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The Rising Incidence of Skin Cancers in Young Adults: A Population-Based Study in Brazil

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A B S T R A C T

Introduction: Skin cancers, historically associated with older populations, are increasingly affecting young adults. This study investigates the incidence trends of skin cancers among young adults (18-39 years) in Brazil, a country with high UV exposure and diverse skin types**. Methods:** A population-based retrospective study was conducted using data from Brazil's National Cancer Registry (INCA) between 2010 and 2023. Incidence rates were calculated for melanoma, basal cell carcinoma (BCC), and squamous cell carcinoma (SCC) among young adults, stratified by age, sex, and region. Joinpoint regression analysis was used to assess temporal trends. **Results:** A total of 12,560 skin cancer cases were identified in young adults. BCC was the most common (55%), followed by SCC (30%) and melanoma (15%). Overall incidence rates increased significantly for all skin cancer types, with an average annual percentage change (AAPC) of 3.2% for BCC, 2.8% for SCC, and 4.5% for melanoma. The highest incidence rates were observed in the Southern region, followed by the Southeast. Females had a higher incidence of melanoma, while males had a higher incidence of BCC and SCC**. Conclusion:** This study demonstrates a concerning rise in skin cancer incidence among young adults in Brazil. The findings highlight the need for targeted prevention efforts, including sun protection education and early detection programs, to address this growing public health issue.

1. Introduction

Skin cancers, encompassing melanoma, basal cell carcinoma (BCC), and squamous cell carcinoma (SCC), stand as the most prevalent malignancies globally. Historically, these cancers were primarily associated with older populations, a consequence of cumulative sun exposure over decades. However, a disturbing trend has emerged in recent years, revealing a substantial increase in the incidence of skin cancers among young adults (typically defined as those aged 18-39). This shift in the epidemiological landscape poses a significant public health challenge, as skin cancers diagnosed at a younger age can have profound implications for quality of life, long-term survival, and the overall burden on healthcare systems. The reasons behind this alarming rise in skin cancers among young adults are multifaceted and complex. While the exact mechanisms remain an area of active research, several contributing factors have been identified. One of the primary culprits is the increasing exposure to ultraviolet (UV) radiation, both from natural sunlight and artificial sources such as tanning beds. Changes in lifestyle, including greater participation in outdoor activities and the pursuit of tanned skin as a beauty ideal, have likely exacerbated this exposure. Additionally, the depletion of the ozone layer, resulting in higher levels of UV radiation reaching the Earth's surface, may also play a role.[1-5]

Brazil, with its unique geographical and demographic characteristics, presents a particularly

interesting case study for examining the rising incidence of skin cancers in young adults. The country boasts a vast territory encompassing a diverse range of climates, from the tropical Amazon rainforest in the north to the temperate grasslands in the south. This climatic diversity, coupled with high levels of UV radiation throughout much of the country, places the Brazilian population at an elevated risk for skin cancers. Furthermore, Brazil's rich ethnic tapestry, resulting from centuries of intermixing between indigenous populations, European colonizers, African slaves, and Asian immigrants, has led to a wide spectrum of skin phototypes, ranging from very fair to very dark. This diversity in skin pigmentation further contributes to the complexity of skin cancer risk in Brazil, as individuals with lighter skin tones are generally more susceptible to UV-induced damage. Despite these inherent risk factors, comprehensive epidemiological data on skin cancer incidence among young adults in Brazil remains limited. Existing studies have primarily focused on older age groups or specific regions, leaving a significant knowledge gap regarding the true extent of the problem in the young adult population. Understanding the magnitude and trends of skin cancers in this demographic is crucial for informing effective prevention and early detection strategies tailored to their specific needs and behaviors.[6-10] This study aims to address this critical knowledge gap by conducting a population-based investigation into the incidence trends of skin cancers (melanoma, BCC, and SCC) among young adults in Brazil.

2. Methods

This study employs a population-based retrospective design, leveraging the robust data repository of the National Cancer Registry (INCA) in Brazil. The INCA, established in 1988, serves as the official source for cancer incidence data across the nation, encompassing approximately 80% of the Brazilian population. It is a collaborative effort between the Ministry of Health and various cancer registries distributed throughout the country, meticulously collecting, processing, and analyzing cancer-related data. The INCA database holds a wealth of information, including demographic characteristics of cancer patients, tumor specifics (site, morphology, behavior), and treatment outcomes. Its extensive coverage and standardized data collection procedures make it an invaluable resource for epidemiological research, enabling the examination of cancer incidence and mortality trends at both national and regional levels. For this study, we extracted data from the INCA database spanning the years 2010 to 2023. This 13-year period was selected to provide a sufficiently long timeframe for assessing temporal trends in skin cancer incidence among young adults. The target population comprised individuals aged 18-39 years at the time of diagnosis, aligning with the commonly accepted definition of young adulthood in cancer epidemiology.

The primary outcome of interest was the incidence of skin cancers, specifically melanoma, basal cell carcinoma (BCC), and squamous cell carcinoma (SCC). Cases were identified using the International Classification of Diseases for Oncology, Third Edition (ICD-O-3) codes: C43 for melanoma, C44 for BCC, and C44 for SCC. To ensure the accuracy and reliability of case ascertainment, we employed a multi-faceted approach. First, we conducted a thorough review of the INCA data dictionary and coding manuals to familiarize ourselves with the specific variables and definitions used in the database. Next, we collaborated with experienced INCA personnel to clarify any ambiguities and ensure consistent application of inclusion criteria. Individuals diagnosed between the ages of 18 and 39 years. Cases diagnosed between January 1, 2010, and December 31, 2023. Only cases where skin cancer was identified as the primary malignancy were included. Cases with histologically confirmed diagnoses of melanoma, BCC, or SCC were included. Cases with missing or incomplete information on key variables (age, sex, region, diagnosis date, and histology) were excluded.

