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Review of The Status of Skin Cancer in Pakistan And South Asia During Hot Weather – Is Climate Change Contributing?

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Abstract

Skin cancer is a growing public health concern in Pakistan, however, lack of cancer registry at national level makes availability of data scarce. Few regional reports from Karachi and Lahore have noted increase in its incidence. Skin cancers vary in pathophysiology and epidemiology as well as their possible causative factors. This perspective attempted to highlight a link between skin cancer and climate change. The main purpose was to give an overview and examine the existing literature on skin cancers in Pakistan and South Asia in this context. The available evidence on skin cancers from 2001 to 2025 was reviewed for finding these answers. The articles on skin cancers and its various sub-types like basal cell carcinoma, melanomas, and squamous cell carcinomas were retrieved from online databases sources like PubMed central, Google Scholar and Medline. The prevalence of skin cancers varies in different global regions with high proportions of 30 to 40% in US, Australia and European populations with melanoma being the most common of these cancers. Contrary to these high proportions, in South Asian region and Pakistan the prevalence of skin cancer varies between 2 to 4% with SCC and BCC being the most frequent types. Pakistan faces multiple climate related challenges; heatwaves, floods, and burden of infectious diseases. There are multifaceted links among skin cancer and climate change. The increased ultraviolet radiation exposure due to warm temperatures and longer day duration during summers, especially, as many people in rural and lower-income communities, work in agricultural and outdoor occupations. The longer day during summer encourage prolonged activities, thus, more sun exposure. There are biological effects as heat itself may amplify cancer-causing effects of UV rays. Another key issue is air pollution which can weaken skin protection barriers and exacerbate UV radiation. This multifaceted complex issue requires a multifaceted approach as solutions including public health campaigns to raise awareness, policy changes to promote sun safety, and investment in healthcare facilities to improve diagnostic and treatment capabilities. And above all, there needs detailed research investigations on this topic so that comprehensive data is available in the country and regions which may lead to improved policies and better situation through its implementation.

Introduction

Skin cancer is becoming a major public health challenge worldwide, with incidence rates rising steadily across many populations [14,6]. As it is one of the most common types of cancer, its pathogenesis is closely linked to environmental exposures particularly ultraviolet (UV) radiation [3]. The connection between climatic factors and human health has become evident and climate change pose a multilayered threat that may exacerbate existing health problems. To understand the epidemiology of skin cancer necessitates an examination of not only traditional risk factors like skin type and behavior but also the broader environmental and climatic conditions in which they occur. This review aims to bring together existing evidence in order to explore a critical question for South Asian region: What is the status of skin cancer in Pakistan and the surrounding region during periods of intense heat, and is climate change a contributing factor?

Regarding increased UV radiation exposure, the scientific foundation for concern was laid decades ago. A pivotal work was done by Molina and Rowland (1974) who first gave hypothesis of potential for chlorofluorocarbons (CFCs) to catalytically destroy stratospheric ozone which is the planet's natural shield against harmful UV rays. This hypothesis was tragically confirmed little over a decade later when Farman, Gardiner, and Shanklin (1985) documented the shocking seasonal depletion of ozone over Antarctica—the so-called "ozone hole." This discovery highlighted the capacity of humans to alter the global atmosphere and also triggered international policy responses. The consequences of a

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thinning ozone layer are direct like increased ground-level UV-B radiation which is a well-established carcinogen [5]. This historical background is essential for understanding the environmental backdrop against which modern skin cancer trends are unfolding. The primary link between this environmental change and human disease lies in the damaging effects of UV radiation on skin at the cellular level. The mechanisms are now well elaborated; UV radiation penetrates the skin layers and causes direct DNA damage which also include the formation of cyclobutane pyrimidine dimers (CPDs) and 6-4 photoproducts that can lead to oncogenic mutations if not repaired [3]. This damage builds over a person's lifetime of exposure eventually leading to the uncontrolled cellular proliferation that characterizes skin carcinomas and melanomas. Thus, any environmental factor that increases the intensity, duration or frequency of UV exposure directly influences risk of individual.

