Review of Contemporary Philosophy
ISSN: 1841-5261, e-ISSN: 2471-089X
Vol 22 (1), 2023
Pp 1414 - 1427

Skin Infections: An Updated Review of Cellulitis and Impact of Climate Change.

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Abstract:

Background: Cellulitis, a bacterial infection affecting the dermis and subcutaneous tissues, presents with redness, warmth, swelling, and tenderness. It is a significant concern in skin and soft tissue infections (SSTIs) and is often caused by beta-hemolytic streptococci and methicillin-sensitive Staphylococcus aureus. Risk factors include diabetes, obesity, and venous insufficiency. While traditionally managed with antibiotics targeting streptococcal species, the rise of methicillin-resistant Staphylococcus aureus (MRSA) complicates treatment. In the U.S., cellulitis accounts for significant healthcare burdens, with millions of cases annually. Emerging evidence suggests climate change may influence cellulitis incidence due to elevated temperatures and seasonal fluctuations.

Methods: This review investigates the relationship between climate change, particularly rising temperatures, and cellulitis incidence. Studies were examined for correlations between temperature, humidity, and cellulitis rates, with a focus on global trends and seasonal patterns. Data from various regions were analyzed to explore the potential impact of climate factors such as humidity, rainfall, and the occurrence of tropical cyclones on cellulitis prevalence.

Results: Higher temperatures, particularly in summer, were consistently linked to increased cellulitis cases, with a dose-dependent relationship between temperature rise and infection rates. Studies from diverse climates, including the U.S., Taiwan, the UK, and Australia, confirm that cellulitis cases peak in warmer months, and a 5°F increase in temperature correlates with a higher likelihood of hospitalization. Furthermore, tropical cyclones and floods exacerbate the condition by increasing skin trauma and providing favorable conditions for bacterial growth, especially Vibrio infections.

Conclusion: Cellulitis incidence is influenced by climate factors, particularly elevated temperatures and humidity, which promote bacterial colonization and skin vulnerability. Future climate change may exacerbate this trend, emphasizing the need for preventative strategies. Healthcare systems must prepare for the growing impact of climate-related cellulitis cases, particularly in high-risk populations.

Keywords: cellulitis, climate change, temperature, humidity, bacterial infections, SSTIs, Vibrio infections, tropical cyclones, healthcare burden, seasonal trends.

Received: 16 october 2023 **Revised**: 29 November 2023 **Accepted:** 13 December 2023

Introduction:

A common bacterial infection that affects the deeper layers of the dermis and surrounding subcutaneous tissue is cellulitis [1]. Localized warmth, redness (erythema), swelling, and tenderness in the afflicted skin area are its defining characteristics [1]. Cellulitis falls under the category of skin and soft tissue infections (SSTIs), which also includes folliculitis, impetigo, erysipelas, and abscesses. A breach in the skin, which serves as a barrier against external pathogens and is an essential part of innate defense, is usually the first step in the development of cellulitis [1]. Bacteria infiltrate the dermis and subcutaneous tissue after the skin's integrity is damaged, frequently triggering an immunological response by producing peptides that draw in neutrophils [1]. Despite the fact that bacterial pathogens are responsible for the majority of cellulitis cases, it can be difficult to pinpoint the exact bacterium because of the challenges associated with culture the infection [1]. Beta-hemolytic streptococci and methicillin-sensitive Staphylococcus aureus are the most common pathogens in cases where they have been found [1]. Although patients with particular risk factors may need broader-spectrum antimicrobial therapy, treatment usually consists of medicines that target streptococcal species [1]. Diabetes mellitus, venous insufficiency, obesity, and advanced age are risk factors for cellulitis [2]. Furthermore, methicillin-resistant Staphylococcus aureus (MRSA), a multidrug-resistant strain that makes treatment choices more difficult, is more likely to affect specific populations, including children, athletes, men who have sex with men, intravenous drug users, military recruits, and residents of long-term care facilities [1]. An estimated 14 million people in the US are thought to get cellulitis each year, with the majority being middle-aged and older adults. The frequency rises with age [3]. There have been no discernible gender-based disparities [3]. Hospitalization is required for severe presentations, even though many patients are treated in outpatient settings. In the United States, cellulitis causes more than 650,000 hospital admissions each year, placing a significant strain on the healthcare system [1]. The economic burden is substantial; according to a 2016 study, ambulatory costs are estimated to be $3.7 billion annually, while inpatient hospitalizations with cellulitis as the primary diagnosis result in costs of around $4 billion [1, 4].