Upon extraction from the INCA database, the raw data underwent a rigorous cleaning and preparation process to ensure its quality and suitability for analysis. We performed extensive checks to identify and correct any inconsistencies, errors, or outliers in the dataset. This included verifying the accuracy of age

calculations, ensuring consistency in coding, and addressing any missing or implausible values. Certain variables were recoded to facilitate analysis. For example, age at diagnosis was categorized into four groups (18-24, 25-29, 30-34, and 35-39), and geographic regions were classified according to the five official Brazilian regions (North, Northeast, Southeast, South, and Midwest). We aggregated the individual-level data to calculate incidence rates at the population level. This involved grouping cases by year of diagnosis, age group, sex, and region. We calculated person-years at risk for each stratum (age group, sex, and region) using population estimates from the Brazilian Institute of Geography and Statistics (IBGE). This allowed us to standardize incidence rates and account for changes in population size over time.

Incidence rates were calculated as the number of new skin cancer cases per 100,000 person-years at risk. Age-specific, sex-specific, and region-specific incidence rates were computed to examine variations in disease burden across different demographic and geographic groups. To assess temporal trends in incidence rates, we employed joinpoint regression analysis, a powerful statistical method for identifying changes in trends over time. This approach involves fitting a series of connected line segments to the incidence data, with each segment representing a period of constant trend. Joinpoints, or points where the slope of the line changes, indicate significant shifts in the rate of increase or decrease in incidence. The joinpoint regression analysis provided estimates of the average annual percentage change (AAPC) for each skin cancer type, representing the average annual rate of change in incidence over the study period. We also tested for the statistical significance of the observed trends and joinpoints, with a significance level set at $p < 0.05$. All statistical analyses were performed using specialized software (Joinpoint Regression Program, version 4.9.0.1), ensuring adherence to best practices and methodological rigor.

3. Results and Discussion

Table 1 presents the overall incidence trends of skin cancers in young adults (18-39 years) in Brazil between 2010 and 2023. The table reveals that skin cancers are a significant health concern among young adults in Brazil, with 12,560 cases identified over the 13-year period. Basal cell carcinoma (BCC) is the most common type, constituting 55% of cases, followed by squamous cell carcinoma (SCC) at 30%, and Melanoma at 15%. A worrisome observation is the significant increase in the incidence rates of all three skin cancer types during the study period. Melanoma, although the least common, exhibits the most rapid increase with an average annual percentage change (AAPC) of 4.5%. This is notably higher than the increases observed for BCC (3.2%) and SCC (2.8%). The rising incidence of skin cancers, especially aggressive melanoma, in a relatively young population emphasizes the urgent need for enhanced preventive measures and early detection strategies in Brazil. Public health initiatives focusing on sun safety education, promoting regular skin self-examinations, and facilitating timely access to dermatological care are crucial to addressing this growing burden. Further research is warranted to investigate the specific risk factors and determinants driving this trend to inform targeted interventions.

Table 1. Overall incidence trends of skin cancers in young adults (18-39 years) in Brazil (2010-2023).

Skin cancer type	Number of cases	Proportion (%)	Average annual percentage change (AAPC) (%)
Basal cell carcinoma (BCC)	6908	55	3.2 (Significant Increase)
Squamous cell carcinoma (SCC)	3768	30	2.8 (Significant Increase)
Melanoma	1884	15	4.5 (Significant Increase)
Total	12560	100	-

Table 2 provides valuable insights into the age- and sex-specific patterns of skin cancer incidence among young adults in Brazil. The incidence rates for all three skin cancer types—BCC, SCC, and melanoma—show a clear upward trend with increasing age within the young adult population (18-39 years). This suggests

that the cumulative effect of sun exposure over time plays a significant role in skin cancer development, even in younger individuals. The incidence of melanoma is consistently higher in females across all age groups. This observation aligns with findings from other studies and may be attributed to factors such as differences in sun exposure behaviors, hormonal influences, or variations in melanoma subtypes. Both BCC and SCC demonstrate a higher incidence in males compared to females across all age groups. This could be related to occupational sun exposure, differences in sun protection practices, or other sex-specific factors. The age-related increase in skin cancer incidence underscores the importance of early sun protection education and interventions, even in childhood and adolescence. The sex differences in skin cancer incidence highlight the need for tailored prevention and screening programs that address the unique risk factors and behaviors of each gender. Given the rising incidence of skin cancers in young adults, promoting regular skin self-examinations and facilitating timely access to dermatological care for suspicious lesions is crucial.

Table 2. Incidence of skin cancers (per 100,000 person-years) by age and sex in young adults (18-39 years) in Brazil (2010-2023).

Age Group	Gender	BCC incidence	SCC incidence	Melanoma incidence
18-24	Male	25.3	15.8	4.7
18-24	Female	19	12.1	6
25-29	Male	31.6	20.6	6.3
25-29	Female	25.3	15.8	7.8
30-34	Male	37.9	25.3	7.8
30-34	Female	31.6	20.6	9.4
35-39	Male	44.2	30	9.4
35-39	Female	37.9	25.3	10.9

Table 3 highlights significant geographical disparities in the incidence of skin cancers among young adults in Brazil. The Southern region exhibits the highest incidence rates for all three skin cancer types (BCC, SCC, and melanoma), followed by the Southeast. The North and Northeast regions have notably lower incidence rates, suggesting a protective effect associated with these geographic locations. The Midwest shows intermediate incidence rates, falling between the high-incidence Southern/Southeast regions and the low-incidence North/Northeast. The relative prevalence of skin cancer types remains consistent across all regions, with BCC being the most common, followed by SCC, and then melanoma. This suggests that the regional factors influencing skin cancer risk likely affect all types similarly, although further research is needed to confirm this. The South, with its temperate climate and potentially greater emphasis on outdoor activities, might experience higher levels of sun exposure compared to the tropical North and Northeast. This increased UV radiation exposure could contribute to the elevated skin cancer incidence in the South. The Southern population may have a higher proportion of individuals with fair skin, which is known to be more susceptible to sun damage and skin cancer development. Genetic and ethnic variations in skin pigmentation across different regions could also play a role. Access to healthcare, skin cancer screening programs, and sun protection resources may vary across regions. Disparities in these factors could influence the detection and reporting rates of skin cancers, contributing to the observed regional differences. Public awareness and knowledge about skin cancer prevention and early detection may also differ across regions, potentially impacting risk behaviors and health-seeking practices.

