This connection underscores the complicated health interactions that require much attention from the health sectors, decision-makers, and researchers.

Effective management of the current and continuing aggravation of climate change concerning chronic diseases mandates broad, multidisciplinary strategies that transcend limitations and include current mitigation,

adaptation, and resilience-building measures. Protecting health for the long-term means embedding climate considerations within the broader agenda of public health planning and policy development, as well as medical education to safeguard public health in an era of climatic uncertainty.

Based on the aforementioned discussions, the following suggestions are recommended in light of the literature:

Integration of Climate and Health Strategies: The adaptation and mitigation strategies for climate change should be integrated by healthcare professionals and policymakers in the strategies designed for chronic disease management to potentially enhance health resilience.

Interdisciplinary Collaboration: Major interdisciplinary collaboration between climate scientists, healthcare providers, public health experts, mental health professionals, and policymakers is needed to develop and implement adaptive strategies concerning the health impacts of climate change on chronic diseases.

Education and Training: The realization of preparedness for the health impacts of climate change among health professionals in their future training may be obtained through full incorporation into medical education curricula.

Vulnerable Populations: There must be effective protection for special groups within a population, which includes children, the elderly, and low-income families from the exaggerated impacts of climate change on chronic diseases.

Public Awareness: Public health campaigns should create awareness of the link between climate change and chronic diseases, leading to preventive measures and resilience building in the general public.

Research and Data Collection: More research is needed on specific pathways through which climate change affects particular chronic diseases, as well as various interventions with adaptive value.

Policy Development: Policies that address threats to health associated with climate change should be developed and implemented, ensuring that they are evidence-based and incorporate preventive and adaptive measures.

Funding and Resources: Sufficient funding and resources are required for climate health initiatives based on research and community-based activities to mitigate the impacts of climate change on chronic diseases.

Assess Health Vulnerabilities and Develop Health Plans: Comprehensive assessments of health vulnerabilities in different regions should be conducted, considering local climate conditions, population demographics, and existing health infrastructure. Targeted health plans addressing specific climate-related risks, such as extreme heat, infectious diseases, and malnutrition, need to be developed.

Integrate Climate Risk and Implement Surveillance Systems: Integration of climate risk information into health systems is essential, enhancing preparedness and response. Timely establishment of climate-informed surveillance and early warning systems for key health risks is crucial.

Support Resilience and Adaptation in Health-Determining Sectors: Strengthening health-determining sectors should be prioritized to enhance resilience against climate impacts while urgently addressing sustainable practices that reduce vulnerability to climate-related health risks. This includes integrating mental health services into primary health care, as climate change can exacerbate stress, anxiety, and depression among affected populations. The incorporation of mental health support in health systems ensures a holistic approach to climate adaptation, helping individuals cope with the psychological impacts of climate-induced events such as displacement and loss of livelihood.

Close the Financing Gap for Health Adaptation and Resilience: Efforts to allocate sufficient resources for health adaptation and resilience must be prioritized. Collective mobilization of funding from international organizations, governments, and private sectors is necessary to bridge financial gaps. Funding should also target mental health initiatives that arise due to climate change-related stressors, such as trauma counseling for communities affected by natural disasters and programs aimed at improving mental well-being among

vulnerable populations.

Enhance Methodological Approaches and Research Collaboration: Improving study designs, exposure assessments, and statistical modeling in climate-health research is critical. Collaboration between researchers, policymakers, and practitioners is essential to address research gaps and share knowledge. Mental health research must be included in climate health assessments to identify the specific impacts of climate-related stressors on mental health outcomes, allowing for tailored interventions that promote psychological resilience alongside physical health.

Expand Geographic Scope and Focus on Marginalized Communities and At-Risk Non-OECD Countries: Studies in diverse regions, including non-OECD countries and marginalized communities, must be conducted, ensuring that research considers the unique vulnerabilities of different populations. Mental health disparities among these groups should be a focal point, as they are often at a higher risk of experiencing adverse mental health outcomes due to climate change. Research efforts should explore the intersectionality of climate impacts and mental health, highlighting how socio-economic factors influence mental health resilience.

Facilitate Access to Reliable Data and Reports: Efforts to address barriers to accessing accurate data on climate change impacts are necessary through promoting transparency and facilitating access to government reports and databases related to climate and health. This includes data on mental health trends related to climate events, which can inform policymakers and healthcare providers about the psychological needs of affected populations. Reliable data is crucial for developing targeted mental health interventions and policies that address the specific challenges faced by communities impacted by climate change.