Impact of Elevated Temperature on Cellulitis

The impact of climate change on global temperatures has been one of its most noticeable effects. The Earth's surface temperature has increased by around 2°F since 1850, and it has increased more than three times faster since 1982 [5]. All nine of the subsequent warmest years have occurred in the past ten years, with 2023 being the warmest year in recorded human history [5]. In particular, the average temperature in 2023 was 2.12°F higher than the 20th-century average of 57.0°F [5]. According to climate scientists' projections, the amount of greenhouse gas emissions will directly affect how much warming occurs in the future [5]. Global temperatures are predicted to increase by 5–10.2°F by 2100 relative to the 1901–1960 average if greenhouse gas emissions continue on their current track [5]. The occurrence of cellulitis has been closely linked to seasonal fluctuations. Peterson et al. used U.S. inpatient records and climate data to indicate that cellulitis incidence is highest in the summer, with July having a 35% higher incidence rate than February, which has the lowest rates [4, 6]. Seasonality is influenced by temperature, humidity, precipitation, and the Earth's axial direction with respect to the sun. Of these, high summer temperatures were the primary cause of this correlation, accounting for more than 70% of the seasonal patterns that were noted [4]. A 5°F increase in temperature was associated with a 3.55% increase in the likelihood of hospitalization for cellulitis, according to the study, which also found a dose-dependent link between average monthly temperature and cellulitis risk [4]. Even after controlling for factors like age, sex, length of hospital stay, geographic location, latitude, and longitude, this association remained [4].

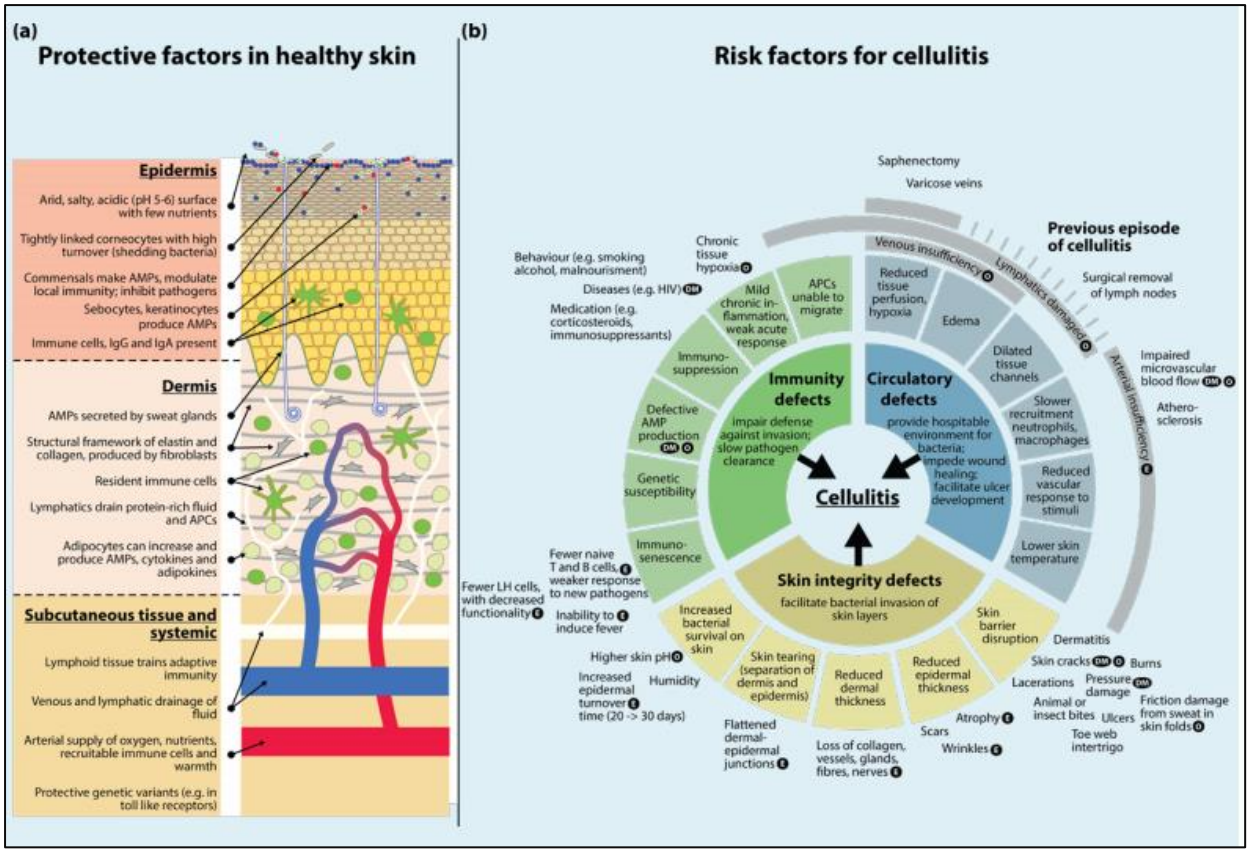

Figure 1: Mechanism and Risk Factors of Cellulitis.

Furthermore, this connection was unaffected by differences in healthcare delivery and access [4]. greater temperatures were substantially associated with greater infection rates in surgical site infections, according to similar findings [7]. Elevated temperatures have been linked to cellulitis in pediatric groups, while the condition primarily affects middle-aged and older adults. SSTIs showed a seasonal pattern, with cases increasing in early September, according to an Arizona study of people ages 0 to 19 [8]. According to this study, average temperatures in this population were strongly correlated with the temporal fluctuation in SSTI instances [8].