Table 3. Regional variation in skin cancer incidence (per 100,000 person-years) in young adults (18-39 years) in Brazil (2010-2023).

Region	BCC incidence	SCC incidence	Melanoma incidence
South	40	28	10
Southeast	35	24	8
Midwest	30	20	6
North	20	12	3
Northeast	18	10	2

The alarming rise in skin cancer incidence among young adults, as evidenced by our study in Brazil, serves as a stark reminder of the pressing need to understand the complex biological processes that contribute to this disease. While epidemiological studies provide invaluable insights into the patterns and distribution of skin cancer, it is imperative to delve deeper into the pathophysiological and molecular mechanisms that drive its development. This understanding is not merely an academic pursuit; it forms the bedrock upon which effective preventive and therapeutic strategies can be built. Let us embark on a comprehensive exploration of the intricate pathways that connect sun exposure, genetic predisposition, and cellular alterations, ultimately leading to the malignant transformation of skin cells. At the heart of skin cancer development lies the relentless assault of ultraviolet (UV) radiation, primarily emanating from sunlight but also from artificial sources such as tanning beds. UV radiation, particularly the UVB spectrum, acts as a potent carcinogen, inflicting significant damage upon the DNA within skin cells. This damage, if left unrepaired, triggers a cascade of events that can culminate in the uncontrolled growth and spread of cancerous cells. The two most prevalent forms of non-melanoma skin cancers, basal cell carcinoma (BCC) and squamous cell carcinoma (SCC), are predominantly driven by the cumulative effects of UV exposure over time. UVB radiation directly damages DNA, primarily through the formation of pyrimidine dimers. These dimers distort the DNA helix, impeding the normal processes of replication and transcription, thereby increasing the likelihood of mutations in critical genes. In addition, UVA radiation, while less directly mutagenic, generates reactive oxygen species (ROS) that can also damage DNA and contribute to the carcinogenic process. The molecular pathways implicated in UV-induced BCC and SCC development are intricate and multifaceted, involving the interplay of numerous oncogenes and tumor suppressor genes. The hedgehog signaling pathway, pivotal in embryonic development and tissue homeostasis, plays a central role in BCC pathogenesis. Mutations in key genes within this pathway, such as PTCH1 or SMO, lead to its constitutive activation, driving uncontrolled cell growth and proliferation. In SCC, mutations in the TP53 tumor suppressor gene are frequently observed. p53, often referred to as the "guardian of the genome," plays a critical role in maintaining genomic integrity by orchestrating DNA repair and apoptosis in response to DNA damage. When TP53 is mutated, these protective mechanisms are compromised, allowing cells with damaged DNA to survive and propagate, thereby increasing the risk of malignant transformation. The RAS-MAPK signaling pathway, a critical regulator of cell growth and survival, is frequently dysregulated in both BCC and SCC. Mutations in genes encoding components of this pathway, such as RAS or BRAF, can lead to its constitutive activation, promoting uncontrolled cell proliferation and resistance to apoptosis. The Notch signaling pathway, involved in cell fate determination and differentiation, has also been implicated in SCC progression, with aberrant Notch signaling promoting tumor growth and invasion. Melanoma, though less common than BCC and SCC, represents the most aggressive and life-threatening form of skin cancer. It arises from melanocytes, the pigment-producing cells of the skin, and is characterized by its ability to metastasize rapidly to distant organs. While UV radiation remains a major risk factor for melanoma, its molecular pathogenesis differs from that of non-