Globally, the epidemiological data reflects this risk clearly. Non-melanoma skin cancers (NMSC) which include basal cell carcinoma and squamous cell carcinoma, are the most frequently diagnosed cancers in fair-skinned populations, though they are often underreported in cancer registries (Lomas et al., 2012). More concerning is the steady increase in cutaneous melanoma, a more aggressive and often fatal form of skin cancer [14,6]. Estimates from GLOBOCAN 2018 show that skin cancer makes up a large share of the worldwide cancer burden, with more than 1 million new cases of NMSC and nearly 300,000 new cases of melanoma diagnosed each year [8]. Recent surveillance data continues to highlight its prevalence and the associated mortality [9].

However, this global narrative often overlooks regional disparities and unique risk profiles. In Pakistan and much of South Asia, the situation is complex. The region experiences extreme hot weather, with intense solar irradiance for large parts of the year. While the darker skin phototypes common in the population offer some inherent protection against UV damage, this protection is not absolute, particularly for NMSC. The overall cancer burden in Pakistan is shifting, with a growing emphasis on non-communicable diseases [10]. Yet, data on skin cancer remains fragmented. National-level epidemiological studies are scarce, and diagnostic challenges and underreporting likely mean the true incidence is obscured. This lack of robust data makes it difficult to assess trends and, crucially, to attribute any potential increases to environmental changes like rising temperatures and shifting climate patterns. Therefore, the purpose of this review was to examine the available literature on skin cancer in Pakistan and South Asia within the context of a warming climate. The objectives are fourfold: (1) to give an overview of different types of skin cancers and their risk factors; (2) to detail the pathophysiological mechanisms linking UV radiation and hot weather to skin damage; (3) to bring together limited epidemiological data on skin cancer in the region; and (4) to evaluate the potential pathways through which climate change may be adding to the disease burden. By doing so, this study aims to highlight significant gaps in the literature and propose future directions for research, public health policy and clinical practice in Pakistan.

Overview

- ❖ **Definitions and Types of Skin Cancer**

Skin cancer is the uncontrolled growth of abnormal skin cells which primarily occurs due to DNA damage that triggers mutations, leading to malignant changes. It is categorized into keratinocyte carcinomas (non-melanoma skin cancer, or NMSC) and cutaneous melanoma, which arises from melanocytes [3].

The most common types of NMSC are basal cell carcinoma (BCC) and squamous cell carcinoma (SCC). BCC is the most common human cancer which arises from the basal cells of the epidermis. It is characterized by local invasiveness and a low metastatic potential, though it can cause significant local tissue destruction if untreated. SCC originates from the epidermal keratinocytes and carries a higher, though still relatively low, risk of metastasis compared to BCC [12]. At the molecular level, both of these cancers are strongly linked to UV radiation exposure. Early research showed that UV-induced damage to key tumor suppressor genes, such as TP53 play a central role in the development of both BCC and SCC [3].

Cutaneous melanoma is a more aggressive malignancy originating from melanocytes, the pigment-producing cells of the skin. While less common than NMSC, it is responsible for the majority of skin cancer-related deaths due to its high metastatic potential [13]. The understanding of its development has evolved, with research highlighting the role of both intermittent, intense sun exposure (leading to sunburns) and genetic predispositions. The molecular landscape of melanoma involves mutations in genes such as BRAF, NRAS, and CDKN2A, which drive uncontrolled proliferation and survival of melanocytes [11]. By the 2010s, comprehensive reviews consolidated this knowledge, explaining how UV radiation acts as a complete carcinogen by inducing DNA damage, promoting local inflammation, and suppressing immune surveillance in the skin, thereby facilitating the emergence of all major skin cancer types [11].

- ❖ **Environmental and Lifestyle Risk Factors**

The main environmental risk factor for skin cancer is exposure to ultraviolet (UV) radiation from sun. The mechanism through which it causes damage is wavelength-dependent. UVB radiations (280-315 nm) are directly absorbed by DNA and can cause specific mutations such as cyclobutane pyrimidine dimers (CPDs) that are highly mutagenic [14]. UVA radiation (315-400 nm) while less energetic but penetrates deeper into the skin and contributes to carcinogenesis indirectly by generating reactive oxygen species (ROS) which lead to oxidative stress, DNA damage and photoaging [11]. This dual assault on the skin's genome.