The correlation between cellulitis and seasonality has been confirmed worldwide in a variety of climatic zones. For example, an examination of mid-2000s admission data in East Anglia, UK, revealed that non-necrotizing cellulitis admissions were considerably higher in late spring and summer, with a peak in May [9]. In a similar vein, Western Australia noted that summer and fall saw a higher prevalence of lower leg cellulitis [10]. A retrospective analysis of Hajj pilgrims from 42 different nationalities in Saudi Arabia from 2004 to 2012 showed that cellulitis was responsible for almost 25% of surgical admissions, with proportionate increases occurring in tandem with seasonal temperature increases [11]. In a Taiwanese investigation of almost 200,000 instances of cellulitis, incidence rates were found to be strongly correlated with both sunshine hours and temperature. The results showed that the incidence rose by 3.47 cases per 100,000 population for every 1°C increase in temperature [12].

There has been a noticeable rise in the prevalence of cellulitis in the US. Hospitalizations for cellulitis increased between 1998 and 2013, with a definite seasonal trend as summertime saw the highest number of hospitalizations [6]. Together with rising average temperatures at the same time period, the dose-dependent link between temperature and cellulitis may help to explain this increase [4]. Future studies are still needed to determine the processes behind the association between high temperatures and cellulitis. Bacteria that are already colonized the host's skin or mucosal surfaces are the source of the majority of SSTIs caused by Staphylococcus aureus [13]. Furthermore, the main way that bacteria spread is through direct person-to-person contact [13]. In order to explain the observed link, Leekha et al. suggest

that environmental changes, such as increased temperatures and humidity, may promote bacterial colonization, host vulnerability, and transmission rates [13]. According to studies, people who live in high-temperature, high-humidity environments have substantially higher bacterial populations in body parts such the foot, axillae, and back than people who live in moderate environments [13, 14]. Additionally, the pathogenesis of cellulitis is linked to insect bites, which are linked to skin damage. Studies conducted in England and Wales discovered a correlation between insect bites and impetigo, another SSTI, as well as a temperature-dependent rise in insect bites [15, 16].

Tropical Cyclones and Sea Levels:

Along with hurricanes and typhoons, tropical cyclones are fast-moving storms that have killed around 800,000 people in the last 50 years [17]. Together, they constitute one of nature's most deadly threats. The effects of climate change, specifically the increase in ocean surface temperatures, are thought to contribute to the creation of these storms [18]. Furthermore, as hurricanes get stronger over time, climate change not only makes tropical cyclones more frequent but also intensifies them [17]. These cyclones have a variety of effects, including significant property damage, fatalities, and injuries due to their strong winds and heavy rainfall [17].

Furthermore, these storms' powerful winds cause storm surges that resemble tsunamis, which force enormous volumes of ocean water towards coastal regions and cause catastrophic floods [17]. As a result of both the melting of glaciers and ice and the thermal expansion of ocean water, climate change is also causing global sea levels to rise in tandem with the prevalence of tropical cyclones [19]. With the worldwide average sea level rising by 8 to 9 inches since 1880, these changes have resulted in high-tide flooding occurrences becoming 3 to 9 times more frequent than they were 50 years ago [19]. An increase in Vibrio infections, which can result in cellulitis and are frequently seen in marine habitats, has also been connected to rising water temperatures. Vibrio infections have historically peaked in the summer, and their frequency is increasing along with water temperatures [20]. Cellulitis has also been linked to other marine bacteria, including Shewanella species, especially in those who have been exposed to marine water [21–24]. Because strains like Shewanella algae show resistance to standard antibiotics like cephalosporins and penicillins, as well as quinolones and carbapenems, these bacterial infections provide special diagnostic and treatment issues [26,27]. Another bacterium linked to severe cellulitis, Vibrio vulnificus, can cause infections that have death rates of 20% and frequently necessitate amputations and intensive care unit treatment [28].

Along with these infectious risks, cellulitis has also been linked to high rainfall, which is a regular occurrence during tropical cyclones. Rainfall and the frequency of wet days are strongly associated with higher rates of cellulitis, according to studies done in Taiwan [12]. Additionally, a study conducted in São Tomé and Príncipe during an outbreak of necrotic skin diseases in 2016–2018 revealed a strong correlation between relative humidity and a greater incidence of cellulitis [29]. According to this study, a rise in cellulitis instances was linked to both higher relative humidity and precipitation. Tropical cyclones do more harm than only physical harm since they frequently leave behind conditions that might lead to cellulitis. For instance, Taiwan saw a sharp increase in cellulitis cases in the two weeks after Typhoon Haitang in 2005, with those afflicted having had their limbs soaked in floodwaters, which probably aided in the start of infection [30]. Similarly, Vibrio vulnificus infections were widespread following Hurricane Katrina in 2005, as the bacteria spread due to flooding [31]. Following tropical cyclones, the incidence of cellulitis has increased in both adult and pediatric populations. A Miami children’s hospital reported increased rates of open wounds and cellulitis in children following Hurricane Andrew in 1992 [32]. Trauma surgeons also saw a rise in cut injuries after catastrophe Sandy in 2012, which occurred both during recovery efforts and as a direct result of the catastrophe [33]. Because skin trauma provides entry routes for microbial infections, cellulitis was also more common in fall-related injuries from Hurricane Maria in 2017 [34, 35].

