Prevalence of Exposure to Solar Radiation Among Workers in Brazil: Support for Actions to Prevent Work-Related Skin Cancer

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Prevalência da Exposição à Radiação Solar em Trabalhadores no Brasil: Subsídios para Ações de Prevenção do Câncer de Pele Relacionado ao Trabalho

Prevalencia de Exposición a la Radiación Solar en Trabajadores en el Brasil: Aportes para Acciones de Prevención del Cancer de Piel Relacionado con el Trabajo

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ABSTRACT

Introduction: In Brazil, there is little information about the prevalence of occupational exposure to solar radiation, the main risk factor for non-melanoma skin cancer, the most common neoplasm in the country. **Objective:** To calculate the prevalence of exposure to solar radiation and its associated factors in the Brazilian employed population. **Method:** Cross-sectional study, with data from the 2019 National Health Survey. Expanded prevalence and respective 95% confidence intervals (95% CI) for exposure to solar radiation were calculated, according to demographic, socioeconomic, geographic and occupational variables. Multiple logistic regression analysis, stratified by sex, was used to identify the determinants of exposure to solar radiation. The complex sampling design was considered. **Results:** 88,904,261 workers were evaluated, 23.5% of whom were exposed to solar radiation. Thirty-six percent of men (36.5%; 95%CI 37.0; 39.3) and 7.9% (95%CI 6.0; 7.2) of women were exposed to solar radiation. The economic sectors of agriculture, construction, water, sewage and material waste management activities had the highest percentages of workers occupationally exposed to the sun. The chance of exposure to solar radiation was greater among Black males, with low education level and income, residents of rural areas, in informal jobs and who worked more than 40h/week. **Conclusion:** The prevalence of exposure to solar radiation in Brazilian workers is high and unequally distributed by sex and economic sectors. Actions to prevent this exposure in work environments must prioritize the most exposed groups of workers, considering economic activities and their demographic, socioeconomic, geographic and occupational determinants.

Key words: Occupational Health; Health Surveys; Solar Radiation; Occupational Exposure.

RESUMO

Introdução: No Brasil, há pouca informação sobre a prevalência de exposição ocupacional à radiação solar, principal fator de risco para a neoplasia mais frequente no país, o câncer de pele não melanoma. **Objetivo:** Calcular a prevalência da exposição à radiação solar e de fatores associados na população ocupada brasileira. **Método:** Estudo transversal, com dados da Pesquisa Nacional de Saúde de 2019. Calcularam-se as prevalências expandidas e respectivos intervalos de confiança de 95% (IC 95%) para a exposição à radiação solar, segundo as variáveis demográficas, socioeconômicas, geográficas e ocupacionais. Utilizou-se análise de regressão logística múltipla, estratificada por sexo, para identificar os determinantes da exposição à radiação solar. Considerou-se o desenho complexo da amostragem. **Resultados:** Foram avaliados 88.904.261 trabalhadores, sendo 23,5% expostos à radiação solar. Trinta e seis por cento dos homens (36,5%; IC 95% 37,0; 39,3) e 7,9% (IC 95% 6,0; 7,2) das mulheres estavam expostos à radiação solar. Os setores econômicos da agricultura, construção, água, esgoto e atividades de gestão de resíduos de materiais apresentaram os maiores percentuais de exposição. A chance de exposição à radiação solar foi maior entre o sexo masculino, os pardos, com baixo nível de escolaridade e renda, residentes da área rural, com vínculo trabalhista informal e que trabalharam acima de 40h/semana. **Conclusão:** A prevalência da exposição à radiação solar nos trabalhadores brasileiros é elevada e desigualmente distribuída por sexo e setores econômicos. Ações de prevenção nos ambientes laborais devem priorizar os grupos de trabalhadores mais expostos, considerando as atividades econômicas e seus determinantes demográficos, socioeconômicos, geográficos e ocupacionais.

Palavras-chave: Saúde Ocupacional; Inquéritos Epidemiológicos; Radiação Solar; Exposição Ocupacional.

