

Biological, social and behavioral patterns as possible risk factors for the development of skin cancer in the Amazonian region

Padrões biológicos, sociais e comportamentais como possíveis fatores de risco para o desenvolvimento de câncer de pele na região amazônica

Patrones biológicos, sociales y conductualizados como posibles factores de riesgo para el desarrollo del cáncer de piel en la región amazónica

Thayse de Oliveira Brito <https://orcid.org/0000-0001-5785-3926>¹; Renata Cardoso Costa <https://orcid.org/0000-0003-3583-4622>¹; Dalberto Lucianelli Junior <https://orcid.org/0000-0002-5919-0975>²; Maria do Carmo Faria Paes <https://orcid.org/0000-0002-4689-6928>³; João Vitor Barbosa Pinheiro <https://orcid.org/0000-0002-1889-161X>⁴; Ana Laura Guimarães Moura <https://orcid.org/0000-0002-6261-2825>⁴; Rodrigo Silveira <https://orcid.org/0000-0001-6330-1669>⁵; Fernanda Nogueira Valentin <https://orcid.org/0000-0002-8279-3758>⁴

Abstract Skin cancer accounts for 33% of all tumors in Brazil and represents a major public health problem both nationally and globally. This study aimed to evaluate biological, social, and behavioral patterns in the Amazon region, to analyze their relationship with health indicators, and to identify the most significant risk factors. An exploratory cross-sectional study was conducted with a sample of the Amazon population (n = 1,014), using a structured questionnaire to collect data on lifestyle habits, as well as social and biological characteristics. The K-means clustering algorithm was applied to classify the sample. Two distinct groups emerged: Group 1 comprised young, white individuals with brown hair and a lower prevalence of skin spots, but with frequent sun exposure between 10 a.m. and 4 p.m. Group 2 comprised older, brown-skinned individuals who were exposed to the sun at non-recommended times primarily due to occupational demands. The findings indicate that both groups are exposed to distinct risk profiles, which are further aggravated by the low use of sunscreen products, which is an essential measure for the prevention of skin cancer.

Key words Skin cancer, Risk factors, Ultraviolet radiation, Prevention

Resumo O câncer de pele representa 33% dos tumores no Brasil, constituindo um grave problema de saúde pública no mundo todo. O objetivo do estudo é avaliar os padrões biológicos, sociais e comportamentais na região amazônica, assim como analisar as características desses padrões em relação aos indicadores de saúde e determinar os fatores de risco considerados mais importantes. Estudo transversal exploratório realizado com uma amostra da população da região amazônica (n = 1.014), a partir da aplicação de questionário estruturado, visando obter informações sobre hábitos de vida, padrões sociais e biológicos. Foi utilizado o algoritmo de agrupamento K-means, dividindo a amostra por clusterização. Foram obtidos dois grupos, sendo o grupo 1 constituído por pessoas jovens, brancas, com cabelos castanhos e menor predominância de manchas na pele, mas que se expõem ao sol no intervalo entre 10 e 16 horas. Já o grupo 2 é formado por pessoas mais adultas, pardas, que se expõem ao sol em horários não recomendados, mas por razões trabalhistas. Infere-se que os dois grupos estão sujeitos a riscos diferentes, apesar da pouca taxa de uso de itens que atuam na prevenção ao câncer de pele.

Palavras-chave Câncer de pele, Fatores de risco, Raios ultravioletas, Prevenção

Resumen El cáncer de piel representa el 33% de los tumores en Brasil, constituyendo un grave problema de salud pública tanto a nivel nacional como mundial. El objetivo del estudio es evaluar los patrones biológicos, sociales y de comportamiento en la región amazónica, así como analizar las características de estos patrones en relación con los indicadores de salud y determinar los factores de riesgo más importantes. Estudio exploratorio transversal realizado con una muestra de la población de la región amazónica (n = 1.014), mediante un cuestionario estructurado para obtener información sobre hábitos de vida, patrones sociales y patrones biológicos. Se utilizó el algoritmo de agrupamiento K-means, dividiendo la muestra por agrupamiento. Se obtuvieron dos grupos: el Grupo 1 está formado por individuos jóvenes, blancos, con cabello castaño y menor predominio de manchas en la piel, pero que se exponen al sol entre las 10:00 y las 16:00. El Grupo 2 está formado por individuos mayores, de piel morena, que se exponen al sol en horarios no recomendados por motivos laborales. Se puede inferir que ambos grupos presentan diferentes riesgos, a pesar del bajo índice de uso de productos que actúan en la prevención del cáncer de piel.

Palabras clave Cáncer de piel, Factores de riesgo, Rayos ultravioleta, Prevención

¹ Faculdade de Medicina, Universidade Federal do Pará. Altamira PA Brasil.

² Faculdade de Medicina, Universidade de Uberaba. Uberaba MG Brasil.

³ Institute for Environmental Research, RWTH Aachen University. Aachen Germany.

⁴ Faculdade de Medicina, Universidade do Estado do Pará – Campus Altamira. R. Coronel José Porfírio 2515, Campus II, São Sebastião. 68372-040. Altamira PA Brasil.

⁵ Escola de Educação Física e Esporte, Universidade de São Paulo. São Paulo SP Brasil.

Introduction

Cancer represents a significant public health concern on a global scale, ranking as one of the primary causes of mortality and posing a considerable challenge to enhancing life expectancy¹. The most prevalent form of cancer globally and in Brazil is skin cancer. As indicated by data from the National Cancer Institute (INCA), this particular form of cancer represents 33% of all cancer diagnoses in the country. Annually, approximately 180,000 new cases of skin cancer are reported in Brazil^{2,3}.