Pollution and Its Impact on Cellulitis

The continuous challenge of climate change is largely caused by pollutants. Among these, air pollutants that are categorized as short-lived climate pollutants and have a significant impact on global warming include methane and black carbon [36]. Methane produces ozone, another powerful air pollutant that is essential to climate dynamics [36]. Ozone is a molecule made up of three oxygen atoms and is chemically denoted by the symbol O3 [37]. Although ozone is found naturally in the upper atmosphere, ground-level ozone is dangerous and helps to smog [37]. Complex chemical processes involving nitrogen oxides, volatile organic molecules, heat, and sunlight result in the production of this gas [37]. When exposed to ultraviolet-B (UV-B) radiation from the sun, the concentration of ground-level ozone tends to rise; these effects are more noticeable in warmer metropolitan settings [38]. Transportation networks, like cars, and industrial sources, such chemical refineries, are major sources of ozone [37]. Notably, ozone can affect even non-urban areas due to its long-distance transfer by wind [37]. The incidence of cellulitis is immediately negatively impacted by nitrogen dioxide and particulate matter with a median aerodynamic diameter of less than 2.5 μm [39].

Exposure to ozone has been positively linked to a higher prevalence of cellulitis, especially Streptococcus species-caused cellulitis [40]. Additionally, a higher frequency of ER visits for cellulitis has been associated with elevated ground-level ozone concentrations, with age affecting the consequences. Notably, people 65 years of age and younger had a greater frequency of cellulitis linked to ozone exposure [3,41]. Research on the specific methods by which ozone affects skin is still continuing. Ozone can cause structural damage to the skin, making it more susceptible to infection, according to studies conducted in avian models [42]. Furthermore, ozone increases nitric oxide synthase and heat shock protein 27 in rodent skin, triggering oxidative stress responses [43]. Ozone exposure in vivo has also been connected to the peroxidation of lipids in mice' epidermis and the depletion of antioxidants such vitamins C and E [44]. Nucleic acids, proteins, and membranes are all impacted by these metabolic alterations, which ultimately result in skin cell injury [45,46]. Additionally, it has been demonstrated that UV-B radiation, which is a catalyst for the creation of ozone layers, suppresses immunological function by preventing T cell activity [47]. Thus, ozone and UV-B radiation together pose a synergistic danger that increases the likelihood of skin diseases such cellulitis [45]. The development of cellulitis may be influenced by broader cellular disruptions, as pollution has also been linked to an increased incidence of a number of skin conditions, including psoriasis, acne, atopic dermatitis, and skin cancer [45].

Wildfires and Their Role in Cellulitis Incidence

Particularly in the western United States, wildfires are becoming more widely acknowledged as a key signal of climate change. According to the US EPA, changes in rainfall and temperature have led to a drier, warmer climate, which in turn creates an environment that is more favorable for wildfires [48]. The peak wildfire season has shifted from August to July as a result of this shift, and future forecasts indicate that both the frequency and intensity of wildfires will likely rise [48]. Although wildfires frequently start in isolated locations, there is growing worry about their capacity to spread and seriously harm residential neighborhoods. Wildfire-induced burns are the most severe of the different kinds of burns. According to a 2021 study, patients who get burns from wildfires are more likely to experience wound infections, death, extended hospital stays, and readmissions [49]. Cellulitis was found to be the second most frequent consequence after burns in a six-year longitudinal study that looked at patients with lower extremity burns [50]. Since gram-positive bacteria are usually treatable with antibiotics, burns themselves pose a serious danger for their first colonization [51,52]. However, gram-negative bacteria, which are frequently resistant to several medicines, are becoming more and more common in burn wounds as they develop [51,52]. Multidrug-resistant bacteria are a major cause of death for burn patients and are often linked to nosocomial infections, such as cellulitis [52]. The likelihood of burn-related injuries and their sequelae, like cellulitis, is expected to grow due to the predicted rise in wildfire frequency and intensity.

Mitigation Strategies for Skin Protection Against Cellulitis in the Context of Climate Change

Climate change is a complex issue that calls for cooperation from a broad spectrum of stakeholders, including national, state, and local governments; multinational corporations; religious organizations; non-profits; and academic institutions. Notwithstanding the inherent difficulties, people can take precautions against cellulitis, especially in view of the changing climate. Increasing skin coverage when outside is a crucial tactic. As was already mentioned, one of the main causes of cellulitis is skin injury. Bowers et al.'s research of collegiate football players found that a higher prevalence of methicillin-resistant Staphylococcus aureus (MRSA) cellulitis was caused by a number of factors, including skin injury from abrasions and "turf burns," as well as perspiration brought on by warm weather [53]. Although it was not fully investigated, the researchers postulated that players who wore more skin-covering apparel because of the colder temperatures were less likely to get skin injuries and, thus, were less likely to contract MRSA [53]. In a similar vein, it has been proposed that skin injuries sustained during summertime activities such as swimming may contribute to the higher prevalence of cellulitis [12]. Furthermore, wearing protective clothes can minimize exposed skin and lower the chance of bug bites, which are a known risk factor for cellulitis [15,54]. Additionally, wearing protective gear near ocean waters might reduce the chance of coming into contact with marine microorganisms that can cause cellulitis, such as Vibrio vulnificus and Shewanella algae.