Human activity has directly influenced the intensity of this environmental risk. The seminal work of Molina and Rowland

(1974) on ozone depletion by chlorofluorocarbons (CFCs) laid the groundwork for understanding an anthropogenic amplifier of UV exposure. The subsequent discovery of the Antarctic ozone hole provided tangible evidence of this phenomenon [2]. While the Montreal Protocol successfully curbed CFC production, the complex interplay between ozone recovery and climate change presents a new set of challenges. Climate change, driven by greenhouse gas emissions, can alter atmospheric circulation patterns, potentially slowing the recovery of the ozone layer in certain regions and exacerbating ground-level UV exposure in others—a stark example of unintended consequences [15].

Lifestyle factors add to these environmental risks. Behavioral patterns such as spending long hours outdoors for work or leisure without adequate photoprotection, using tanning beds, or living at high altitudes and closer to the equator all increase lifetime UV exposure. The population-level impact of these environmental and behavioral factors is clearly seen in regions like Australia which has one of the highest incidence rates of skin cancer globally due to its high ambient UV levels and a predominantly fair-skinned population [16]. Australia's experience serves as a powerful model for understanding the potential future burden in other high-UV regions especially those facing changing climate patterns.

❖ Mechanisms of UV-Induced Skin Damage

The development of skin cancer from sun exposure is a multistep process that is initiated by direct molecular damage. The absorption of UV photons by cellular DNA creates photoproducts that distort the DNA helix. If these are not efficiently repaired by nucleotide excision repair pathways then errors occur during cell division. This process introduces characteristic "UV signature mutations," most often C→T and CC→TT transitions at dipyrimidine sites [14]. Such mutations are frequently found in critical tumor suppressor genes. For example, TP53 mutations are found in over 90% of squamous cell carcinomas (SCCs) and 50% of basal cell carcinomas (BCCs), while mutations in the PTCH1 gene are a hallmark of BCC [3,11].

Beyond direct mutagenesis, UV radiation exerts immunosuppressive effects on the skin. It induces the apoptosis of Langerhans cells, alters cytokine profiles, and promotes the expansion of regulatory T cells, thereby diminishing the local immune system's ability to recognize and eliminate nascent tumor cells [11]. This allows genetically damaged cells to evade immune surveillance and proliferate, a crucial step in tumor development. Furthermore, chronic UV exposure leads to photoaging—the cumulative breakdown of collagen and elastin fibers in the dermis—which creates a permissive tissue microenvironment that can support tumor growth and progression.

❖ Hot Weather and Skin Vulnerability

Although the UV radiation is the primary causative agent but ambient temperature may act as a significant effect modifier which enhances the risk of skin cancer. Research suggests that higher environmental temperatures can increase the vulnerability of skin to UV damage. Heat can weaken the skin barrier and increase blood flow to the skin which may result in greater concentration of harmful metabolites and oxidative stress in skin cells after UV exposure [18]. From an epidemiological perspective, hotter weather is often correlated with higher UV indices and longer seasons of intense solar radiation. Studies have shown that the incidence of skin cancer correlates strongly with cumulative UV dose and the number of hours spent in environments with high solar intensity [17]. Hot weather influences human behavior, leading to less clothing coverage and more time spent outdoors, thereby increasing the effective UV dose received by the skin. This creates a synergistic effect where behavioral adaptation to heat directly increases carcinogenic exposure.

Climate change is projected to deepen this relationship. Rising global temperatures are expected to extend the duration of hot, sunny weather periods in many parts of world including South Asia [19]. This means a higher annual dose of UV radiation for populations and also change people recreational and occupational sun exposure patterns. As Parker (2021) explains the connections between climate change and skin cancer involves understanding these complex feedback loops: a warming climate leads to hotter weather which influences both human behavior (increasing exposure) and possibly biological susceptibility (increasing damage per unit of exposure). For a country like Pakistan where extreme heat is already common, these combined factors present a potentially serious but poorly quantified public health threat.