Skin cancers can be classified as non-melanoma and melanoma. The most prevalent form is non-melanoma and although it has low lethality, this category of cancer encompasses basal cell carcinoma (BCC) and squamous cell carcinoma (SCC), with an incidence rate in the Brazilian population of 70% and 25%, respectively, responsible for 177,000 new cases of the disease annually^{4,5}.

Melanoma skin cancer (MSC) is the most aggressive and lethal type of skin cancer. Despite being the least common, it has the highest mortality rate, with approximately 8,400 cases reported annually. However, if diagnosed at an early stage, the cure rate is high, exceeding 90%⁵.

The primary cause of skin cancer is natural ultraviolet (UV) radiation emitted by the sun. Ultraviolet radiation can penetrate the skin's layers, reaching the basal cells, where epidermal cells multiply. This results in damage to the molecular bases of DNA and RNA, altering their structure and function⁶. Regions with a tropical climate and high altitudes experience more intense UV radiation.

For Brazil, the estimated number of new cases of non-melanoma skin cancer for the period between 2023 and 2025 is approximately 220,000. Of these, it is estimated that 102,000 will be men and 118,000 women¹.

Non-melanoma skin cancer represents the most prevalent form of cancer in Brazil. The prevalence of this condition is higher in men residing in the South, Southeast, and Central-West regions. In women, non-melanoma skin cancer is the most prevalent in all Brazilian regions, with the highest estimated risk observed in the South (164.79 per 100,000 women), followed by the Southeast (123.33 per 100,000)¹.

While the incidence of skin cancer is relatively low in the North Region compared to other regions of Brazil, the combination of high

levels of sunlight and a population with specific social, biological, and behavioral characteristics may contribute to an increased risk of developing this neoplasm^{7,8}.

Furthermore, a significant proportion of the Amazonian population, comprising a diverse range of ethnic groups, engages in various outdoor activities, including agriculture and fishing, which are known to involve prolonged exposure to the sun. It is crucial to consider the challenges associated with accessing healthcare, the limited availability of specialized services, and the potential for underreporting of cases due to insufficiently trained professionals who are unable to make a proper diagnosis⁹.

Although studies have been conducted on the prevalence and incidence of skin cancer cases in Brazil, there is a lack of information regarding the population's knowledge and prevention practices in the Amazon region. It is therefore imperative that comprehensive research be conducted in order to accurately portray the sociodemographic, behavioral, and biological patterns that contribute to the emergence of skin cancer, particularly in this region, where there is a high incidence of sunlight¹⁰.

Therefore, the utilization of unsupervised algorithms and the application of clustering techniques are capable of exploring patterns in the characteristics of this population that may correlate with the risk of skin cancer. In this context, the objective of this study was to provide a comprehensive assessment of biological, social, and behavioral patterns in municipalities in the North region. Additionally, the characteristics of these patterns were examined concerning health indicators, and the risk factors deemed most significant were identified.

Methodology

Ethical-legal aspects

The research was approved by the Ethics Committee of the Tropical Medicine Center of the Federal University of Pará (NMT) under the following number: CAAE: 33548620.0.0000.0018. The participants were informed about the objective of the study, the optional nature of their participation, and the necessity of signing the Informed Consent Form in accordance with the resolutions of the National Health Council (CNS) No. 466/2012 and 510/2016.

Study type and location, population, and sample

This is a cross-sectional quantitative study conducted through the administration of a questionnaire to a representative sample of the population in the Amazon region. The research was conducted in the municipalities of Altamira (PA), Belém (PA), Cametá (PA), Parauapebas (PA), and Porto Velho (RO).

In accordance with data regarding demographic diversity from the Brazilian Institute of Geography and Statistics¹¹, the sample size was calculated to ensure the inclusion of a representative number of individuals aged 18 and above in the Amazonian region.

Therefore, as these are exploratory analyses, there is no way to establish an effect size hypothesis based solely on the population studied. However, it was estimated by the G Power software that the effects would be at least moderate due to clustering by K-means, hypothesizing a moderate effect size in the variables with 5 categories, for a value of $p < 0.05$ and statistical power = 95%. The statistical test that estimated the largest sample size was the Chi-square test for comparing age range, ethnicity, and education. This test estimated a sample size of $n = 220$ for four degrees of freedom (five categories), adding approximately 10% in case of sample loss due to eligibility criteria, totaling $n = 245$.

Due to the cultural plurality in the regions studied, to ensure a greater representation of the local population, 50% of the sample size estimated in the main analysis was added for each municipality. Thus, a total sample size of $n = \sim 613$ was estimated (122.5 [half of $n = 245$ estimated for main analysis] $\times$ the five municipalities studied).

The study population consisted of individuals of both genders who were over 18 years of age, had provided informed consent, and completed the questionnaire. Individuals with cognitive, learning, or communication impairments, as well as those who declined to participate despite having signed the informed consent form, were excluded from the study. A total of 1,014 individuals consented to participate in the research.

Data collection and instrument

The data was gathered through direct engagement with individuals in public settings that

are prone to prolonged sun exposure, including public squares, beaches, and open-air tourist attractions in the aforementioned cities. The data collection was conducted over the course of two years, from July 2021 to June 2022.