Clothing may act as a barrier at the microscopic level in addition to providing protection against obvious wounds like cuts and scrapes. Studies have indicated that the correlation between elevated ozone levels and cellulitis is stronger in skin regions that are exposed to more air, such the face, arms, and neck, than in parts that are more covered, like the trunk and legs [41]. Moreover, the development of cellulitis has been linked to human-to-human transmission. MRSA infections in collegiate football players only appeared after more physical contact with teammates, underscoring the significance of sweat exchange and skin-to-skin contact in the spread of pathogens [53]. Researchers in Taiwan found that during the school year, the prevalence of cellulitis rose, indicating that overcrowding could help germs spread [12].

Clothing can serve as a conduit for the transfer of bacteria when shared across groups, even though it protects against cellulitis by limiting skin damage and lowering pathogen transmission. In a Colorado fencing club, a sport with little skin-to-skin contact, a cluster of MRSA skin infections was mostly caused via shared clothing and equipment, according to a CDC report [55]. The CDC suggests methods including washing with soap after exercise, not sharing clothes and towels, and routinely checking the skin for lesions to help prevent the spread of skin infections [55]. Given that cellulitis is predicted to become more common as a result of climate change, these preventative strategies may be beneficial for people in general as well as athletes. By causing skin injuries that permit bacterial infiltration, insect bites have also been linked to an increased risk of cellulitis and other skin and soft tissue infections (SSTIs) [15,16]. Because warmer temperatures probably enhance insect activity and the amount of time people spend outside, research shows a strong link between temperature and the incidence of insect bites [16]. This trend has been made worse by climate change, as rising temperatures encourage mosquito reproduction and increase the frequency of bites [56]. The CDC advises using insect repellents, putting pesticides like permethrin on clothing, and using physical barriers like stroller netting, door screens, and mosquito nets to avoid insect bites [54]. These tactics will become more and more crucial for reducing the risk of cellulitis if the climate keeps encouraging the growth of biting insects.

Factors Affecting the Incidence and Development of Cellulitis Under Climate Change:

Cellulitis is a common bacterial skin infection that involves the dermis and subcutaneous tissue, typically caused by *Streptococcus* and *Staphylococcus* bacteria. While climate change and increased exposure to environmental factors, such as skin injuries and insect bites, can influence the risk of cellulitis, other factors play an equally significant role in its incidence and development. These factors include underlying medical conditions, lifestyle behaviors, immune system status, environmental exposure, and healthcare practices. Understanding these contributing elements is essential for developing effective strategies for prevention and treatment.

Underlying Medical Conditions

One of the most significant risk factors for cellulitis is the presence of underlying medical conditions that compromise the skin or the immune system. Diabetes mellitus is among the most prominent conditions associated with cellulitis. Individuals with diabetes often experience impaired circulation, neuropathy, and skin changes such as dry, cracked skin, making them more susceptible to infections. Poor glycemic control can also weaken the immune response, increasing the likelihood of bacterial infections, including cellulitis. A study by Chlebicki et al. (2013) found that individuals with diabetes have a significantly higher risk of developing cellulitis, particularly in the lower extremities, due to poor circulation and nerve damage that may go unnoticed until infection is advanced. Other medical conditions that predispose individuals to cellulitis include venous insufficiency, which leads to poor blood flow, particularly in the legs, and thus a greater chance of skin breakdown and bacterial invasion. Chronic conditions such as lymphedema and obesity also increase the risk, as they lead to fluid retention and altered tissue integrity, creating favorable conditions for bacterial growth. Similarly, immunocompromised states, such as those associated with HIV, cancer treatment (chemotherapy), and organ transplantation, elevate the risk of cellulitis due to a weakened immune system. These individuals are less able to mount an effective immune response to infections, which can lead to more severe and frequent cellulitis episodes.

Lifestyle Factors and Hygiene Practices

Personal hygiene and lifestyle behaviors are crucial in preventing cellulitis. Poor hygiene practices, particularly neglecting to wash the skin after physical activity or exposure to contaminated environments, can increase the risk of cellulitis. Sweat, dirt, and bacteria can accumulate on the skin, leading to abrasions or cuts that provide an entry point for pathogens. Individuals involved in contact sports or activities with high skin exposure (such as wrestling or rugby) are particularly vulnerable to cellulitis due to frequent skin-to-skin contact, abrasions, and shared equipment. In addition, behaviors such as excessive alcohol consumption or smoking can further predispose individuals to cellulitis. Both alcohol and tobacco use are associated with compromised immune function, which impairs the body's ability to fight infections. Alcohol can also increase the likelihood of accidental injuries and the development of other conditions (such as liver disease or chronic ulcers), which make the skin more vulnerable to infection. Smoking, on the other hand, constricts blood vessels and impairs circulation, reducing the flow of immune cells to areas where infections may develop. Thus, these lifestyle factors can compound the risk of cellulitis by impairing the body's natural defenses.