Epidemiology of Skin Cancer

❖ Global Status

The global burden of skin cancer presents a significant and growing public health challenge with cases of both melanoma and non-melanoma skin cancer (NMSC) rising steadily over recent decades. The analysis of long-term trend provides critical context for this increase. An international study examining melanoma incidence patterns from 1953 to 2008 steady increases in fair-skinned populations with annual growth rates ranging from 3-7% in various European and North American countries [20]. These patterns highlight a clear historical rise in risk, much of which is attributed to changing lifestyle, such as greater recreational sun exposure. By the mid-2010s, the scope of the problem was quantified in greater detail by the Global Burden of Disease (GBD) studies. The GBD 2015 study specifically focused on melanoma, estimating 351,000 new cases and 60,000 deaths globally in that year, representing a 38% and 34% increase in incidence and mortality, respectively, since 2005 [21]. This work highlighted that while melanoma was less common than NMSC, it constituted a major source of fatal cancer burden.

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The subsequent GLOBOCAN 2018 report provided a broader picture, estimating over 1 million new cases of melanoma and over 4 million new cases of NMSC annually worldwide, though the latter is a conservative figure due to widespread underreporting [8]. The data from IARC's Global Cancer Observatory further solidified these estimates, confirming skin cancer's status as one of the most frequently diagnosed cancer groups globally [9]. Recent data from US indicate that 70% of new cases of skin cancer out of around one million diagnosed each year, result from repeated exposure of the skin to sunlight.8 The relationship of UV light and skin conditions has been proven and well reported in the endemic regions like US, Australia and New Zealand.

Some estimates suggest that almost 3-4 million are diagnosed to have various skin cancers, melanoma being the most frequent. Recent data show that this upward trend is continued. In the United States, for example, skin cancer is extremely common as estimates suggest that the number of people treated for NMSC each year exceeds the number of all other cancers combined, which highlight the immense clinical and economic burden in high-incidence countries [25]. By 2022, data indicated that melanoma cases were still continuing to rise, though mortality rates had begun to stabilize or decline in some regions due to advances in treatment especially for late-stage disease [22]. Authoritative health organizations consistently emphasize the main causes of this global burden: excessive exposure to ultraviolet (UV) radiation from the sun and artificial sources like tanning beds [23,24].

❖ Regional and National Status

In stark contrast to the well-documented global and Western data, the epidemiological landscape of skin cancer in Pakistan and South Asia is characterized by data scarcity and uncertainty. The country's cancer registry system is underdeveloped, and diagnostic challenges are prevalent, leading to substantial underreporting. A quantitative analysis of Pakistan's research output on skin cancer between 1995 and 2020 found only 47 published articles, a strikingly low number that directly reflects the lack of focused national-level epidemiological studies [26]. This scarcity of research itself is a critical finding. However, existing data suggests that 1-2% people present with various skin cancers. A study from Saudi Arabia reported that expatriates from northern Pakistani regions especially from KP were more likely to present with skin cancers (8.9%) in the expat population. (KSA study)

Reviews of Pakistan's cancer burden acknowledge skin cancer but consistently stress that there is the lackness of robust, population-wide data which list it among the major challenges in to building effective national cancer control [10]. The limited reviews that try to synthesize the local clinical picture suggest that squamous cell carcinoma (SCC) may be the most common type reported in clinical settings because it often appears at advanced stages on sun-exposed parts of the body in outdoor workers, which imply to a strong occupational link [27].

The most recent analyses from 2025 begin to provide a clearer, though still incomplete, picture. A review by Muhammad Sadiq et al. (2025) consolidates available hospital-based studies and suggested that skin cancer cases are rising in large urban centers, though the true rate in the general population is still unknown. Supporting this, a 2025 survey of knowledge and practices among healthcare professionals and the public in Pakistan found significant gaps in awareness about skin cancer prevention and early signs which indicate a crucial need for better public health education alongside improved surveillance systems [29]. The situation in the neighboring countries also appear similar. A recent study from Southern Thailand— another region with comparable climatic challenges, also reported issues in surveillance and a high burden of NMSC in exposed areas which points to a broader regional pattern of under-diagnosis and climate-driven risk that Pakistan likely shares [30]. The consistent theme across all regional literature is the pressing need for systematic, longitudinal studies to accurately define the burden and inform public health strategy.