The questionnaire consisted of closed-ended questions designed to elicit information about various characteristics based on different variables. The variables included biological factors such as (a) age, ethnicity, sex, eye and hair color, and the presence of spots or sunburns on the body. Additionally, social factors (b), such as level of education, behavioral factors (c), such as the reason, frequency, and time of exposure to the sun, the frequency of sunscreen, hat, cap, sunglasses, long-sleeved t-shirt, umbrella use, and sources of information about skin cancer, were included in the questionnaire. The questionnaire also evaluated the respondents' familiarity with the ABCDE method for identifying melanoma, which includes the following criteria: A (asymmetry of the lesion), B (irregular edges), C (variable colors), D (diameter > 6 mm), and E (evolution).

Statistical analysis

Given the assumption that the development of skin cancer is multifactorial¹⁰ and can be affected by various factors (e.g., age, education level, place of work, exposure to the sun, among others), the sample was divided through clustering, adopting the *K-means* clustering algorithm. This unsupervised method enables the algorithm to learn how all variables in a data set relate to each other, subsequently dividing participants into different predetermined groups^{12,13}.

Based on the hypothesis that biological, social, and behavioral factors influence the occurrence of skin cancer, we propose that individuals may exhibit distinct patterns of characteristics and behaviors. Accordingly, the *K-means* algorithm was configured to partition the sample into two distinct groups. To guarantee the quality of the clustering, specific strategies were implemented.

In the present study, the application of the *K-means* algorithm was enhanced by the *K-means++* initialization method¹⁴ for clustering a set of categorical data. The application of this algorithm to categorical data presents a significant challenge due to the inherent limitations of the dissimilarity metric when compared to the Euclidean distance used for quantitative

variables¹⁵. To mitigate these challenges and increase the algorithm's effectiveness, the following complementary steps were implemented:

1) Normalization of columns – column normalization was a fundamental step in the analysis process. Considering that the database contained a total of 25 variables, each with 2 to 5 categories, normalization ensured that all variables contributed equally to the calculation of distances between data points. Without normalization, variables with more categories could dominate the cluster formation, resulting in biased outcomes. With normalization, the influence of each variable was balanced, promoting a fairer and more accurate analysis.

2) Application of K-means++ – K-means is a widely used clustering algorithm, recognized for its simplicity and effectiveness in data segmentation. However, its performance can be significantly affected by the initial choice of centroids. To address this issue, we employed the K-means++ method, which optimizes the initialization of cluster centers, reducing the probability of convergence to local minima and improving the quality of the formed clusters. This technique proved especially useful in the context of categorical data, ensuring a more balanced initial distribution of centroids.

3) Application of the elbow method – to ensure that the suggested quantity of 2 clusters in the study's hypothesis was indeed ideal, the Elbow Method, a visually intuitive and effective technique, was used. This method involves plotting the sum of squared distances within clusters (inertia) as a function of the number of clusters. The point at which the rate of inertia reduction decreases significantly, forming an "elbow" in the curve, is considered the ideal number of clusters. This approach allowed the identification of a balance point where the addition of new clusters provides marginal benefits, avoiding over-segmentation of the data.

4) Application of the multilayer perceptron algorithm – to ensure the efficacy of the previous steps and the quality of clustering, the multilayer perceptron algorithm was also applied^{16,17}. Through the area under the curve (AUC) coefficient¹⁸, it tested the separability of the data by the clusters obtained by K-means.

The multilayer perceptron is a supervised machine learning algorithm that, through artificial neural networks, is capable of identifying non-linear patterns among different variables in a dataset and, consequently, provides a prediction of some predetermined variable. The learning process of this algorithm involves the

following steps: 1) initializing the weights; 2) calculating the outputs from the input layer to the hidden layer followed by the outputs from the hidden layer to the output layer; 3) calculating the error rate in the predictions of the output layer and adjusting the weights; 4) repeating all previous steps until the error rate becomes as low as possible¹⁸.

All quantitative variables were rescaled to intervals between 0 and 1. The sample was randomly divided into two datasets, with 70% of the entire sample used to train the algorithm and 30% used for testing. The minibatch method was selected for training, and the gradient descent method was chosen for optimization. Due to the multilayer perceptron potentially presenting different results each time it is executed, due to the randomization of data partitions for cross-validation and weight initialization, the algorithm was executed three times. The attempt with the lowest average cross-entropy error ($[\text{training error} + \text{test error}] / 2$) was selected.

To identify the variables that most contributed to the division of the obtained clusters, the importance of each variable in determining the artificial neural networks was calculated, thereby performing a sensitivity analysis based on the combined training and test samples, creating a table displaying a ranking of importance for each variable¹⁹. For application of the sensitivity analysis in the present study, the multilayer perceptron was reapplied following the same architecture cited above, however, with only the variables with the significant statistical difference ($p < 0.05$) between the clusters.

For proportions, categorical data were used to evaluate the characteristics of the groups. For comparisons between groups in categorical data, chi-square was used with Fisher corrections (if there were < 6 individuals in any position in the contingency table). The significance level was set at $p < 0.05$.

To identify the most important values in the contingency tables $> 2 \times 2$, in all significant categorical analyses, the residual adjustment > 2 was adopted. To evaluate the effect size of the chi-square test, the *Phi* and Cramer tests were used (v). For the quality of adjustment in 2×2 contingency tables, *Phi* was used, equivalent to the correlation coefficient r , defined as: 0.1 considered as a small effect, 0.3 (intermediate effect), 0.5 (large effect). The Cramer's effect measure (v) was applied to a contingency table greater than 2. For each degree of freedom, a different value is considered in classifying the effect size.

The formula for calculating Cramér's V coefficient is as follows:

$$V = \sqrt{\frac{\chi^2}{n \cdot \min(k - 1, r - 1)}}$$

Where: χ^2 represents the chi-square value obtained from the test; n denotes the sample size (total number of observations); k indicates the number of categories in the column variable (number of columns in the contingency table); and r signifies the number of categories in the row variable (number of rows in the contingency table)²⁰.