Immune System Status

The immune system plays a central role in preventing the onset of cellulitis. A weakened immune system, either from an underlying medical condition or due to the use of immunosuppressive treatments, significantly increases the risk of skin infections. Individuals with compromised immunity, such as those undergoing chemotherapy, HIV-positive individuals with low CD4 counts, or transplant recipients on immunosuppressive therapy, are particularly vulnerable. In these populations, the body's ability to detect and eliminate invading pathogens is diminished, allowing bacteria such as *Staphylococcus aureus* and *Streptococcus pyogenes* to establish infections more easily. Additionally, conditions such as chronic stress, which is known to alter immune function by affecting cortisol levels and immune cell activity, can make the body more susceptible to infections. Psychological stress has been linked to a higher frequency of infections, including cellulitis, suggesting that immune function may be impaired by sustained stress responses.

Environmental and Seasonal Factors

Environmental and seasonal factors can also play a role in the risk of cellulitis. For example, certain weather conditions, such as hot, humid environments, can increase the likelihood of skin injuries and insect bites, both of which are significant contributors to cellulitis. During the summer months, as temperatures rise, people are more likely to sweat, which can cause skin irritation and breakdown, particularly in areas of friction (e.g., underarms, groin, and feet). These skin abrasions provide an entry point for bacteria. Additionally, increased outdoor activity during warmer months raises the chance of cuts, scrapes, and

exposure to pathogens. Seasonal changes also influence the behavior of insects that contribute to cellulitis. For instance, mosquitoes, ticks, and other biting insects are more active during warmer months, which increases the risk of insect bites that can lead to cellulitis. Insects such as mosquitoes, which are carriers of pathogens like *West Nile Virus* and *Dengue Fever*, can also increase the risk of cellulitis through secondary bacterial infections at the site of bites. Moreover, geographic location plays a role in the types of bacteria present in the environment. Areas with high humidity or those located near bodies of water may have higher concentrations of marine pathogens like *Vibrio vulnificus* or *Shewanella algae*, which are known to cause cellulitis when introduced into broken skin through cuts, abrasions, or insect bites. Those who frequently engage in outdoor activities like swimming or fishing in these areas are at an increased risk of developing cellulitis from exposure to these pathogens.

Healthcare Practices and Antibiotic Resistance

Healthcare practices are critical in managing the risk of cellulitis. The inappropriate or overuse of antibiotics can contribute to the development of antibiotic-resistant bacteria, which are more difficult to treat and increase the severity of cellulitis infections. The rise in methicillin-resistant *Staphylococcus aureus* (MRSA) has significantly impacted the management of cellulitis, as this strain is more resistant to standard antibiotics. Inadequate or delayed treatment of cellulitis can lead to complications, including abscess formation, sepsis, and, in severe cases, death. In addition, improper wound care, such as failure to adequately clean or dress cuts and abrasions, increases the risk of cellulitis. Studies have shown that inadequate wound management can delay healing and provide a breeding ground for bacteria. Ensuring that healthcare professionals adhere to strict protocols for wound care, hygiene, and the use of appropriate antimicrobial therapies is crucial in reducing the incidence and severity of cellulitis.

Age and Skin Integrity

Age is another factor that can affect the likelihood of developing cellulitis. Older adults, in particular, are at greater risk due to age-related changes in skin integrity, including thinning of the skin, reduced circulation, and a slower immune response. As the skin becomes more fragile and prone to damage with age, the likelihood of cuts, abrasions, and infections increases. Additionally, older adults are more likely to have chronic conditions, such as diabetes and venous insufficiency, which further heighten the risk of cellulitis. Cellulitis is a multifactorial condition influenced by a range of factors, including underlying medical conditions, immune status, lifestyle behaviors, environmental and seasonal factors, and healthcare practices. Understanding these factors is essential for the effective prevention and management of cellulitis, particularly in the context of an aging population and the rise of antibiotic-resistant pathogens. Clinicians must consider these various risk factors when assessing patients and developing treatment plans to ensure optimal outcomes and prevent complications from cellulitis.

Limitations and Future Directions in Climate Change and Cellulitis Research

The intersection between climate change and the incidence of cellulitis is a growing area of research, yet there are several limitations in the current body of knowledge that need to be addressed for a more comprehensive understanding of this complex relationship. This section discusses the key limitations identified in the literature and suggests potential future directions for research.

Limitations in Understanding Underlying Mechanisms

A significant limitation in the current literature is the lack of a clear understanding of the underlying mechanisms behind the associations between climate-related factors and cellulitis. While several studies have identified correlations between climate change variables, such as temperature, rainfall, and insect activity, with an increased incidence of cellulitis, these studies often fall short in explaining the biological or physiological mechanisms that mediate these relationships. For instance, although there is evidence suggesting that increased rainfall can be associated with a rise in cellulitis cases, the exact mechanism linking these two factors remains unclear. The pathophysiology behind this association has yet to be fully explored. The same issue arises with the effect of ozone on cellulitis, where animal studies have provided some insight, but human data are scarce. These gaps in knowledge present important areas for

future research, particularly the need for studies that investigate how environmental factors such as climate variables influence bacterial growth, skin integrity, and immune response in humans. In the absence of such mechanistic studies, the link between climate change and cellulitis remains largely observational, limiting the ability to make causal inferences. Future research should focus on elucidating the biological mechanisms through which climate factors, such as changes in temperature, humidity, and rainfall, directly affect the skin's susceptibility to infections like cellulitis. Investigating how climate-induced changes in microbial flora and skin barrier function contribute to the pathogenesis of cellulitis could open new avenues for targeted interventions.