RESUMEN

Introducción: En el Brasil hay poca información sobre la prevalencia de la exposición ocupacional a la radiación solar, principal factor de riesgo para el cáncer de piel, la neoplasia más común del país. **Objetivo:** Calcular la prevalencia de exposición a la radiación solar y factores asociados en los trabajadores brasileños. **Método:** Estudio transversal con datos de la Encuesta Nacional de Salud de 2019. Se calcularon las prevalencias expandidas y los respectivos intervalos de confianza del 95% (IC 95%) para la exposición a la radiación solar, según variables socioeconómicas, geográficas y ocupacionales. Se utilizó un análisis de regresión logística múltiple, estratificado por sexo, para identificar los determinantes de la exposición a la radiación solar. Se consideró el diseño de muestreo complejo. **Resultados:** Se evaluaron 88 904 261 trabajadores, de los cuales el 23,5% estuvo expuesto a la radiación solar. Treinta y seis por ciento de los hombres (IC 95%: 37,0-39,3) y el 7,9% de las mujeres (IC 95%: 6,0-7,2%) estuvieron expuestos a la radiación solar. Los sectores económicos de agricultura, construcción, agua, alcantarillado y actividades de gestión de residuos de materiales presentaron los mayores porcentajes de exposición. La probabilidad de exposición a la radiación solar fue más alta entre los hombres, los mestizos, de bajo nivel de educación e ingresos, los residentes de zonas rurales, las que tenían un trabajo informal y las que trabajaron más de 40h/semana. **Conclusión:** La prevalencia de exposición a la radiación solar en los trabajadores brasileños es alta y desigualmente distribuida por género y sectores económicos. Acciones para prevenir esta exposición en los entornos laborales deben priorizar los grupos de trabajadores más expuestos, considerando las actividades económicas y sus determinantes demográficos, socioeconómicos, geográficos y ocupacionales.

Palabras clave: Salud Laboral; Encuestas Epidemiológicas; Radiación Solar; Exposición Ocupacional.

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INTRODUCTION

The International Agency for Research on Cancer (Iarc)[1] determined solar radiation as a group 1 carcinogenic agent for melanoma and non-melanoma skin cancer and probable carcinogenic (group 2) for lip and eye cancer.

In Brazil, non-melanoma skin cancer is the most frequent neoplasm with preview of 220,490 new cases annually between 2023 and 2025, accounting for 32% of all new cases of cancer per year[2]. Despite being avoidable, of low lethality and highly curable, if not detected early, can cause suffering and anguish to the individual and family and a burden to health systems. In 2010, costs of skin cancer diagnostic and treatment in Brazil reached nearly R$ 37 million and R$ 26 million for the public and health system respectively[3].

Skin cancer prevention occurs by elimination or reduction of solar radiation through sun blockers and physical barriers as wide brim hats, ultraviolet A and B (UVA/UVB) protective glasses and clothing[4]. If exposure is occupational, prevention is a limitation because occupation is the main determinant of time and intensity of solar radiation exposure.

Protection depends on the ability of the employer of creating artificial shadow, workload breaks and work shift rescheduling. The worker should find, if possible, natural shadowed places and individual protection, influenced by education level, age, duration of the work shift and inspection by the employer[5].

International studies showed that outdoor labourers working in agriculture, civil construction, gardening, courier and door-to-door distributors, physical activities coach and children caretakers are the most exposed[6,7], receiving at least two to three times more UVA/UVB radiation dose than indoor labourers[8].

In addition to cancer, cataract, skin early ageing, persistent pigmentation, actinic keratosis and immunosuppressors effects increase the risk of allergic reactions and opportunistic infections[5,9].

According to the International Labour Organization (ILO), 1.6 billion workers were exposed to solar radiation in 2019, accounting for 28.4% of the economically active population[10].

There is scarce information in Brazil about the prevalence of occupational exposure to solar radiation. In a previous study with 44,428 labourers, 38.1% of the men and 6.6% of the women were occupationally exposed to solar radiation in 2019[11]. Continuing with these studies, the objective of this study is to evaluate the populational prevalence of occupational exposure to solar radiation and identify the associated factors.

METHOD

Cross-sectional study with data obtained from the 2019 National Health Research (PNS), a household-based nation-wide investigation conducted by "*Instituto Brasileiro de Geografia e Estatística (IBGE)*" in partnership with the Ministry of Health. PNS microdata are available at IBGE website for free access.