To evaluate the division of groups and classify the degree of importance of each variable in determining the belonging groups, the *multilayer perceptron* algorithm was applied. It is considered a supervised machine learning algorithm that, through artificial neural networks, is capable of finding non-linear patterns between different variables in a set of data, and the response provides a prediction of some predetermined variable. The algorithm was applied in triplicate and the one chosen was the one with the lowest error. The quantitative variables were rescaled into intervals of 0 and 1. Only the variables that gave statistical significance ($p < 0.05$) were considered in the test to indicate the groups provided by *K-means* and thus calculate and classify the importance of each factor.

All group division evaluation procedures were carried out using the IBM SPSS Statistics for Windows.

Results

The algorithm has classified the sample into two distinct groups, designated as Group 1 and Group 2. With regard to the biological and social characteristics presented in Table 1, Group 1 is predominantly composed of young adults aged 18-30 years (58.6%), who are primarily white (34.2%), female (68.9%), with brown hair (52.8%), and exhibit fewer skin blemishes (70.8%) but more sunburns (52.8%). Additionally, individuals in group 1 have attained higher levels of education than those in group 2. In contrast, group 2 is predominantly exposed to the sun due to occupational requirements (93.5%), whereas group 1 is exposed to the sun for leisure purposes (53.3%). The study indicates that group 1 is occasionally exposed to the sun, whereas group 2 is frequently exposed to the sun due to occupational reasons. Significant differences and large effect sizes are evident with

Table 1. Biological and social characteristics between groups.

	Group 1 (n = 599)	Group 2 (n = 415)	Size effect	P
Age Range				
< 18 years old	8.2%	5.5%	$\nu = 0.21^{++}$	< 0.001
18-30	58.6%	40.5%		
31-50	19.5%	35.2%		
51-70	10.5%	15.4%		
> 70	3.2%	3.4%		
Ethnicity				
White	34.2%	14.5%	$\nu = 0.24^{++}$	< 0.001
Brown	55.8%	72.5%		
Black	8.3%	11.8%		
Indigenous	0.5%	1.2%		
Yellow	1.2%	0.0%		
Sex				
Female	68.9%	37.6%	$\phi = 0.31^{++}$	< 0.001
Male	31.1%	62.4%		
Eye color				
Brown	70.6%	67.0%	$\nu = 0.05$	0.39
Black	24.0%	28.7%		
Green	4.2%	3.4%		
Blue	1.2%	1.0%		
Hair color				
Brown	52.8%	32.0%	$\nu = 0.23^{++}$	< 0.001
Black	40.4%	63.9%		
Blonde	5.3%	3.4%		
Red	1.5%	0.7%		
Have you noticed any different spots on your body?				
Yes	23.5%	29.2%	$\phi = 0.06$	< 0.05
No	76.5%	70.8%		
Have you ever had a sunburn?				
Yes	52.8%	31.8%	$\phi = 0.21^{+}$	< 0.001
No	47.2%	68.2%		
Education degree				
Incomplete elementary education	4.3%	16.9%	$\nu = 0.26^{+++}$	< 0.001
Complete elementary education	4.7%	9.2%		
Incomplete high school	13.2%	17.6%		
Complete high school	52.9%	38.1%		
Graduated	24.9%	18.3%		

Effect size: + small, ++ intermediate, +++ large. "a", "b", "c" and "d" represents respectively the importance of value in the contingency table based on residual adjustment > 2 ("a" for the highest and "d" for the lowest value).

Source: Authors (2023).

regard to both sun exposure and its frequency, as illustrated in Table 2.

Table 2. Behavioral characteristics regarding sun care between groups.

	Group 1 (n = 599)	Group 2 (n = 415)	Effect Size	P
Sun exposure				
Recreation				
Yes	53.3%	10.4%	$\phi = 0.44^{++}$	< 0.001
No	46.7%	89.6%		
Work				
Yes	4.8%	93.5%	$\phi = 0.89^{+++}$	< 0.001
No	95.2%	6.5%		
Others				
Yes	43.6%	4.1%	$\phi = 0.43^{++}$	< 0.001
No	56.4%	95.9%		
Frequency of sun exposure				
Rare	27.9%	10.6%	$\nu = 0.48^{+++}$	< 0.001
Possibly	47.9%	16.6%		
Daily	24.2%	72.8%		
Sun exposure time				
Between 8 e 10 am or after 4 pm	41.9%	34.0% ^c	$\nu = 0.27^{++}$	< 0.001
Between 10 am and 4 pm	37.6%	21.0% ^b		
At all times	20.5%	45.1% ^a		
Frequency of using sunscreen				
Never	28.9%	53.0%	$\nu = 0.24^{++}$	< 0.001
Sometimes	49.7%	31.6%		
Daily	21.4%	15.4%		
Frequency of use of accessories				
Hat Cap				
Never	61.9%	50.6%	$\nu = 0.30^{++}$	< 0.001
Sometimes	31.9%	21.2%		
Daily	6.2%	28.2%		
Long sleeve t-shirts				
Never	45.7%	33.0%	$\nu = 0.23^{++}$	< 0.001
Sometimes	44.9%	41.0%		
Daily	9.3%	26.0%		
Sunglasses				
Never	42.2%	54.0%	$\nu = 0.12^{+}$	< 0.01
Sometimes	42.1%	32.0%		
Daily	15.7%	14.0%		
Sunshade				
Never	41.7%	58.6%	$\nu = 0.17^{+}$	< 0.001
Sometimes	44.1%	29.6%		
Daily	14.2%	11.8%		

it continues

With regard to the duration of sun exposure, the most notable differences were observed “at all times,” with group 2 exhibiting a high prevalence (45.1%), and between “10 am and 4 pm,” group 1 demonstrated a higher prevalence (37.6%) (Table 2). Furthermore, as illustrated in the table, the majority of individuals in Group 1 rarely utilize sunscreen (49.7%) and a cap or

hat (31.9%), whereas in group 2, 53.0% of respondents never use sunscreen. However, when it comes to protecting themselves with a cap or hat, the majority of them use it daily (28.2%). With regard to the use of long-sleeved t-shirts, notable discrepancies were observed between the categories “daily” and “never.” Group 2 exhibited a proclivity for daily use, whereas Group

Table 2. Behavioral characteristics regarding sun care between groups.