Gaps in Quantitative Analysis of Climate-Related Factors

Another limitation identified in the literature is the lack of quantitative analysis regarding the specific contribution of various climate-related factors to the development of cellulitis. While the association between warmer temperatures and increased cellulitis cases has been noted in several studies, there is little evidence comparing the relative contributions of different environmental factors. For example, it remains unclear whether insect bites, which are more common in warmer months, contribute more significantly to cellulitis development than other factors such as human-to-human transmission or pre-existing medical conditions. As the literature currently stands, we are left with generalized assumptions about the role of climate variables, without a clear understanding of how much each factor contributes to the overall burden of cellulitis. Future research should aim to address these gaps by conducting studies that quantify the effects of specific climate-related factors on cellulitis risk. This could include longitudinal studies that track cellulitis incidence in relation to climate data over multiple seasons, controlling confounding factors such as insect bite frequency, human contact, and medical comorbidities. Identifying which factors—whether environmental (e.g., temperature, humidity) or biological (e.g., insect bites, human interactions)—are most strongly associated with cellulitis would allow for more targeted public health interventions.

Exploration of Mitigation Strategies

While several studies have highlighted mitigation strategies such as the use of insect repellents or the implementation of public health campaigns to reduce the incidence of cellulitis, there is limited research on the effectiveness of these strategies, particularly on an individual level. For instance, it remains unknown whether individuals who use insect repellent during high-risk seasons, such as summer, have a lower incidence of cellulitis compared to those who do not. This is a critical gap, as such strategies could potentially serve as cost-effective measures to prevent cellulitis outbreaks, especially in high-risk populations. Future research should investigate the effectiveness of climate-related mitigation strategies at an individual level, evaluating their impact on cellulitis prevention. Randomized controlled trials or cohort studies could assess the outcomes of various interventions, such as the use of insect repellent, wearing protective clothing, or implementing public health awareness campaigns. Understanding the most effective mitigation strategies would enable public health agencies to prioritize interventions that offer the greatest benefit, potentially reducing the burden of cellulitis in regions affected by climate change.

Complex Interplay Between Medical Risk Factors and Climate Change

Peterson et al. (2021) highlight the association between warmer weather and medical risk factors for cellulitis, such as lower extremity swelling. The interplay between a patient’s medical history, climate change, and cellulitis susceptibility remains largely unexplored. For example, how do conditions such as diabetes, venous insufficiency, or obesity interact with environmental changes like rising temperatures or increased rainfall to affect cellulitis risk? Additionally, research could explore the synergistic effects of multiple risk factors, such as impaired immune function in individuals with chronic conditions combined with the added stress of heat or humidity. There is also a need for studies that explore how climate change may exacerbate the burden of cellulitis in specific populations, such as the elderly or those living in areas with limited access to healthcare. For instance, aging populations are more likely to have compromised immune systems and pre-existing medical conditions that increase their risk of cellulitis. Understanding

how these factors interact with climate-related changes could provide valuable insights for public health strategies aimed at protecting vulnerable populations.

Limited Geographic and Linguistic Scope

Another important limitation in the existing literature is the geographical and linguistic bias inherent in many studies. While the review included research from diverse parts of the world, it primarily relied on studies published in English. This exclusion of non-English literature limits the generalizability of the findings, as climate change impacts and healthcare practices vary significantly across regions with different climatic conditions, healthcare infrastructures, and cultural norms. Future research should aim to include studies from non-English-speaking countries, particularly those in the Global South, where climate change and its health implications are often under-researched. Additionally, there is a need for studies that focus on regions with unique climatic conditions that have not yet been fully explored in the context of cellulitis. For example, countries with tropical climates or those affected by extreme weather events such as hurricanes or flooding may experience cellulitis outbreaks in ways that have not been well studied. Expanding the geographical scope of research would provide a more comprehensive understanding of how climate change affects cellulitis on a global scale. In conclusion, while the literature on the relationship between climate change and cellulitis has expanded in recent years, several critical limitations hinder the development of a complete understanding of this issue. Future research should focus on uncovering the underlying mechanisms that connect climate variables to cellulitis, as well as conducting quantitative studies to measure the relative impact of different climate-related factors. Additionally, more work is needed to explore the effectiveness of mitigation strategies, the complex interactions between medical risk factors and climate change, and the global variability in cellulitis incidence. By addressing these gaps, future studies will not only contribute to the academic understanding of cellulitis but also inform practical public health interventions aimed at reducing the impact of climate change on skin infections worldwide.