PNS is part of IBGE household-based integrated research system utilizing a subsample of IBGE[12] master sample with the same stratification of the primary selection units (UPA) formed by one or more census tracts. The sample by conglomerates was obtained in three stages. In the first, UPA was selected for each stratum, in the second, for each UPA a fixed number of domiciles was randomly selected and in the third, one resident aged 15 years or more was selected randomly in each domicile to respond to the questionnaire. The population living in special census tracts as indigenous villages, barracks, military bases and lodgings was excluded.

90,846 residents participated of PNS, the non-response rate was 6.4%[13]. Calibration to forecast the population was utilized in the present article and absolute figures presented in the text refer to population size. Further details about the research, sampling process and data weighting are available in previous publications[14].

The study population was obtained from a sample representative of the population employed aged 18 years or more at the reference week to collect the data (July 21 to 27 2019), corresponding to 52,582 Brazilian individuals.

The occupation was determined by the function performed by the individual in his/her main work, defined as the function with more hours or high month income or highest work load.

The exposure to solar radiation at work was evaluated by the question: "Are you exposed to any of these factors at your job(s) that can affect your health as long-term sun exposure?" (Yes/No).

- Sociodemographic and economic: sex (male/female), age (18-29 years, 30-39, 40-59 and 60 or more), skin color (White, Brown and Black), education level given by the highest grade completed (illiterate or incomplete elementary, complete elementary, complete high school, complete university), per capita income: less than one minimum wage (MW), between one and two MWs and two MWs.
- Residence: rural or urban area, macroregion (North, Northeast, South, Southeast and Midwest) and federative units.

- Type of job: employment relationship (formal/informal), work environment (indoor, outdoor and mixed), work shift (up to 40h/week/more than 40h/week).
- Economic activity of the main job according to the Household CNAE 2.0[15] per activity (agriculture, livestock, forest, fishing and aquaculture production; extractive industries; transformation industries; power and gas; water, sewage, waste management; construction; commerce, maintenance of vehicles and motorcycles; transportation, storage and courier services; lodging and feeding; information and communication; financial, insurance and related services activities; real estates; professional, scientific and technical activities; administrative and complementary services activities; public administration, defense and social security; education; human health and social services; arts, culture, sport and recreation; other activities and household services.

The prevalence of long solar radiation exposure at work was estimated according to the sociodemographic and economic variables, residence location and characteristics of the job. Confidence intervals (CI) and Pearson's chi-square test were calculated at level of confidence of 5%. For Federative Units and economic activities according to the National Classification of Economic Activities (CNAE), the prevalence was estimated by sex.

Bivariate and multivariate regression analyzes stratified by sex were performed, considering long solar radiation exposure at work (yes/no) as independent variable and as response variables, age-range, skin color, education, per capita income, geographical area, macroregion, employment relationship, work environment and work shift. The software SPSS[16] version 21.0 was utilized for all the statistical analyzes with level of significance of 5% ($p \leq 0.05$) due to the complexity of the sample design.

The review by the Institutional Review Board was waived because only deidentified secondary data were utilized in compliance with Directive 510 of 2016[17] of the National Health Council (CNS).

RESULTS

In 2019, approximately 23 million workers were occupationally exposed to solar radiation, corresponding to 23.5% of the employed Brazilian workers (Table 1). High percent of exposure to solar radiation were found in 40-59 years old (25.7%) males (36.1%), Brown race (27.1%), illiterate or incomplete elementary school (40.8%), per capita income of one minimum wage (31.2%), living in rural area (54.1%), at the North (27.9%) and Northeast (30.1%) regions with informal job (22.9%), work shift over 40/h week (25.2%) and outdoor work (59.7%).

Table 2 presents the prevalence of solar radiation exposure per federative unit. High prevalence were found in the State of Bahia (34.2%) and low at *Distrito Federal* (13.9%).

Table 3 portrays the percent distribution of solar radiation in economic sectors stratified by sex. For all sectors, men were more exposed than women; for both sexes, farming and related activities presented highest percent of exposure, 81.0% for men and 60.3% for females. Construction (67.1%), power and gas (58.5%), water, sewage and management of residual wastes (59.1%) were more prevalent in men. For females, the following sectors stood out: a) water, sewage and management of residual wastes (50.4%), b) transportation, storage and mail (26.4%), c) and extractive industries (13.8%).

Table 4 shows the bivariate analysis of solar radiation exposure and demographic, socioeconomic, geographic and occupational variables. Solar radiation exposure was positively associated with both sexes, low age-ranges, low education and income, living in rural areas and outdoor and mixed (indoor/outdoor) working environments.