melanoma skin cancers. Intermittent, intense sun exposure, particularly during childhood and adolescence, appears to be a critical trigger for melanoma initiation. This type of exposure can lead to the acquisition of UV-induced signature mutations, such as C>T transitions at dipyrimidine sites. These mutations are frequently observed in melanoma driver genes like BRAF and NRAS. BRAF, encoding a serine/threonine kinase within the MAPK signaling pathway, is mutated in approximately 50% of melanomas. The most common BRAF mutation, V600E, results in the constitutive activation of the kinase, driving uncontrolled cell proliferation, survival, and invasion. NRAS mutations, though less frequent than BRAF mutations, also contribute to melanomagenesis by activating the MAPK pathway and promoting oncogenic signaling. Beyond UV-induced mutations, inherited genetic susceptibility plays a pivotal role in melanoma development. Individuals harboring germline mutations in genes like CDKN2A and CDK4, which function as critical regulators of cell cycle progression, face a significantly elevated risk of developing melanoma. These mutations disrupt the normal checkpoints that control cell division, permitting cells with DNA damage to bypass apoptosis and continue proliferating, thereby increasing the likelihood of malignant transformation. While UV radiation is undeniably the principal driver of skin cancer, other factors contribute to the escalating incidence observed in young adults. The use of tanning beds, which emit high levels of UVA radiation, has been strongly linked to an increased risk of all skin cancer types, particularly melanoma. Tanning bed use often commences during adolescence or young adulthood, a critical window for melanoma development, further underscoring its potential impact. Fair skin, characterized by low levels of melanin pigment, is a well-established risk factor for skin cancer. Melanin serves as a natural sunscreen, absorbing UV radiation and shielding DNA from damage. Individuals with fair skin, particularly those with red or blonde hair and blue or green eyes, are more susceptible to sunburn and consequently have a higher risk of developing skin cancers. A history of sunburns, especially blistering sunburns during childhood or adolescence, is strongly associated with an increased risk of melanoma. Sunburns represent a severe inflammatory response to UV-induced DNA damage, and repeated episodes can lead to the accumulation of mutations and genomic instability, setting the stage for melanoma development. Beyond the biological and environmental factors, changes in lifestyle and behavior patterns may also be contributing to the rising tide of skin cancers in young adults. Increased participation in outdoor recreational activities, coupled with inadequate sun protection practices, can result in greater UV exposure and elevate skin cancer risk. The pursuit of tanned skin as a societal beauty standard, perpetuated by media and cultural norms, may further exacerbate this problem, as individuals may engage in risky sun-seeking behaviors or resort to artificial tanning methods to achieve a desired aesthetic. Moreover, a lack of awareness or understanding about the dangers of UV radiation and the importance of sun protection may be prevalent among young adults. Many may underestimate their personal risk or hold the misconception that skin cancers primarily afflict older individuals. This knowledge gap can lead to complacency and a disregard for sun-safe practices, leaving them vulnerable to the harmful effects of UV radiation. The specific findings of our study, demonstrating a rising incidence of skin cancers among young adults in Brazil, warrant careful consideration in the context of the country's distinct environmental and demographic characteristics. Brazil's tropical and subtropical climate, characterized by abundant sunshine and high levels of UV radiation throughout much of the year, intrinsically places its population at an elevated risk for skin cancers. This environmental factor, coupled with the remarkable diversity of skin phototypes present in the Brazilian populace, creates a complex tapestry of risk and susceptibility. While lighter skin tones are generally more susceptible to UV-induced DNA damage and skin cancer, it is imperative to recognize that skin cancer can affect individuals of all skin tones. In Brazil, where racial admixture is commonplace, assessing skin cancer risk based solely on skin color can be misleading and potentially dangerous. Furthermore,

cultural and behavioral factors unique to Brazil may also influence skin cancer risk. Outdoor leisure activities, such as beachgoing and sunbathing, are deeply ingrained in the Brazilian lifestyle, potentially leading to increased sun exposure, particularly during peak UV radiation hours. The pursuit of tanned skin as a symbol of beauty and health, while not exclusive to Brazil, may be particularly pronounced in a society that celebrates outdoor living and physical attractiveness. The alarming increase in skin cancer incidence among young adults in Brazil calls for a concerted and multi-pronged approach to prevention and early detection. Public health campaigns promoting sun-safe behaviors, such as seeking shade, wearing protective clothing, and using broad-spectrum sunscreen with a high SPF, should be intensified and tailored to resonate with young adults. Educational initiatives should leverage social media, popular culture, and peer-to-peer networks to reach this demographic effectively. The long-term consequences of UV exposure, including premature aging and skin cancer, should be emphasized, dispelling the misconception that these are concerns solely for older individuals. Early detection of skin cancers, particularly melanoma, remains the cornerstone of improved survival outcomes. Promoting regular skin self-examinations and facilitating access to dermatological care for suspicious lesions can enable timely diagnosis and treatment. Healthcare providers should be vigilant in educating young adults about the warning signs of skin cancer and encouraging them to seek medical attention promptly if they notice any changes in their skin. Sunlight, a source of life and vitality, harbors a darker side in the form of ultraviolet (UV) radiation. This invisible spectrum of light, while essential for vitamin D synthesis and other physiological processes, also possesses potent carcinogenic properties. The link between sun exposure and skin cancer is irrefutable, backed by decades of epidemiological and experimental evidence. UV radiation, particularly the UVB spectrum, acts as a relentless assailant, inflicting damage upon the DNA within skin cells. If left unchecked, this damage sets in motion a series of molecular events that can lead to the uncontrolled growth and spread of cancerous cells. The sun emits three types of UV radiation: UVA, UVB, and UVC. While UVC is largely absorbed by the ozone layer, UVA and UVB readily penetrate the atmosphere and reach the Earth's surface. UVB radiation, with its shorter wavelength and higher energy, is the primary culprit behind sunburn and direct DNA damage. UVA radiation, though less directly mutagenic, penetrates deeper into the skin and contributes to long-term skin damage, photoaging, and carcinogenesis. The interaction of UV radiation with DNA is a complex process with profound consequences for cellular integrity. UVB photons, upon absorption by DNA, can cause the formation of pyrimidine dimers. These abnormal chemical bonds between adjacent pyrimidine bases (cytosine or thymine) distort the DNA helix, impeding the normal processes of replication and transcription. This disruption can lead to errors in DNA copying, resulting in mutations that alter the function of critical genes. UVA radiation, while less efficient at causing direct DNA damage, generates reactive oxygen species (ROS) within skin cells. These highly reactive molecules can damage DNA, proteins, and lipids, contributing to oxidative stress and inflammation. Chronic exposure to UVA radiation can lead to the accumulation of DNA damage and promote genomic instability, increasing the likelihood of malignant transformation. The two most prevalent forms of skin cancer, basal cell carcinoma (BCC) and squamous cell carcinoma (SCC), are predominantly driven by the cumulative effects of UV exposure over time. Years of sunbathing, outdoor work, or even casual strolls in the sun without adequate protection can take a toll on the skin, gradually accumulating DNA damage and increasing the risk of these cancers. BCC arises from basal cells, the small, round cells found in the lower layer of the epidermis. UV-induced DNA damage can disrupt the hedgehog signaling pathway, a critical regulator of cell growth and differentiation in these cells. Mutations in key genes within this pathway, such as PTCH1 or SMO, lead to its constitutive activation, driving uncontrolled cell proliferation and the formation of BCC tumors. These tumors, while rarely metastasizing, can cause significant local tissue destruction if left untreated.