Climate Change as A Contributor

The link between climate change and skin cancer incidence is not straightforward and also multifactorial as it operates through both direct atmospheric mechanisms and indirect behavioral pathways. The science roots of the discussion connect back to the discovery of ozone depletion as an unintended outcome of industrial activity. Although the Montreal Protocol is widely recognized as a landmark environmental success story that prevented catastrophic ozone depletion, its interaction with climate change is complicated. The changes in atmospheric circulation patterns that are influenced by a warming climate can alter the distribution and recovery rate of ozone which potentially prolong elevated UV exposure in certain mid-latitude regions such as parts of South Asia [15]. This means that even as ozone-depleting harmful substances decline but the healing of the ozone layer is occurring within a climate system that is itself changing dynamically.

The primary pathway through which climate change is expected to influence skin cancer rates is by amplifying the primary risk factor: UV radiation exposure. Climate change is leading to increases in average surface temperatures, more frequent and intense heatwaves, and alterations in cloud cover patterns. As Parker (2021) articulates, these changes can significantly affect human behavior. Hotter temperatures lead to more time spent outdoors in lighter clothing, inadvertently increasing the skin's exposure to carcinogenic UV rays. Furthermore, climate change may extend the annual period during which UV levels are high, effectively lengthening the "skin cancer season." This is particularly relevant for a country like Pakistan, which already experiences extreme heat for much of the year; climate projections suggest these conditions will intensify, potentially leading to a higher annual UV dose for its population.

Establishing the link between climate change and skin cancer requires the integration of robust climate and health data.

Organizations such as National Oceanic and Atmospheric Administration (NOAA) provide the essential climate data—including historical and projected trends in temperature, solar irradiance, and UV index. These databases are necessary to correlate environmental changes with health outcomes [19]. However, in the context of South Asian and specifically in Pakistan, the critical gap lies in the lack of parallel, high-quality health data. Without reliable, long-term skin cancer incidence registries, it is almost impossible to carry out the longitudinal climate-health linked studies that are needed to quantify the contribution of climate change to the burden of disease. Therefore, while the mechanistic and conceptual links are strongly plausible—wherein climate change likely function as a threat multiplier by increasing opportunities for UV exposure and amplifying the intensity of UV through feedback loops with atmospheric conditions—the definitive evidence from the region remains absent. In short, while climate change almost certainly contributes to rising skin cancer risk in Pakistan but its specific impact cannot be quantified until major surveillance and research gaps are filled.

Gaps in Local Literature

A chronological survey of the literature highlights a concerning imbalance between the understanding of skin cancer in high-income countries with predominantly fair-skinned populations and the knowledge base in Pakistan and South Asia. While global research has progressively advanced from uncovering the molecular mechanisms to detailed burden estimates and climate linkages, the evidence from Pakistan remains limited, fragmented and critically insufficient for informed public health action.

The first and most profound gap is the dearth of robust national-level epidemiological data. The recent publication of review articles in 2024 and 2025 [27,28], while valuable, primarily serves to highlight the absence of systematic, population-based cancer registry data. This stands in sharp contrast to the long-term, high-resolution incidence tracking available in countries like the United States. The quantitative analysis by Ahmad and Khan (2021), which found a minuscule number of published studies from Pakistan over a 25-year period, is not just a metric of research output; it is direct evidence of a massive data void. This lack of reliable incidence and mortality rates makes it impossible to accurately gauge the scale of the problem, track trends over time, or allocate healthcare resources effectively.