The multiple logistic regression model stratified by sex (Table 5) demonstrated that the odds of exposure to solar radiation in men was high among those with low education level (odds ratio – OR: 2.157; CI 95% 1.532-3036), living in rural area (OR: 1.782; CI 95% 1.490-2.130), in the Northeast (OR: 1.474; CI 95% 1.182-1.839) and Southeast (OR: 1.760; CI 95% 1.374-2.254) regions with informal labor (OR: 1.627; CI 95% 1.370-1.933), working outdoor (OR: 23.540; CI 95% 16.531-33.521) and mixed (indoor/outdoor) (OR: 10.567; CI 95% 7.180-15.554) environment. For women, the odds of solar radiation exposure occurred in the age range of 30-49 years old (OR: 1.526; CI 95% 1.024-2.272), complete high-school (OR: 1.716; CI 95% 1.255-2.347), living in rural areas (OR: 1.716; CI 95% 1.255-2.347), in the Northeast (OR: 2.45; CI 95% 1.662-3.481) and Southeast (OR: 1.598; CI 95% 1.082-2.361) regions, and working outdoor (OR: 40.815; CI 95% 28.815-58.419) and (indoor/outdoor) (OR: 12.487; CI 95% 8.863-17.593) environment.

DISCUSSION

Nearly one quart – 23 million labourers in 2019 – of the Brazilian workers were occupationally exposed to solar radiation. The national prevalence was slightly lower than

Table 1. Prevalence of long-term solar radiation exposure according to demographic, socioeconomic, geographical and occupational variables. Brazil, PNS-2019

Variables		Total number of workers (n = 97,485,182)	Solar radiation %	CI 95%	*p**
Total		**22,894,308**	**23.5**	**22.8-24.2**	**-**
Sex	Male	19,482,625	36.1	34.9-37.1	<0.001
	Female	3,411,683	7.9	7.2-8.6	
Age range (years)	18 to 29	4,604,846	20.4	19.0-21.9	<0.001
	30 to 39	6,006,336	22.8	21.7-24.0	
	40 to 59	10,268,887	25.7	24.6-26.8	
	≥ 60	2,014,239	23.5	21.7-25.4	
Skin color	White	8,313,088	19.3	18.3-20.4	<0.001
	Brown	11,241,437	27.1	26.1-28.0	
	Black	3,049,030	26.3	24.3-28.4	
Education	Illiterate or incomplete education	10,181,045	40.8	39.4-42.1	<0.001
	Complete elementary	3,980,957	28.1	26.1-30.2	
	Complete high-school	6,997,876	18.2	17.1-19.3	
	Complete university	1,734,430	8.7	7.7-9.9	
Per capita income	< 1 MW	6.591,584	31.2	29.8-32.6	<0.001
	Between 1 and 2 MW	9,397,546	22.2	21.1-23.4	
	> 2 MW	6,336,144	19.4	18.3-20.5	
Geographic area	Urban	16,402,309	19.2	18.4-20.0	<0.001
	Rural	6,491,999	54.1	52.3-55.8	
Macroregion	North	2,091,721	27.9	26.4-29.6	<0.001
	Northeast	6,986,300	30.1	28.9-31.2	
	Southeast	9,039,810	20.6	19.3-22.0	
	South	3,052,224	20.3	19.0-21.7	
	Midwest	1,413,936	21.6	19.7-23.6	
Type of job	Formal	6,865,078	15.9	14.7-17.0	<0.001
	Informal	4,507,341	22.9	21.4-24.4	
Work environment	Indoor	1,601,644	3.0	2.5-3.6	<0.001
	Outdoor	14,969,280	59.7	58.3-61.2	
	Mixed	6,323,384	32.4	30.8-34.0	
Work shift	≤ 40h	12,780,951	22.3	21.5-23.1	<0.001
	> 40h	10,113,357	25.2	24.1-26.4	

Caption: CI (95%) = confidence interval 95%; MW = minimum wage; * = *p* Pearson's chi-square test.

the world's (28.4%) for the same year, equivalent to 1.6 billion workers globally exposed[10]. Nearly 14.5 million workers of the European Union are exposed to solar radiation in at least 75% of their workload and men are the most exposed[18].