SCC originates from squamous cells, the flat, scale-like cells that form the outermost layer of the epidermis. UV-induced DNA damage can impair the function of the TP53 tumor suppressor gene in these cells. p53, often referred to as the "guardian of the genome," plays a vital role in maintaining genomic stability by orchestrating DNA repair and apoptosis in response to DNA damage. When TP53 is mutated, these protective mechanisms are compromised, allowing cells with damaged DNA to survive and proliferate, leading to the development of SCC. SCC has a higher potential for metastasis compared to BCC, although the risk remains relatively low. In addition to these key players, other molecular pathways are implicated in UV-induced BCC and SCC development. The RAS-MAPK signaling pathway, a critical regulator of cell growth and survival, is often dysregulated in both BCC and SCC. Mutations in genes encoding components of this pathway, such as RAS or BRAF, can lead to its constitutive activation, promoting uncontrolled cell proliferation and resistance to apoptosis. The Notch signaling pathway, involved in cell fate determination and differentiation, has also been implicated in SCC progression, with aberrant Notch signaling promoting tumor growth and invasion. Melanoma, the most aggressive and deadly form of skin cancer, arises from melanocytes, the pigment-producing cells of the skin. While UV radiation is a major risk factor for melanoma, the molecular mechanisms involved differ from those in BCC and SCC. Intermittent, intense sun exposure, such as that experienced during sunburns, appears to be particularly critical for melanoma initiation. This type of exposure can lead to the formation of UV-induced signature mutations, such as C>T transitions at dipyrimidine sites. These mutations are frequently observed in melanoma driver genes like BRAF and NRAS. BRAF, encoding a serine/threonine kinase within the MAPK signaling pathway, is mutated in approximately 50% of melanomas. The most common BRAF mutation, V600E, results in the constitutive activation of the kinase, driving uncontrolled cell proliferation, survival, and invasion. NRAS mutations, though less frequent than BRAF mutations, also contribute to melanomagenesis by activating the MAPK pathway and promoting oncogenic signaling. In addition to UV-induced mutations, inherited genetic susceptibility plays a pivotal role in melanoma development. Individuals harboring germline mutations in genes like CDKN2A and CDK4, which function as critical regulators of cell cycle progression, face a significantly elevated risk of developing melanoma. These mutations disrupt the normal checkpoints that control cell division, permitting cells with DNA damage to bypass apoptosis and continue proliferating. This unchecked proliferation increases the likelihood of accumulating further mutations and ultimately leading to malignant transformation.[11,12]

The development of skin cancer is a complex process involving the interplay of multiple factors, including UV radiation exposure, genetic predisposition, and environmental influences. UV radiation acts as a potent carcinogen, inflicting DNA damage and triggering mutations in critical genes that regulate cell growth and differentiation. The specific molecular pathways involved vary depending on the type of skin cancer, with BCC, SCC, and melanoma each exhibiting distinct patterns of genetic alterations. Furthermore, inherited genetic susceptibility can significantly increase an individual's risk of developing skin cancer, particularly melanoma. Germline mutations in tumor suppressor genes and cell cycle regulators can disrupt normal cellular processes and create a fertile ground for malignant transformation. Understanding the intricate pathophysiological and molecular mechanisms underlying skin cancer development is paramount to developing effective preventive and therapeutic strategies. By targeting key pathways and identifying individuals at high risk, we can strive to reduce the burden of this devastating disease and improve patient outcomes. While natural sunlight remains the primary source of UV exposure, the allure of a year-round tan has led many to seek solace in the artificial glow of tanning beds. These devices, emitting high levels of UVA radiation, have become a popular, albeit controversial, means of achieving a bronzed complexion. However, the pursuit of a tan through tanning beds comes at a steep price, significantly increasing the risk of all skin cancer types, particularly melanoma. The link between

tanning bed use and skin cancer risk is well-established, with numerous studies demonstrating a dose-dependent relationship. The intense UVA radiation emitted by tanning beds penetrates deep into the skin, causing DNA damage and promoting the formation of reactive oxygen species (ROS). This oxidative stress can lead to mutations in critical genes, disrupt cellular signaling pathways, and contribute to the malignant transformation of skin cells. Tanning bed use is often initiated during adolescence or young adulthood, a period of heightened vulnerability to the carcinogenic effects of UV radiation. Studies have shown that individuals who begin using tanning beds before the age of 35 have a significantly increased risk of developing melanoma compared to those who have never used them. The cumulative exposure to UVA radiation from repeated tanning sessions can accelerate the accumulation of DNA damage and increase the likelihood of developing skin cancer at a younger age. Furthermore, the perception of tanning beds as a "safe" alternative to sunbathing is a dangerous misconception. Tanning beds emit UVA radiation at levels several times higher than that of natural sunlight, making them a particularly potent source of DNA damage. The use of tanning beds, even for short durations, can have long-lasting consequences for skin health and increase the risk of developing skin cancer later in life. Skin pigmentation, determined by the amount and type of melanin pigment present in the skin, plays a crucial role in modulating an individual's susceptibility to UV radiation and skin cancer. Melanin acts as a natural sunscreen, absorbing UV radiation and preventing it from reaching and damaging the DNA within skin cells. Individuals with darker skin tones, possessing higher levels of melanin, enjoy a degree of natural protection against UV-induced DNA damage. Fair-skinned individuals, on the other hand, have lower levels of melanin and are more susceptible to sunburn and the long-term consequences of UV exposure. This increased vulnerability is reflected in the epidemiological data, which consistently shows a higher incidence of skin cancers, particularly melanoma, in individuals with fair skin, red or blonde hair, and blue or green eyes. The lack of melanin's protective shield allows UV radiation to penetrate deeper into the skin, causing more extensive DNA damage and increasing the likelihood of mutations that can lead to cancer. While individuals with darker skin tones are less susceptible to UV-induced DNA damage, it is crucial to remember that they are not immune to skin cancer. Although the incidence of skin cancers is generally lower in this population, they can still occur, and often present at later stages when they are more difficult to treat. Therefore, individuals of all skin tones should practice sun-safe behaviors and be vigilant in monitoring their skin for any suspicious changes. Sunburns, often dismissed as a temporary inconvenience, leave a lasting legacy on the skin, increasing the risk of developing skin cancer, especially melanoma. Sunburns represent a severe inflammatory response to UV-induced DNA damage, characterized by redness, pain, and blistering. This inflammatory cascade triggers the release of various signaling molecules and immune cells, which attempt to repair the damaged tissue. However, repeated episodes of sunburn can overwhelm the skin's repair mechanisms, leading to the accumulation of DNA damage and genomic instability. Studies have shown a strong association between a history of sunburns, particularly blistering sunburns during childhood or adolescence, and an increased risk of melanoma. The immature skin of children and adolescents is particularly vulnerable to UV radiation, and the DNA damage incurred during sunburns can lay the groundwork for melanoma development years or even decades later. Furthermore, the inflammatory response triggered by sunburns can create a pro-tumorigenic microenvironment within the skin. Inflammatory cells release growth factors and cytokines that can stimulate cell proliferation and angiogenesis, providing a fertile ground for the growth and spread of cancer cells. Chronic inflammation, resulting from repeated sunburns or other skin insults, can further perpetuate this pro-tumorigenic state and increase the risk of malignant transformation.[13,14]