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RESEARCH ARTICLE
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Review Article

Anticancer agents from Bacillus thuringiensis Delta-endotoxins

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Abstract

Cancer is one of the most fatal diseases that rarely any cancer patient survives from it. Cancer affect different ages and sex causing great humanity losses reaches up to 100,000 patient / year according to the recent statistical analysis. It also, affects different tissues causing irreversible cytopathological changes result in highly undifferentiated cells that hard to be controlled or eradicated. The chemotherapy, radiotherapy and surgical interference still used in elimination of the disease since decades however both radiotherapy and chemotherapy did not prove acceptable success in the cancer treatment until now, unfortunately the surgical interference could not be more helpful as it did not overcome the malignancy metastasis which gets back wilder after surgical interference due to metastasis. So, it was sound good to use the biological anti-malignancy agents in eradication of cancer cells. Biological anticancer agents provide a confident success in cancer therapy which includes many microbial metabolites derived from the members of Family *Bacillacae* such as *Bacillus thuringiensis*, *Bacillus polymixa* and other members explored recently in the Saudi environment. For example in a previous studies recorded by us some serovars of *Bacillus thuringiensis* enzymatically activated parasporal inclusion proteins proved a potent anti-malignancy effect on acute lymphocyte leukemia, lung carcinoma, larynx carcinoma and uterine cervix carcinoma *in vitro* and a great result was recorded *in vivo* on the Ehirlch Acites Carcinoma. These biological anti-malignancy agents had a selective direct cytotoxic effect on cancer cells in addition to improving the immune status (immunomodulation) which helps in destruction of the cancer cells and dysfunction of their metastasis properties. So, this project is aimed at extraction of potent biological anti-malignancy agents from new members of Family *Bacillacae* and broadly investigating their direct cytotoxic effects on cancer and normal mammalian cells, their ability to differentiate between normal and cancer cells, *in vivo*, vital functions disturbance, *in vivo* immunomodulation in tested lab animals, diminishing of the metastasis properties in the cancer bearing lab animals, cancer cell receptors, pest rout of administration and formulation of the explored biological anti-malignance agents in a stable and suitable forms.

Keywords: Anticancer agents, *Bacillus thuringiensis*, Biotherapy, Delta endotoxins.

1-Malignancy and public health importance

Cancer is now highly common among other disease in Kingdom of Saudi Arabia. Progress made in cancer therapy has not been sufficient to significantly lower annual deaths rate, so there is an urgent need for new strategies in cancer control. Prevention is most practical strategy to control cancer occurrence and spread. Cancer bio-prevention aims at halt or reverses the development and progression of precancerous cells through use of non-cytotoxic microbial metabolites. Subsequently, the identification, mechanistic investigation, validation and utilization of microbial metabolites have become an important issue in current public health-related research. It will be of importance to provide a variety of cancer bio-preventive and biotherapeutic agents with different molecular, cellular targets and acting by multiple mechanisms.

For the identification of novel cancer bio-preventive a broad spectrum of cell and enzyme based *in vitro* assays with markers relevant was set up for measuring inhibition of carcinogenesis during the initiation, promotion, and progression stages. These bioassay systems offer fast and sensitive identification and evaluation of lead compounds for the development of effective bio-preventive and anti-tumor agents and then elucidation of their mechanism of action.

Genus *Bacillacae* importance as Immunogin, Food preservative (antimicrobial) and anticancer.

a- Antimicrobial importance of genus *Bacillacae*:-

Lactic acid bacteria (LAB) and their probio-active cellular substances exert many beneficial effects in the gastrointestinal tract. LABS prevent adherence, establishment and replication of several enteric mucosal pathogens through several antimicrobial mechanisms (Nadu AS, ***et al.*, 1999).** LABS also release various enzymes into the intestinal lumen and exert potential synergistic effects on digestion and alleviate symptoms of intestinal meal absorption. Consumption of LAB fermented dairy products with LAB may elicit antitumor mutagenic activity, decrease is several enzymes implicated in the generation of carcinogens, mutagens, or tumor promoting agents, suppression of tumors, and the epidemiology correlating dietary regimes and cancer. Specific cellular components in LAB strains seem to induce strong adjuvant effects including modulation of cell mediated immune responses, activation of reticuloendothelial system, augmentation of cytokine pathways and regulation of interleukins, and tumor necrosis factors (Naidu AS*, et al.,* 1999). Enteric pathogens may cause gastrointestinal disease in humans & animals and antibiotics have often been used to prevent such disorders. However, the use of antibiotics is no longer recommended due to complications including the emergence of drug resistant strains (Karmartiar *et al*., 2004, *O'flaherty* et al., 2005 and *Takeuchi* et al., 2005) and the potential for chronic toxicity (Dundas *et al*., 1999); thus, alternative approaches to the prevention of gastrointestinal disorders have been suggested. Many reports show the usefulness of lactic acid bacteria (LAB) as probiotics for humans and animals (Brashears *et al*.**,** 2003; Hamilton-Miller 2003 and Sartor 2005) for the probiotic functions, several factors are usually considered. For example, the capability of LAB to adhere to cells of the host gastrointestinal epithelium and to serve as a barriers to protect it from infection by enteric pathogens, such as *Salamonella* spp. or *Escherichia coli* (Jin *et al*.**,** 1996; Chou and Wemer 1999, Coconnier *et al*., 2000); the organic acids produced by LAB which maintain a competitive advantage by inhibiting enteric pathogens in the gastrointestinal tract (Naidu *et al*., 1999).