Comparing the current data with other countries, the prevalence of the occupational exposure to solar radiation was higher than in Canada (8.8% of the workers exposed to solar radiation)[6] and in European countries as Hungary, Romania and Slovakia (13%)[19]. According to Bernadelli[20], Latin American and Caribbean countries can present higher numbers of workers exposed to solar radiation due to the high incidence of solar rays in these countries, especially those at Equator line.

Table 2. Prevalence of long-term solar radiation at work according to the economic activity of the main work per sex. Brazil, PNS-2019

Economic activity	Workers total	Long-term solar radiation exposure at work								
		Total			Men			Women		
		N	%	CI 95%	N	%	CI 95%	N	%	CI 95%
Agriculture, livestock, forest, fishing and aquaculture	9,398,137	7,245,279	77.1	75.3-78.8	6,162,279	81.0	79.2-82.8	1,083,000	60.3	56.1-64.5
Construction	7,206,667	4,665,711	64.7	61.7-67.7	4,638,303	67.1	64.1-69.9	27,407	9.4	3.9-20.9
Water, sewage, waste material management	647,833	363,903	56.2	43.5-68.1	253,726	59.1	47.0-70.2	110,177	50.4	21.9-78.7
Power and gas	186,312	83,273	44.7	29.7-60.7	81,987	58.5	41.1-74.0	1,286	2.8	0.6-12.4
Transportation, storage and courier services	4,734,000	1,737,150	36.7	33.5-40.0	1,611,399	37.8	34.5-41.3	125,751	26.4	15.7-40.9
Extractive industries	501,563	178,762	35.6	25.2-47.7	171,667	38.2	26.8-51.1	7,095	13.6	2.5-48.5
Public administration, defense and social security	5,498,766	1,331,931	24.2	21.7-27.0	1,040,716	30.8	27.2-34.6	291,215	13.8	10.8-17.3
Complementary administrative and services	4,056,801	901,823	22.2	19.2-25.6	759,628	29.4	25.2-33.9	142,195	9.7	6.5-14.2
Real estate	698,392	137,772	19.7	11.6-31.6	105,064	25.7	14.0-42.9	32,709	11.3	3.9-28.5
Commerce, servicing of cars and motorcycles	17,569,954	2,615,241	14.9	13.5-16.3	2,019,975	21.1	19.1-23.4	595,265	7.4	6.1-9.0
Information and communication	1,322,425	195,434	14.8	7.6-26.7	188,712	18.6	9.5-33.0	6,722	2.2	0.5-8.5
Arts, culture, sport and recreation	1,091,380	143,859	13.2	9.3-18.4	94,190	14.1	9.4-20.7	49,669	11.7	6.0-21.8
Transformation industry	11,165,716	1,269,971	11.4	10.0-12.9	1,132,899	16.3	14.3-18.6	137,073	3.3	2.4-4.5
Professional, scientific and technical activities	3,176,320	274,493	8.6	6.4-11.6	200,024	11.7	8.3-16.1	74,469	5.1	2.6-9.8
Lodging and food	5,731,799	389,447	6.8	5.6-8.2	263,782	11.2	8.7-14.2	125,665	3.7	2.9-4.9
Human and social services	4,914,215	328,238	6.7	5.3-8.4	122,980	9.3	6.1-14.0	205,258	5.7	4.4-7.5
Other services	4,036,851	253,613	6.3	4.8-8.2	171,552	11.7	7.9-17.0	82,061	3.2	2.1-4.9
Household	7,465,446	436,903	5.9	4.8-7.1	259,521	49.9	40.4-59.4	177,382	2.6	1.9-3.5
Education	6,796,406	295,145	4.3	3.4-5.5	166,088	9.3	7.0-12.3	129,056	2.6	1.8-3.8
Financial, insurance and related services	1,273,513	46,361	3.6	1.7-7.4	38,132	6.4	2.7-14.3	8,229	1.2	0.4-3.3

Caption: CI 95% = confidence interval 95%.