While UV radiation and skin pigmentation are the primary determinants of skin cancer risk, other factors also contribute to the complex etiology of this disease.

These factors, often intertwined with sun exposure and genetic predisposition, can further modulate an individual's susceptibility to skin cancer. A family history of skin cancer, particularly melanoma, is a significant risk factor. This suggests a genetic predisposition to the disease, with inherited mutations in certain genes increasing an individual's susceptibility to UV-induced DNA damage and malignant transformation. Individuals with weakened immune systems, such as those with HIV/AIDS or organ transplant recipients, are at an increased risk of developing skin cancers. The immune system plays a crucial role in recognizing and eliminating abnormal cells, including those that have undergone malignant transformation. When the immune system is compromised, this surveillance mechanism is impaired, allowing cancerous cells to evade detection and proliferate unchecked. Exposure to certain chemicals, such as arsenic and polycyclic aromatic hydrocarbons (PAHs), has been linked to an increased risk of skin cancer. These chemicals can damage DNA and disrupt cellular signaling pathways, contributing to the carcinogenic process. Certain chronic skin conditions, such as xeroderma pigmentosum and actinic keratosis, can increase the risk of developing skin cancers. These conditions often involve defects in DNA repair mechanisms or precancerous changes in skin cells, making them more susceptible to UV-induced damage and malignant transformation. The rising incidence of skin cancers, particularly among young adults, cannot be solely attributed to environmental and genetic factors. Lifestyle and behavioral patterns play a significant role in modulating an individual's exposure to UV radiation and, consequently, their risk of developing skin cancer. In recent decades, shifts in lifestyle and societal norms have contributed to an increased vulnerability to UV-induced damage, particularly among younger generations. The modern lifestyle, with its emphasis on outdoor recreation and physical activity, has inadvertently increased sun exposure for many individuals. While spending time outdoors offers numerous benefits for physical and mental well-being, it also entails greater exposure to UV radiation. Activities such as swimming, hiking, camping, and sports, particularly during peak sun hours, can lead to significant UV exposure, even on cloudy days. Unfortunately, this increased outdoor activity is often accompanied by inadequate sun protection practices. Many young adults fail to consistently use sunscreen, seek shade, or wear protective clothing, leaving their skin vulnerable to the harmful effects of UV radiation. The perception that sun protection is only necessary during intense sunbathing or beach outings is a dangerous misconception. Even incidental sun exposure during daily activities can accumulate over time and contribute to skin damage and cancer risk. Moreover, the pursuit of a tanned complexion, fueled by social media and cultural norms, can further exacerbate this issue. The association of tanned skin with beauty, health, and social status can lead individuals to engage in risky sun-seeking behaviors or utilize artificial tanning methods, such as tanning beds, to achieve a desired aesthetic. This pursuit of a tan often overrides concerns about skin health and long-term consequences, putting young adults at an increased risk of UV-induced damage and skin cancer. The advent of social media has profoundly impacted how young adults perceive and interact with the world around them. Platforms like Instagram and TikTok, with their emphasis on visual content and curated self-presentation, have created a virtual space where beauty ideals are constantly reinforced and redefined. The portrayal of tanned skin as a desirable attribute, often associated with attractiveness, success, and a carefree lifestyle, can exert a powerful influence on young people's attitudes and behaviors. Studies have shown a correlation between social media use and sun-seeking behaviors, with individuals who frequently engage with content promoting tanned skin being more likely to engage in risky sun exposure practices. The constant bombardment of images featuring bronzed bodies can normalize and even glamorize tanning, leading young adults to underestimate the risks associated with UV radiation and prioritize aesthetic goals over skin health. Moreover, the rise of influencer marketing and sponsored content on social media can further perpetuate the tanning culture. Brands promoting tanning products, sunless tanners, and even tanning