	Group 1 (n = 599)	Group 2 (n = 415)	Effect Size	P
Sources of information about skin cancer				
Internet				
Yes	56.3%	41.9%	<i>phi</i> = 0.14 ⁺	< 0.01
No	43.7%	58.1%		
Television				
Yes	29.7%	48.7%	<i>phi</i> = 0.19 ⁺	< 0.01
No	70.3%	51.3%		
Newspaper				
Yes	9.5%	11.3%	<i>phi</i> = 0.03	0.35
No	90.5%	88.7%		
Doctors				
Yes	12.4%	10.4%	<i>phi</i> = 0.03	0.33
No	87.6%	89.6%		
School				
Yes	9.7%	9.2%	<i>phi</i> = 0.06	0.07
No	90.3%	93.5%		
Family				
Yes	8.7%	6.5%	<i>phi</i> = 0.01	0.79
No	91.3%	90.8%		
Others				
Yes	10.5%	8.4%	<i>phi</i> = 0.03	0.27
No	89.5%	91.6%		

Effect size: + small, ++ intermediate, +++ large. "a", "b", "c" and "d" represents respectively the importance of value in the contingency table based on residual adjustment > 2 ("a" for the highest and "d" for the lowest value).

Source: Authors (2023).

1 never uses them, as evidenced in Table 2. As evidenced in the aforementioned table, the behavior related to the period of sun exposure, the use of sunscreen, caps/hats, and the use of long-sleeved t-shirts exhibited a medium effect size, with $p < 0.001$.

When observing the frequency of use of sunglasses and parasols, still in Table 3, it is possible to notice that group 1 sometimes uses sunglasses and parasols and, on the other hand, group 2 never uses sunglasses/umbrella. Despite the differences $p < 0.01$ (sunglasses) and $p < 0.001$ (umbrella), such habits had a small effect size.

Regarding the primary sources of information about skin cancer (Table 2), it was determined that the most utilized sources are the internet and television. Among group 1, the majority (56.3%) reported the internet as their primary source of information about skin cancer. As evidenced by the data presented in this table, the effect size of these items was found to be statistically insignificant ($p < 0.01$).

When it comes to awareness of the ABCDE method as a means of detecting indications of

skin cancer, a minority of individuals in both groups demonstrated a lack of awareness and knowledge regarding its implementation. Nevertheless, group 1 exhibited a slight advantage (12.7%) in comparison to group 2 (6.5%). The majority of respondents in both groups (87.3% and 93.5%, respectively) were unable to provide information on the subject. The effect size between groups was considered small (0.10), with $p < 0.01$.

A sensitivity analysis of the combined samples was conducted to create a table displaying the importance classification for each predictor. All analyses conducted by the multilayer perceptron in the present study demonstrated an area under the curve (AUC) = 1, showing beyond clustering, the quality of the ranking. The rankings were rescaled into intervals between 0 and 1, thereby revealing that behavioral factors, such as the reason for sun exposure (work and leisure) and frequency of exposure, as well as social factors like level of education, were the most significant predictors among the others (Figure 1).

Table 3. Frequency of correct answers for each question in the questionnaire on adolescent students' knowledge about contraceptive methods, difference between the proportions of correct answers, and comparison between assessment times. Recife, 2023.

Question themes	T0	T1	T2	T3
	n (%)	n (%)	n (%)	n (%)
Meaning of double protection	47 (75.8)	58 (93.6)	59 (96.7)	53 (91.4)
How double protection works	36 (58.1)	58 (93.6)	57 (93.4)	54 (93.1)
What is needed to practice safe sex	39 (62.9)	57 (91.9)	56 (91.8)	52 (89.7)
Step-by-step instructions for using a female condom	44 (71.0)	57 (91.9)	55 (90.2)	53 (91.4)
Step-by-step instructions for using a male condom	42 (67.7)	53 (85.5)	52 (85.3)	47 (81.0)
Description of hormonal contraceptive pills	25 (40.3)	44 (71.0)	41 (67.2)	40 (69.0)
Action of minipills	25 (40.3)	49 (79.0)	47 (77.1)	42 (72.4)
How to use emergency contraception	38 (61.3)	58 (93.6)	56 (91.8)	54 (93.1)
Description of what an intrauterine device is	49 (79.0)	56 (90.3)	53 (86.9)	51 (87.9)
Use of a diaphragm	12 (19.4)	47 (75.8)	45 (73.8)	42 (72.4)
Description of contraceptive implants	29 (46.8)	43 (69.4)	40 (65.6)	39 (67.2)
Identification of behavioral methods	11 (17.7)	32 (51.6)	31 (50.8)	32 (55.2)
Surgical sterilization methods	44 (71.0)	53 (85.5)	53 (86.9)	48 (84.2)
Visual differentiation of contraceptive methods	49 (79.0)	54 (87.1)	53 (86.9)	51 (87.9)
Description of the symptothermal method	27 (43.5)	47 (77.1)	47 (77.1)	47 (81.0)