b- Anti Cancer and Immuno-modulating importance:

Lactobacilli species, which is used in dairy based foods and dietary supplements, is nonpathogenic and safe for human consumption (Salminen,S *et al*., 1998 and Naidu, A. *et al.,* 1999). It is also a common compared of the human commercial microflora. Their long record of human exposure and consumption has led to their generally regarded as safe classification. Viable and nonviable *lactobacillus* species have anti-tumor abilities (Seow S.W., *et al*., 2002). Patients with carcinoma of the uterine cervix who received heat killed *Lactobacillus casei* YIT9018 intradermally and radiation therapy had enhanced

tumor regression compared with those given only radiation therapy (Aseno M., *et al*., 1986). In animal models such as Meth A fibrosarcoma bearing mice intrapleural administration of lactobacillus prolonged the survival of tumor bearing animals and suppressed tumor development (Aso, Y., *et al*., 1992). Similarly for azoxymethane induced colon cancer in rats consumption of Lactobacillus species prolonged the survival of tumor bearing animals and reduced the number of colon cancers formed (Aso,Y., *et al.,* 1995). In humans with superficial bladder cancer oral consumption of *Lactobacillus* was found to increase recurrence free periods (Masuno T., *et al.*, 1991), the same thing was noted in mice that oral consumption of *L. rhamnosus* GG (Aseno *et al.,* 1985*,* Lim, B *et al.,* 2002).

Lactobacillus species is believed to primarily act by enhancing the host immune system, although there have been some reports of cytotoxic effects on cancer cells (Manjunath, N. *et al.,* 1989 and Fichera, G.A. and Giese, G.,1995) *Lactobacillus casei*, Shirota strain, has been recognized as a typical probiotic strain.

Pre- clinical studies, in several animal experimental models have shown that LC9018, a heat killed preparation of the Shirota strain, exerts potent anti-tumor and anti-metastatic activities after intra pleural, intralesional, intra venous and oral administration. The anti-tumor activity of the Shirota strain has also been investigated in several clinical trials. The oral administration of Biolactis Powder, a powder formulation of *L. casei*, Shirota strain, reportedly suppressed recurrence after transurethral bladder tumor resection (Aso,Yand Akazan, H.,1992 and *Aso,Y et al*.,1995).

Intrapleural injection of LC9018 combined with doxorubicin significantly prolonged the survival of patients with malignant pleural effusions (Masuno, T. *et al.,* 1991). Moreover, intra-dermal administration of LC9018 with radiation therapy also had a survival prolonging effect in patients with stage IIIB cervical cancer (Okawa, T. *et al.,* 1993).The mechanism of anti-tumor activity has been recognized as the augmentation of the innate cell mediated immune system, including macrophages and natural killer cells by *L. casei*, Shirota strain (Kato,I *et al* 1983 and Matsuzaki,T *et al*., 1988). Intra-vesical BCG caused the infiltration of macroplages and T cells, probably type Th_1, in bladder submucosal tissue (Bohle, A. *et al*., 1990).

It has been reported that tumor necrosis factor- α (TNF-α) directly induces tumor cell apoptosis *in vitro* and enhances the tumoricidal activity of macrophages (Wang,C.Y *et al*., 1996 and Hori, K *et al*., 1987). LC9018 enhanced production of TNF-α when co-cultured with macrophages derived from peripheral blood *in vitro* (Hara,h *et al* 1989). Also, it has been reported that intra-pleural injection of LC9018 induces marked production of cytokines, such as IL-1B, interferon-Gamma, IL-12 and TNF -α, in the pleural cavities of tumor bearing mice (Takahashi, T. *et al*., 2001). Furthermore, treating mice with anti-tumor necrosis factor-α mAb completely abolished the anti-tumor activity of LC9018. In addition intra-pleural injection of recombinant TNF-α partially restored the survival prolonging effect of LC9018 in Meth A-bearing mice pretreated with anti-tumor necrosis factor-α mAb (Yasutake, N. *et al*., 1999).Therefore, it is likely that LC9018 induces the production of TNF-α by macrophages in bladder tissues. Together these results suggest that TNF-α has a pivotal role in the anti-tumor activity of LC9018 against MBT-2 bladder tumors.

Therefore, the mechanisms by which LC9018 enhances cell mediated anti-tumor immune responses are thought to involve the stimulation of macrophages infiltrating the bladder mucosa by LC9018 (Le,J *et al*., 1983).In clinical trials there were no serious symptoms after intra-pleural or intra dermal injection of LC9018 except for a few mild cases of fever, transient hepatic dysfunction and skin lesion(Masuno, T.*et al*., 1991 and Okawa, T. *et al.*, 1993). Intravesical instillation of LC9018 may represent potent immunotherapy for prophylaxis against bladder tumor recurrence without severe side effects.

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