Table 3. Prevalence of exposure to long-term solar radiation at work according to federative unit per sex. Brazil, PNS-2019

Federative Units	Workers Total	Long-term solar radiation exposure at work								
		Total			Men			Women		
		N	%	CI 95%	N	%	CI 95%	N	%	CI 95%
Bahia	6,550,540	2,240,140	34.2	31.3-37.2	1,826,880	49.3	45.1-53.5	413,260	14.5	11.3-18.5
Acre	337,259	107,460	31.9	28.2-35.8	95,178	47.4	42.5-52.3	12,283	9.0	6.7-12.0
Sergipe	1,036,818	329,644	31.8	28.8-35.0	271,714	44.8	40.7-48.9	57,931	13.5	10.3-17.4
Tocantins	682,012	211,913	31.1	27.3-35.1	185,980	47.8	42.2-53.5	25,933	8.8	6.0-12.8
Piauí	1,427,150	444,284	31.1	27.6-34.8	369,225	45.0	40.1-49.9	75,058	12.4	9.3-16.3
Rondônia	816,124	244,731	30.0	26.9-33.3	211,546	44.3	39.8-48.8	33,185	9.8	7.0-13.6
Maranhão	2,552,138	754,635	29.6	27.2-32.0	645,014	43.9	40.8-47.1	109,621	10.1	8.0-12.6
Alagoas	1,118,564	330,292	29.5	26.7-32.6	268,519	43.1	38.7-47.6	61,773	12.5	9.5-16.2
Rio Grande do Norte	1,460,498	422,632	28.9	25.6-32.6	371,587	43.4	39.0-48.0	51,046	8.4	5.7-12.2
Pernambuco	3,814,299	1,090,844	28.6	26.1-31.3	898,833	40.6	37.3-44.1	192,011	12	9.2-15.4
Minas Gerais	10,454,721	2,963,810	28.3	25.8-31.1	2,543,718	44.0	40.1-47.9	420,091	9.0	6.9-11.6
Amazonas	1,623,984	448,866	27.6	24.9-30.6	356,437	36.2	32.5-40.0	92,430	14.5	11.6-17.9
Roraima	231,013	63,735	27.6	24.4-31.1	54,250	40.7	36.1-45.4	9,485	9.7	7.2-13.0
Pará	3,466,222	936,531	27.0	24.2-30.1	828,818	39.8	35.6-44.0	107,713	7.8	6.0-10.0
Ceará	3,697,208	966,232	26.1	23.8-28.6	827,278	39.2	35.8-42.8	138,954	8.8	6.7-11.3
Paraíba	1,581,732	407,598	25.8	22.3-29.6	359,582	39.4	34.5-44.6	48,016	7.2	4.8-10.5
Espírito Santo	1,991,018	504,553	25.3	22.6-28.3	412,670	37.8	33.9-41.8	91,884	10.2	8.2-12.7
Mato Grosso	1,694,427	424,963	25.1	21.1-29.5	377,456	39.2	33.5-45.2	47,507	6.5	4.6-9.1
Amapá	332,746	78,484	23.6	18.5-29.6	62,810	33.7	27.3-40.7	15,674	10.7	6.5-17.2
Goiás	3,321,094	775,860	23.4	20.6-26.4	692,726	36.2	31.8-10.8	83,133	5.9	4.0-8.7
Mato Grosso do Sul	1,350,106	310,316	23.0	20.5-25.7	270,719	36.3	32.3-40.4	39,597	6.6	4.9-8.8
Paraná	5,499,228	1,226,683	22.3	20.1-24.7	1,043,581	34.2	30.5-38.0	183,103	7.5	5.8-9.6
Rio Grande do Sul	5,902,041	1,258,496	21.3	19.1-23.7	1,056,286	33.4	29.7-37.2	202,210	7.4	5.7-9.6
São Paulo	23,557,346	4,318,375	18.3	16.2-20.7	3,710,855	29.3	26.0-32.8	607,519	5.6	3.9-8.0
Rio de Janeiro	7,850,345	1,253,073	16.0	14.3-17.8	1,094,700	26.4	23.6-29.4	158,373	4.3	3.2-5.7
Santa Catarina	3,604,655	567,045	15.7	13.8-17.9	473,218	23.6	20.6-26.8	93,826	5.9	4.3-8.0
Distrito Federal	1,531,894	213,114	13.9	11.6-16.6	173,046	21.6	18.0-25.7	40,069	5.5	3.6-8.2

Caption: CI 95% = confidence interval 95%.