Question themes	T0 x T1		T0 x T2		T0 x T3	
	Δ%	p*	Δ%	p*	Δ%	p*
Meaning of double protection	+17.8	0.004	+20.9	< 0.001	+15.6	0.012
How double protection works	+35.5	< 0.001	+35.3	< 0.001	+35.0	< 0.001
What is needed to practice safe sex	+29.0	< 0.001	+28.9	< 0.001	+26.8	0.002
Step-by-step instructions for using a female condom	+20.9	0.004	+19.2	0.010	+20.4	0.004
Step-by-step instructions for using a male condom	+17.8	0.011	+17.6	0.016	+13.3	0.126
Description of hormonal contraceptive pills	+30.7	0.002	+26.9	0.006	+28.7	0.003
Action of minipills	+38.7	< 0.001	+36.8	< 0.001	+32.1	< 0.001
How to use emergency contraception	+32.3	< 0.001	+30.5	< 0.001	+31.8	< 0.001
Description of what an intrauterine device is	+11.3	0.089	+7.9	0.345	+8.9	0.225
Use of a diaphragm	+56.4	< 0.001	+54.4	< 0.001	+53.0	< 0.001
Description of contraceptive implants	+22.6	0.019	+18.8	0.039	+20.4	0.013
Identification of behavioral methods	+33.9	< 0.001	+33.1	< 0.001	+37.5	< 0.001
Surgical sterilization methods	+14.5	0.038	+15.9	0.018	+13.2	0.029
Visual differentiation of contraceptive methods	+8.1	0.225	+7.9	0.226	+8.9	0.133
Description of the symptothermal method	+33.6	< 0.001	+33.6	< 0.001	+37.5	< 0.001

Question themes	T1 x T2		T1 x T3		T2 x T3	
	Δ%	p*	Δ%	p*	Δ%	p*
Meaning of double protection	+3.1	0.157	-2.2	0.705	-5.3	0.179
How double protection works	-0.2	1.0	-0.5	1.0	-0.3	1.0
What is needed to practice safe sex	-0.1	1.0	-2.2	0.317	-2.1	0.317
Step-by-step instructions for using a female condom	-1.7	0.563	-0.5	1.0	+1.2	0.654
Step-by-step instructions for using a male condom	-0.2	1.0	-4.5	0.179	-4.3	0.317
Description of hormonal contraceptive pills	-3.8	0.157	-2.0	1.0	+1.8	0.763
Action of minipills	-1.9	0.563	-6.6	0.102	-4.7	0.083
How to use emergency contraception	-1.8	0.317	-0.5	0.317	+1.3	1.0
Description of what an intrauterine device is	-3.4	0.157	-2.4	0.157	+1.0	1.0
Use of a diaphragm	-2.0	0.317	-3.4	0.179	-1.4	0.317
Description of contraceptive implants	-3.8	0.157	-2.2	0.654	+1.6	0.563
Identification of behavioral methods	-0.8	1.0	+3.6	0.317	+4.4	0.317
Surgical sterilization methods	+1.4	0.317	-1.3	1.0	-2.7	0.563
Visual differentiation of contraceptive methods	-0.2	1.0	+0.8	0.317	+1.0	0.317
Description of the symptothermal method	0	1.0	+3.9	0.317	+3.9	0.317

T0: pre-test; T1: immediate post-test; T2: 7-day post-test; T3: 15-day post-test; Δ% = proportion difference; *P-value of McNemar test.

Source: Authors.

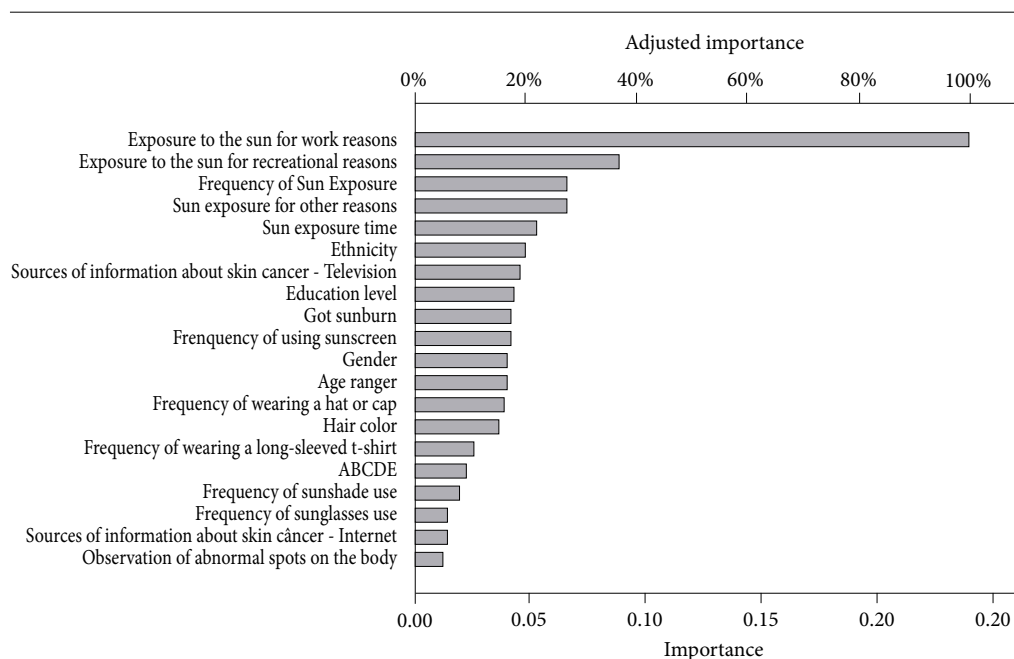


Figure 1. Classification of importance of quantitative variables rescaled into intervals between 0 and 1 showing the degree of importance (from highest to lowest).