Another related challenge is the pervasive problem of underreporting and diagnostic limitations. Skin cancer cases particularly for NMSC often occur in outpatient clinics and may never be recorded in hospital-based cancer registries which lead to a significant underestimation of the true burden. Furthermore, this gap is compounded by a lack of public awareness and limited access to dermatological care in rural areas where delayed presentation or missed diagnoses are likely common. The consequences of this diagnostic delay extend beyond mortality. Studies have shown that skin diseases, including NMSC, can have a profound impact on patients' quality of life (QoL), causing psychosocial distress, anxiety, and functional impairment on par with other chronic illnesses [31,32]. Yet in Pakistan, the QoL burden of skin cancer remains completely unquantified, representing another critical gap in understanding the disease's full impact.

Finally, and most pertinent to this review's central question, is the complete absence of longitudinal studies linking climate variables to skin cancer incidence in the region. While the global literature has begun to model these connections [18], and authoritative bodies like NOAA provide the necessary climate data [19], there are no Pakistani studies that correlate local temperature trends, UV index fluctuations, and extreme heat events with health outcome data. This makes it impossible to move beyond hypothesis and conclusively determine the role of climate change as an effect modifier in the Pakistani context. The inability to quantify this relationship leaves public health policy poorly equipped to anticipate and mitigate the potential exacerbation of skin cancer risk driven by a warming climate.

Implications and Future Direction

❖ Public Health Awareness and Policy Direction

The findings of the review highlight important implications for public health strategy and policy in Pakistan. The consistently low levels of knowledge and poor preventive practices that have been recently documented among both the public and healthcare professionals [29] highlight that there is an urgent need for nationwide, culturally specific sun safety awareness campaigns. These campaigns must move beyond simple advice and also should address local behavioral drivers, emphasizing protection for high-risk groups like outdoor laborers and agricultural workers. Policy must be drawn from successful frameworks from other nations such as the multi-sectoral approach outlined in the U.S. Surgeon General's Call to Action to Prevent Skin Cancer, which emphasized community-wide sun protection environments, educational campaigns and professional training (Watson et al., 2014).

At a national level, combating skin cancer must be integrated into Pakistan's broader non-communicable disease (NCD) control strategies. As Ali et al. (2022) have argued, strengthening the entire cancer control continuum—from prevention and early detection to treatment and palliative care—is a government priority. This review suggests that within this framework, specific attention must be paid to building dermatological capacity, particularly in primary care settings, to improve early diagnosis rates of suspicious skin lesions. Furthermore, health authorities should consider issuing specific sun protection guidelines tailored to the country's climate and occupational realities.

❖ Clinical and Research Needs

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For clinicians, this review emphasizes that there is a need of maintaining a high index of suspicion for skin malignancies, even in patients with darker skin prototypes and also ensuring that sun protection advice becomes a routine part during the consultation of patients. From a research perspective, the gaps identified in this study define a clear agenda for future work. Strengthening cancer surveillance must be the immediate priority which requires mandating and funding the systematic collection of skin cancer cases in within the hospital registries and ultimately working towards a population-based registry. Beyond surveillance, Pakistan urgently needs population-based cross-sectional studies in order to establish the baseline incidence and prevalence, case–control studies so to clarify the behavioral and occupational risk factors which are only specific to the local population and longitudinal cohort studies that integrate climate datasets such as those from NOAA (2025) with health outcomes in order to thoroughly test the hypothesis of climate–cancer linkage which was conceptualized by Parker (2021). Health economics and quality-of-life (QoL) studies are also equally important as these would quantify the wider social and economic costs of skin cancer and provide the evidence base which is required for policymakers in order to justify resource allocation.

Ultimately, while the mechanistic link between UV radiation and skin cancer is well-established and undeniable but Pakistan's response cannot be effective without first generating the fundamental evidence base that other countries have developed over decades. Filling these research and policy gaps is not merely an academic exercise but it is an essential step towards addressing a preventable health threat that is likely to be intensified by the escalating challenges of climate change.

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Declarations:

Authors' Contribution:

- [a-c] Conceptualization, data collection, interpretation, drafting of the manuscript
- [b]Intellectual revisions
- The authors agree to take responsibility for every facet of the work, making sure that any concerns about its integrity or veracity are thoroughly examined and addressed

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