Conclusion:

Cellulitis, a widespread bacterial infection affecting the skin and subcutaneous tissue, is primarily caused by pathogens like beta-hemolytic streptococci and Staphylococcus aureus. The infection is linked to risk factors such as diabetes, obesity, and venous insufficiency, while the rise of methicillin-resistant Staphylococcus aureus (MRSA) has complicated treatment strategies. Seasonal fluctuations in cellulitis incidence, with higher rates observed during warmer months, suggest that environmental factors, particularly temperature, play a significant role in the infection's prevalence. Recent studies demonstrate a clear association between rising temperatures and an increased likelihood of cellulitis, with a 5°F rise in temperature linked to a 3.55% higher risk of hospitalization. The impact of climate change is evident in the rising global temperatures, and this increase is likely to exacerbate cellulitis cases, particularly in vulnerable populations. Studies from various countries, including the U.S., the UK, Taiwan, and Australia, consistently report that cellulitis incidence peaks in the summer, and regions experiencing warmer temperatures witness higher rates of infection. Additionally, tropical cyclones and floods, both exacerbated by climate change, contribute to cellulitis cases by increasing skin trauma and providing favorable conditions for bacterial growth, especially Vibrio species, which are associated with severe infections. Furthermore, studies indicate that exposure to high humidity and rainfall, common during tropical cyclones, is associated with increased cellulitis rates. For instance, Taiwan's post-typhoon studies show a surge in cellulitis cases due to prolonged skin exposure to contaminated floodwaters. Additionally, tropical storm-related injuries and insect bites further facilitate infection onset. The increase in cellulitis cases can be attributed to environmental changes that enhance bacterial colonization and host vulnerability. As climate change continues to drive global warming, it is crucial to focus on preventative measures, including timely medical intervention, heightened public awareness, and improved healthcare infrastructure to manage the growing burden of cellulitis. More research is needed to fully understand the mechanisms behind the climate-cellulitis relationship, allowing for the development of effective strategies to mitigate the impact of climate change on skin infections.

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العدوى الجلدية: مراجعة محدثة للالتهاب الخلوي وتأثير تغير المناخ

الملخص:

الخلفية: يعتبر السلوليت، وهو عدوى بكتيرية تؤثر على الأدمة والأنسجة تحت الجلد، من الحالات التي تظهر مع احمرار، حرارة، تورم، وألم عند اللمس. يعد من القضايا المهمة في العدوى الجلدية والأنسجة الرخوة (SSTIs) وغالبًا ما يكون سببها المكورات العقدية بيتا hemolytic-و *Staphylococcus aureus*الحساسة للمثيسيلين. تشمل عوامل الخطر مرض السكري، السمنة، وقصور الأوردة. بينما كان يُدار تقليديًا باستخدام المضادات الحيوية المستهدفة للمكورات العقدية، فإن زيادة *Staphylococcus aureus*المقاوم للمثيسيلين (MRSA) تجعل العلاج أكثر تعقيدًا. في الولايات المتحدة، يمثل السلوليت عبئًا صحيًا كبيرًا، مع ملايين الحالات سنويًا. تشير الأدلة الناشئة إلى أن تغير المناخ قد يؤثر على معدل حدوث السلوليت بسبب ارتفاع درجات الحرارة والتقلبات الموسمية.

الطرق: تهدف هذه المراجعة إلى دراسة العلاقة بين تغير المناخ، وخاصةً ارتفاع درجات الحرارة، ومعدل حدوث السلوليت. تم فحص الدراسات للبحث عن الارتباطات بين درجة الحرارة، الرطوبة، ومعدلات حدوث السلوليت، مع التركيز على الاتجاهات العالمية والنماذج الموسمية. تم تحليل البيانات من مناطق مختلفة لاستكشاف التأثير المحتمل لعوامل المناخ مثل الرطوبة، والأمطار، وظهور الأعاصير الاستوائية على انتشار السلوليت.

النتائج: ارتبطت درجات الحرارة العالية، خاصة في الصيف، بزيادة حالات السلوليت بشكل مستمر، مع وجود علاقة تعتمد على الجرعة بين ارتفاع درجة الحرارة ومعدلات الإصابة. أكدت الدراسات من مناخات متنوعة، بما في ذلك الولايات المتحدة، تايوان، المملكة المتحدة، وأستراليا، أن حالات السلوليت تصل إلى ذروتها في الأشهر الأكثر حرارة، وأن زيادة درجة الحرارة بمقدار 5 درجات فهرنهايت ترتبط بزيادة احتمال الحاجة إلى الاستشفاء. علاوة على ذلك، فإن الأعاصير الاستوائية والفيضانات تزيد من تفاقم الحالة عن طريق زيادة إصابات الجلد وتوفير ظروف ملائمة لنمو البكتيريا، خاصةً إصابات الفيبريو.

الاستنتاج: تتأثر معدلات حدوث السلوليت بعوامل المناخ، خاصةً درجات الحرارة المرتفعة والرطوبة، التي تعزز استعمار البكتيريا وزيادة القابلية للإصابة بالعدوى. قد يؤدي تغير المناخ في المستقبل إلى تفاقم هذا الاتجاه، مما يبرز الحاجة إلى استراتيجيات وقائية. يجب على أنظمة الرعاية الصحية الاستعداد للتأثير المتزايد لحالات السلوليت المرتبطة بتغير المناخ، خاصة في الفئات السكانية المعرضة للخطر.

الكلمات الرئيسية: السلوليت، تغير المناخ، درجة الحرارة، الرطوبة، العدوى البكتيرية، SSTIs، إصابات الفيبريو، الأعاصير الاستوائية، عبء الرعاية الصحية، الاتجاهات الموسمية.