salons often collaborate with influencers to reach a wider audience and create a sense of aspiration around tanned skin. This can subtly normalize and even encourage the use of potentially harmful products and practices, putting young adults at an increased risk of UV-induced damage and skin cancer. Despite widespread public health campaigns and educational initiatives, a lack of awareness about the dangers of UV radiation and the importance of sun protection remains prevalent among young adults. Many individuals underestimate their personal risk of developing skin cancer, believing it to be a disease primarily affecting older populations. This misconception stems from the fact that skin cancers often take years or even decades to develop, with the cumulative effects of UV exposure manifesting later in life. However, the damage inflicted by UV radiation begins early, and even a single severe sunburn during childhood or adolescence can significantly increase the risk of developing melanoma later in life. Furthermore, the asymptomatic nature of early-stage skin cancers can contribute to a false sense of security. Many young adults may not be aware of the subtle changes in their skin that could indicate the presence of a malignancy. This lack of awareness can lead to delayed diagnosis and treatment, potentially impacting prognosis and survival. Addressing the rising incidence of skin cancers in young adults requires a multi-faceted approach that tackles both individual behaviors and societal norms. Public health campaigns should be tailored to resonate with young adults, utilizing social media, peer-to-peer networks, and relatable messaging to promote sun-safe behaviors. Educational initiatives should emphasize the long-term consequences of UV exposure, including premature aging and skin cancer, and dispel the myth that these are concerns solely for older individuals. Empowering young adults with knowledge about the risks of UV radiation and the importance of sun protection is crucial. Teaching them how to perform regular skin self-examinations and recognize the warning signs of skin cancer can enable early detection and prompt medical attention. Additionally, promoting healthy coping mechanisms for stress and body image concerns can help reduce the reliance on tanning as a means of achieving self-esteem or social validation.[15,16]

The alarming rise in skin cancer incidence among young adults in Brazil, as revealed by our study, underscores the complex interplay of environmental, genetic, and sociocultural factors that shape the country's unique skin cancer landscape. Understanding these factors is essential not only for interpreting our findings but also for developing targeted interventions that address the specific needs and vulnerabilities of the Brazilian population. Brazil's geographical location and climate create an environment where sun exposure is an integral part of daily life. The country spans a vast territory, encompassing a diverse range of climates, from the tropical Amazon rainforest in the north to the temperate grasslands in the south. However, a significant portion of the country lies within the tropics and subtropics, where sunlight is abundant and UV radiation levels are high throughout much of the year. The intensity of UV radiation is influenced by several factors, including latitude, altitude, time of day, and cloud cover. In Brazil, the combination of its proximity to the equator, high altitude regions, and predominantly clear skies results in significant UV exposure for much of the population. Even during winter months or cloudy days, UV radiation levels can remain substantial, posing a continuous risk for skin damage and cancer development. This environmental backdrop creates a unique challenge for skin cancer prevention in Brazil. While sun exposure is essential for vitamin D synthesis and other physiological processes, the high levels of UV radiation prevalent in the country necessitate a heightened awareness of the risks and a proactive approach to sun protection. Brazil's rich ethnic diversity, stemming from centuries of intermixing between indigenous populations, European colonizers, African slaves, and Asian immigrants, has resulted in a wide spectrum of skin phototypes, ranging from very fair to very dark. This genetic diversity creates a complex landscape of skin cancer susceptibility, as individuals with lighter skin tones are generally more prone to UV-induced DNA damage and have a higher risk of developing skin cancers compared to those with darker skin tones.

Melanin, the pigment that gives skin its color, acts as a natural sunscreen, absorbing UV radiation and protecting against DNA damage. Individuals with darker skin tones, possessing higher levels of melanin, enjoy a degree of natural protection against the harmful effects of UV radiation. However, this protection is not absolute, and skin cancer can still occur in individuals with darker skin tones, often presenting at later stages when they are more difficult to treat. In Brazil, where racial admixture is common, assessing skin cancer risk based solely on skin color can be challenging. Many individuals possess a mix of genetic ancestries, resulting in intermediate skin tones that may not neatly fall into traditional categories. Moreover, self-reported race or ethnicity may not accurately reflect an individual's genetic predisposition to skin cancer. Therefore, a more nuanced approach that considers individual skin phototype, family history, and sun exposure behaviors is necessary to assess skin cancer risk accurately. Beyond the environmental and genetic factors, cultural and behavioral norms also shape the Brazilian relationship with the sun. Outdoor leisure activities, such as beachgoing, sunbathing, and sports, are deeply ingrained in the Brazilian lifestyle, particularly in coastal regions and during the summer months. These activities, while promoting physical activity and social interaction, can also lead to increased sun exposure, particularly during peak UV radiation hours when the sun's rays are most intense. Furthermore, the pursuit of tanned skin as a symbol of beauty and health is deeply rooted in Brazilian culture. A bronzed complexion is often associated with attractiveness, vitality, and a carefree lifestyle. This cultural ideal can encourage risky sun-seeking behaviors, particularly among young adults who may prioritize aesthetic goals over long-term skin health. The pressure to conform to societal beauty standards can lead to excessive sun exposure, neglect of sun protection measures, and even the use of artificial tanning methods, such as tanning beds, all of which increase the risk of skin cancer. The influence of media and popular culture on body image and beauty ideals cannot be underestimated. Images of tanned celebrities and models, often perpetuated through social media and advertising, can reinforce the notion that tanned skin is desirable and healthy. This can create a disconnect between the perceived benefits of tanning and its actual risks, particularly among young adults who are more susceptible to social influence and media messaging. The unique combination of environmental, genetic, and sociocultural factors in Brazil presents a complex challenge for skin cancer prevention and control. Addressing this challenge requires a multi-pronged approach that tackles not only individual behaviors but also societal norms and cultural attitudes towards sun exposure and skin health. Public health campaigns should be designed to resonate with the Brazilian population, taking into account the country's cultural values and lifestyle patterns. These campaigns should promote sun-safe behaviors, such as seeking shade, wearing protective clothing, and using sunscreen regularly, while also challenging the notion that tanned skin is synonymous with beauty and health. Educational initiatives should leverage social media, popular culture, and peer-to-peer networks to reach young adults effectively and empower them to make informed choices about their skin health. Furthermore, improving access to dermatological care and skin cancer screening programs is essential, particularly in underserved regions and populations. Early detection of skin cancers, especially melanoma, remains the cornerstone of improved survival outcomes. By facilitating timely diagnosis and treatment, we can reduce the burden of skin cancer and improve the quality of life for those affected.[17,18]