Source: Authors (2023).

Discussion

Two profiles of individuals in the Amazon region were outlined based on their biological, social, and behavioral characteristics that are associated with the development of skin cancer. These groups presented two complex sun exposure patterns, both with characteristics that represent significant risks of skin cancer. Those who engage in recreational sun exposure tend to be individuals with higher purchasing power, who engage in sports activities and outdoor tourism. In contrast, the second group is exposed due to occupational activities such as construction, agriculture, and fishing, which entail prolonged sun exposure during the course of their daily work.

These patterns are frequently linked to ethnic disparities and socioeconomic challenges. Furthermore, the North region is distinguished by its high incidence of ultraviolet radiation and a deficiency in public health funding and personnel, which are crucial elements in elucidating the demographic consequences^{10,21}. An additional factor of great relevance that contributes to the incidence of cancer is the economic activity of the region, which is closely linked to its natural resources. The primary economic

activities in the region include agriculture, livestock production, mineral extraction, and tourism. Such activities frequently expose workers and individuals engaged in leisure activities to prolonged periods of sun exposure, often without the necessary protection²².

The first group is composed of younger Caucasian individuals with a lower prevalence of pigmented spots on their skin. These individuals are more susceptible to sunburns due to their prolonged exposure to solar radiation during a period of heightened risk, specifically between 10 a.m. and 4 p.m., when solar intensity is at its peak. This profile aligns with the observed changes in recent decades, including an increase in outdoor activities and sunbathing habits, both natural and artificial, which have been linked to an elevated risk of developing skin cancer²³. In white people, intense early sunburn and blistering sunburn have been identified as risk factors for the development of melanoma²⁴.

This behavior is similar to what was found in the Federal District and São Paulo, where over 50% of university students opt to sunbathe between 10 am and 4 pm. They relate this habit to carrying out social activities and practicing outdoor sports, aiming to enjoy the day more^{7,25}.

Although the use of tanning beds, based on the emission of ultraviolet radiation, has not been permitted in Brazil since 2009²⁶, their use for aesthetic purposes remains popular, particularly among women²⁷. However, it comes with a significant risk of skin cancer, including a 6-fold increase in melanoma risk for those under 25 and exposure to UV-A doses 12 times higher than natural sunlight²⁸.

A study of Irish students found that over 33% believed they looked healthier with a tan, while 64% felt more attractive and 56% felt better about themselves²⁹. This highlights how tanning is still a preponderant factor among young people, thereby increasing the risk for the development of skin cancer, especially the incidence of melanoma in younger women²⁸.

In contrast, group 2, consisting of individuals aged 31-50 with darker skin and more spots. Besides the higher exposure to the sun, this group has a lower risk of developing cancer due to their skin characteristics³⁰. Although people with brown or black skin have a lower risk of skin cancer, they often face higher morbidity and mortality due to delayed diagnosis³¹. This is attributable to factors such as the difficulty in recognizing suspicious lesions in darker skin, the development of lesions in non-exposed areas, and the late diagnosis resulting from a lack of knowledge³².

Moreover, epidemiological research on patients with skin cancer indicates that the likelihood of developing the disease is higher in older individuals due to prolonged and intermittent sun exposure, resulting in a cumulative impact of solar radiation³³. The vulnerability in these people is further exacerbated by their weaker immune system and reduced DNA repair capacity, which makes them more susceptible to the condition and delays the recognition of cancerous cells within their bodies³⁴.

Additional factors associated with the aging process, such as actinic keratoses, decreased visual acuity, and an increased number of nevi (moles), impede the ability of these patients to identify changes in their skin, resulting in delayed medical attention and an early diagnosis³⁵. Consequently, the process of aging represents a significant risk factor for group 2, which is predominantly typified by older individuals.

With regard to occupational hazards, individuals in group 2 are subjected to constant exposure to solar radiation as a consequence of the nature of their work environment. Consequently, they are more vulnerable to the carcinogenic effects of ultraviolet radiation and are classified

as occupational cancer victims, given the established link between their profession and the disease's development³⁶. Individuals engaged in outdoor occupations are subjected to a considerably higher level of ultraviolet radiation than that recommended by experts, with exposure levels reaching six to eight times those experienced by individuals engaged in indoor work³⁷. Moreover, these types of workers are associated with an increased prevalence of high-risk neoplasms³⁸.

Professions such as bricklaying, farming, livestock farming, fishing, mining, military service, and gardening are among those with the highest risk of developing non-melanoma skin cancer³⁹. However, it is challenging for these professionals to protect themselves from the sun due to the potential for sunscreen formulations to cause sweating, which is inconvenient for them. Additionally, they must reapply sunscreen every two hours, which requires maintaining hygiene of the skin, which is often difficult to do in their work environment. It is important to note that there is currently no legislation requiring the use of sunscreen, which may contribute to a reduction in its usage⁴⁰.

The findings of the study indicate a correlation between sun exposure frequency and socioeconomic factors. Group 2, which exhibited lower levels of education and potentially less access to healthcare, demonstrated a higher risk of mortality⁴¹.

The study indicated that group 1 demonstrated a greater awareness of the use of sunscreen as a photoprotective measure. The concern about protecting oneself is also related to social issues, given that low knowledge about the harm caused by ultraviolet radiation can lead to inadequate sun exposure habits⁴².