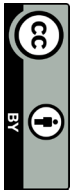


Table 4. Bivariate logistic regression to long-term solar radiation exposure at work according to demographic, socioeconomic, geographic and occupational variables. Brazil, PNS-2019

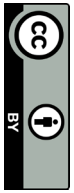
Variables		Total			Men			Women		
		OR	CI 95%	*p*	OR	CI 95%	*p*	OR	CI 95%	*p*
Age range (years)	18 to 29	1.000	-	-	1.000	-	-	1.000	-	-
	30 to 39	1.154	1.037 – 1.283	0.008	1.182	1.043 – 1.341	0.009	1.364	1.067 – 1.743	0.013
	40 to 59	1.345	1.209 – 1.497	<0.001	1.421	1.259 – 1.604	<0.001	1.608	1.266 – 2.041	<0.001
	≥ 60	1.196	1.044 – 1.370	0.010	1.148	0.985 – 1.338	0.078	1.244	0.860 – 1.800	0.247
Skin color	White	1.000	-	-	1.000	-	-	1.000	-	-
	Brown	1.546	1.425 – 1.678	<0.001	1.584	1.426 – 1.758	<0.001	1.373	1.154 – 1.633	<0.001
	Black	1.490	1.322 – 1.679	<0.001	1.645	1.431 – 1.890	<0.001	1.191	0.911 – 1.556	0.201
Education	Illiterate or incomplete elementary	7.173	6.219 – 8.275	<0.001	7.740	6.423 – 9.327	<0.001	3.683	2.854 – 4.752	<0.001
	Complete elementary	4.074	3.416 – 4.859	<0.001	4.138	3.319 – 5.160	<0.001	1.981	1.474 – 2.662	<0.001
	Complete high-school	2.316	1.996 – 2.688	<0.001	2.501	2.076 – 3.012	<0.001	1.393	1.079 – 1.798	0.011
	Complete university	1.000	-	-	1.000	-	-	1.000	-	-
Per capita income	< 1 MW	1.881	1.708 – 2.071	<0.001	3.380	3.009 – 3.797	<0.001	2.625	2.023 – 3.406	<0.001
	Between 1 and 2 MW	1.187	1.085 – 1.299	<0.001	1.481	1.343 – 1.633	<0.000	1.280	1.022 – 1.604	0.032
	> 2 MW	1.000	-	-	1.000	-	-	1.000	-	-
Geographic area	Urban	1.000	-	-	1.000	-	-	1.000	-	-
	Rural	4.960	4.543 – 5.415	<0.001	4.556	4.114 – 5.045	<0.001	5.685	4.749 – 6.806	<0.001
Macroregion	North	1.000	-	-	1.000	-	-	1.000	-	-
	Northeast	1.109	1.007 – 1.221	0.035	1.159	1.033 – 1.300	0.012	1.205	0.994 – 1.460	0.057
	Southeast	0.670	0.597 – 0.753	<0.001	0.722	0.630 – 0.826	<0.001	0.625	0.485 – 0.804	<0.001
	South	0.659	0.588 – 0.739	<0.001	0.675	0.588 – 0.775	<0.001	0.701	0.561 – 0.876	0.002
	Midwest	0.711	0.617 – 0.818	<0.001	0.757	0.643 – 0.891	0.001	0.584	0.438 – 0.777	<0.001
Type of job	Formal	1.000	-	-	1.000	-	-	1.000	-	-
	Informal	1.575	1.395 – 1.778	<0.001	2.394	2.078 – 2.757	<0.001	1.363	1.074 – 1.129	0.011
Work environment	Indoor	1.000	-	-	1.000	-	-	1.000	-	-
	Outdoor	47.538	38.887 – 58.113	<0.001	31.744	24.572 – 41.010	<0.001	51.453	39.067 – 67.766	<0.001
	Mixed	15.328	12.516 – 18.771	<0.001	11.588	9.003 – 14.916	<0.001	14.311	10.770 – 19.018	<0.001
Work shift	≤ 40h	1.000	-	-	1.000	-	-	1.000	-	-
	> 40h	1.175	1.094 – 1.262	<0.001	1.062	0.977 – 1.155	0.156	1.367	1.121 – 1.667	0.002

Captions: OR = odds ratio; CI (95%) = confidence interval 95%; MW = minimum wage.