The alarming rise in skin cancer incidence among young adults in Brazil, as revealed by our study and corroborated by the growing body of global evidence, underscores the urgent need for comprehensive and targeted prevention and early detection strategies. The battle against skin cancer is a multifaceted one, requiring a concerted effort from healthcare providers, public health officials, educators, policymakers, and individuals themselves. In this section, we will explore the implications of our findings for the development and implementation of effective prevention and early detection programs, with a focus on empowering young adults to make informed choices about their

skin health and reducing the burden of this devastating disease. Sun protection lies at the heart of skin cancer prevention. Shielding the skin from the harmful effects of UV radiation is paramount to reducing the risk of DNA damage and malignant transformation. While complete avoidance of sun exposure is neither feasible nor desirable, adopting sun-safe behaviors can significantly mitigate the risk of skin cancer. Public health campaigns play a crucial role in promoting sun protection practices and raising awareness about the dangers of UV radiation. These campaigns should be tailored to resonate with young adults, utilizing engaging and relatable messaging that emphasizes the long-term consequences of UV exposure, including premature aging and skin cancer. Leveraging social media, popular culture, and peer-to-peer networks can help reach this demographic effectively and encourage them to adopt sun-safe behaviors. Educational initiatives should focus on dispelling the myth that skin cancers only affect older individuals. The cumulative nature of UV damage means that even seemingly harmless sun exposure during childhood and adolescence can contribute to skin cancer risk later in life. By emphasizing the importance of early sun protection, we can empower young adults to make informed choices about their skin health and reduce their long-term risk of developing skin cancer. Sun protection encompasses a range of behaviors and practices aimed at minimizing UV exposure and reducing the risk of skin damage. Avoiding direct sun exposure, particularly during peak UV radiation hours (typically between 10 am and 4 pm), is crucial. Seeking shade under trees, umbrellas, or other structures can significantly reduce UV exposure. Covering the skin with tightly woven clothing, including long-sleeved shirts, pants, and wide-brimmed hats, provides an effective barrier against UV radiation. Choosing clothing with a UPF (Ultraviolet Protection Factor) rating can further enhance protection. Applying broad-spectrum sunscreen with a high SPF (Sun Protection Factor) to all exposed skin is essential. Sunscreen should be applied generously and reapplied frequently, especially after swimming or sweating. Tanning beds emit high levels of UVA radiation, significantly increasing the risk of skin cancer. Avoiding tanning beds altogether is the safest option for protecting skin health. Certain medications and cosmetics can increase skin sensitivity to UV radiation. Individuals should be aware of any potential interactions and take extra precautions when using these products. While prevention remains the cornerstone of skin cancer control, early detection is crucial for improving survival rates, particularly for melanoma. Melanoma, if detected early, is highly treatable, but its aggressive nature means that delays in diagnosis can have devastating consequences. Promoting regular skin self-examinations is a simple yet effective way to empower individuals to take an active role in their skin health. By familiarizing themselves with their skin and monitoring for any changes, individuals can identify suspicious lesions early and seek medical attention promptly. Educational materials and resources, such as the "ABCDEs of melanoma" (Asymmetry, Border irregularity, Color variation, Diameter greater than 6 mm, Evolving), can help individuals recognize the warning signs of skin cancer. Facilitating access to dermatological care is another critical aspect of early detection. Dermatologists are trained to identify and diagnose skin cancers, and their expertise is invaluable in ensuring timely and appropriate treatment. Reducing barriers to dermatological care, such as long wait times and high costs, can improve access for young adults and enable early intervention for suspicious lesions. Technological advancements, such as teledermatology and artificial intelligence-based diagnostic tools, offer promising avenues for improving access to dermatological care and enhancing early detection efforts. Teledermatology allows individuals to consult with dermatologists remotely, eliminating geographical barriers and reducing wait times. AI-based tools can aid in the analysis of skin lesions, providing additional information to support clinical decision-making and potentially enabling earlier diagnosis of skin cancers. The rising incidence of skin cancer among young adults necessitates tailored interventions that address the unique needs and behaviors of this population. Traditional public health campaigns may not resonate with young adults, who may perceive skin cancer as a

distant concern or prioritize aesthetic goals over long-term health. Interventions targeting young adults should leverage social media, popular culture, and peer-to-peer networks to promote sun-safe behaviors and challenge the prevailing tanning culture. Utilizing relatable messaging and engaging visuals can help capture the attention of this demographic and encourage them to adopt healthy skin practices. Educational programs in schools and universities can play a vital role in instilling sun-safe behaviors from a young age. Incorporating skin cancer prevention into health education curricula can equip young people with the knowledge and skills they need to protect their skin throughout their lives. Collaborations between healthcare providers, public health organizations, and community groups can also enhance the reach and impact of prevention and early detection efforts. By working together, these stakeholders can develop comprehensive programs that address the multifaceted nature of skin cancer risk and promote a culture of sun safety.[19,20]

4. Conclusion

This population-based study underscores the alarming rise in skin cancer incidence among young adults in Brazil. The significant increase in BCC, SCC, and melanoma rates, particularly the concerning trend in melanoma, emphasizes an urgent public health challenge. The findings highlight the imperative for targeted interventions, including robust sun protection education and accessible early detection programs. Future research exploring risk factors and determinants in this population is crucial to tailor effective preventive strategies. This study serves as a clarion call for concerted action to address this growing burden and safeguard the health of young Brazilians.

5. References

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