An important tool against skin cancer is sunscreen⁴³, and the low daily adherence found in the study is worrying. Despite its importance, it is very common for people to not know how to use the product correctly and also because they underestimate the appearance of the disease on the skin⁴⁴.

In addition to the considerations already mentioned, further factors must be taken into account when developing sunscreens, including price, formula composition, and texture. It is often the case that these factors are not particularly appealing. Furthermore, it is essential to consider the heterogeneity of skin types and individual lifestyles when developing diverse formulations, thereby ensuring the creation of a product that is more suitable and more accessible to all⁴⁵.

It is therefore recommended that a broad-spectrum sunscreen with UVA and UVB filters and a sun protection factor (SPF) of at least 30 be used. Higher SPFs may be employed to compensate for underapplication⁴³.

Group 2 demonstrated a lack of sunscreen usage habits. However, they exhibited a higher frequency of headwear, cap, and long-sleeved shirt utilization, which is likely attributable to their daily occupational exposure to solar radiation. Group 1 demonstrated a greater propensity for utilizing a parasol. The deployment of physical barriers, in conjunction with sunscreen, can prove an efficacious strategy for the prevention and minimisation of UV-induced harm, particularly when coupled with clothing materials that offer photoprotection against UVA and UVB radiation⁴⁶.

Group 1 is more inclined to utilize the internet as a source of information in comparison to group 2. This behavior can be attributed to the higher levels of education and enhanced access to the internet. Nevertheless, the availability of reliable information can influence an individual's attitudes and outcomes regarding sun exposure.

It is therefore imperative to promote the implementation of more effective public policy incentives with the objective of disseminating information regarding the dangers of excessive sun exposure.

A city in Australia observed that two-thirds of its residents developed skin cancer by the age of 70. In response to this situation, a program was developed to promote the use of sunscreen, hats, sunglasses, and seeking shade as methods of protecting oneself from the sun's ultraviolet radiation. The campaign was efficacious, preventing an estimated 50,000 cancers and 1,400 deaths⁴⁷. In the same country, three episodes about melanoma and sun protection were broadcast on television over a two-year period. Following the broadcast of the programs, there was a 167% increase in the number of diagnoses of melanoma in the subsequent three-month period²⁸.

During the evaluation process, the participants' familiarity with the ABCDE method was taken into account. The majority of participants in both groups indicated that they were not familiar with the method. The ABCDE mnemonic is a vital instrument in identifying the clinical morphology of melanoma⁴⁸. It can facilitate the early detection of spots or moles, particularly when there is no alternative screening test other

than a skin examination by a qualified professional⁴⁹.

A survey conducted in Turkey revealed that educational materials, such as posters and pamphlets, were effective in reducing the number of students who were unfamiliar with the ABCDE method⁵⁰. This rule should be disseminated widely among the general population, given that approximately 64% of melanomas are detected by patients themselves or by their friends or family members^{51,52}.

The study was subject to certain limitations, particularly with regard to the diversity of participants, who were largely concentrated in the state of Pará due to the ease of data collection. As a cross-sectional study, the sample was monitored only during the research period. However, it is noteworthy that the research yielded positive results in evaluating the biological, social, and behavioral patterns of the population in the Amazonian municipalities. This resulted in the identification of distinct profiles, thereby facilitating the implementation of more targeted prevention strategies tailored to the specific needs of these groups.

In this regard, these nuances must be taken into account when developing effective public primary care policies. Such measures may include the implementation of educational campaigns directed at specific demographic groups, the establishment of screening and prevention programs tailored to diverse socioeconomic and ethnic contexts, and the formulation of occupational health policies that encourage the use of sun protection equipment and promote workplace safety measures^{53,54}.

The use of social media platforms such as Instagram and other forms of digital advertising represents an effective strategy for reaching these groups in a targeted and impactful manner. The integration of detailed information on sun exposure patterns and their socioeconomic contexts into public health policies can enhance their efficacy in mitigating the risks of skin cancer and improving the dermatological health of diverse target audiences^{55,56}.

It is of paramount importance to incentivize public health policies in the Amazon region, as this will contribute to reducing costs in an area that is characterized by a scarcity of human and financial resources⁵⁷. Investment in preventive health and adequate medical care not only enhances the quality of life of the local population but also reduces expenditure on complex treatments. This approach alleviates the financial

burden on health systems and fosters a more balanced and sustainable development trajectory⁵⁸.

It is anticipated that the study will furnish health professionals with invaluable data in a region where research is scarce. Nevertheless, further insight could be gained through longitudinal studies of population behavior and skin cancer prevention needs. It is the intention of the study to provide further insight into this under-researched topic in a region situated close to the equator, where solar radiation is more intense.

Conclusion

In conclusion, the research demonstrated that behavioral elements, including the rationale, frequency, and timing of sun exposure, in conjunction with the social factor of educational attainment, were the principal predictors of an elevated susceptibility to skin cancer in municipalities located in the Amazonian region. This study makes a notable contribution to the field by providing an initial analysis of the correlation between the behavioral and social patterns of the local population and the incidence of skin cancer.

Collaborations

Article conception and design: FN Valentin, and D Lucianelli Junior. Data collection, analysis, and interpretation, and article writing: TO Brito, RC Costa, R Silveira, JVB Pinheiro, and ALG Moura. Interpretation, writing, and critical review: FNV Lucianelli, R Silveira, and D Lucianelli Junior. Final review of writing, formatting, and translation: MCF Paes.

Data availability statement

The data sources adopted in the research are indicated in the article's body.

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