Table 5. Multivariate logistic regression of long-term solar radiation exposure at work according to sociodemographic, socioeconomic, geographical and occupational variables. Brazil, PNS-2019

Variables		Total			Men			Women		
		OR	CI 95%	*p*	OR	CI 95%	*p*	OR	CI 95%	*p*
Age range (years)	18 to 29	1.000	-	-	1.000	-	-	1.000	-	-
	30 to 39	1.161	0.951 – 1.416	0.143	1.183	0.921 – 1.518	0.188	1.526	1.024 – 2.272	0.038
	40 to 59	0.974	0.801 – 1.183	0.787	1.071	0.844 – 1.360	0.571	1.170	0.808 – 1.695	0.406
	≥ 60	0.632	0.481 – 0.829	0.001	0.706	0.514 – 0.970	0.032	0.509	0.296 – 1.169	0.130
Skin cancer	White	1.000	-	-	1.000	-	-	1.000	-	-
	Brown	1.112	0.929 – 1.332	0.247	1.179	0.949 – 1.464	0.137	0.973	0.713 – 1.329	0.864
	Black	1.111	0.868 – 1.421	0.404	1.144	0.858 – 1.524	0.360	1.158	0.758 – 1.770	0.497
Education	Illiterate or incomplete elementary school	1.982	1.523 – 2.578	<0.001	2.157	1.532 – 3.036	<0.001	1.124	0.741 – 1.703	0.583
	Complete elementary school	1.675	1.229 – 2.284	0.001	1.698	1.143 – 2.523	0.009	1.094	0.773 – 1.547	0.613
	Complete high-school	1.325	1.006 – 1.746	0.045	1.420	0.990 – 2.038	0.057	1.716	1.255 – 2.347	0.001
	Complete university	1.000	-	-	1.000	-	-	1.000	-	-
Geographical area	Urban	1.000	-	-	1.000	-	-	1.000	-	-
	Rural	1.846	1.590 – 2.142	<0.001	1.782	1.490 – 2.130	<0.001	1.716	1.255 – 2.347	0.001
Macroregion	North	1.000	-	-	1.000	-	-	1.000	-	-
	Northeast	1.644	1.367 – 1.977	<0.001	1.474	1.182 – 1.839	0.001	2.405	1.662 – 3.481	<0.001
	Southeast	1.610	1.305 – 1.986	<0.001	1.760	1.374 – 2.254	<0.001	1.598	1.082 – 2.361	0.019
	South	1.249	0.980 – 1.592	0.072	1.241	0.930 – 1.655	0.142	1.445	0.912 – 2.292	0.117
	Midwest	1.238	0.978 – 1.566	0.076	1.208	0.927 – 1.574	0.161	1.609	0.990 – 2.614	0.055
Type of job	Formal	1.000	-	-	1.000	-	-	1.000	-	-
	Informal	1.063	0.916 – 1.233	0.419	1.627	1.370 – 1.933	<0.001	0.777	0.587 – 1.027	0.076
Work environment	Indoor	1.000	-	-	1.000	-	-	1.000	-	-
	Outdoor	38.067	28.968 – 50.024	<0.001	23.540	16.531 – 33.521	<0.001	40.815	28.515 – 58.419	<0.001
	Mixed	13.711	10.194 – 18.443	<0.001	10.567	7.180 – 15.554	<0.001	12.487	8.863 – 17.593	<0.001
Work shift	≤ 40h	1.000	-	-	1.000	-	-	1.000	-	-
	> 40h	1.149	1.013 – 1.303	0.003	1.062	0.916 – 1.230	0.426	0.619	0.469 – 0.835	0.002

Captions: OR = odds ratio; CI (95%) = confidence interval 95%.



In that same line, Azevedo and Silva et al.[21] estimated the prevalence of solar radiation exposure for the Brazilian population, considering only the environmental exposure (39.6%), which possibly justifies the results. There are other national publications about the prevalence of environmental solar radiation exposure in specific Brazilian regions. A populational investigation in the South region with 15 years old individuals or more revealed the prevalence of 77.1% of exposure to solar radiation for at least 30 minutes even if sporadically[22]. A cross-sectional study with older adults registered at the Basic Health Units (UBS) of the rural area of the city of Pelotas concluded that the prevalence of sun exposure was 34.9% in men and 11.9% in women for more than 7h/day[23].

Few Brazilian studies evaluated the occupational exposure of workers to solar radiation. The investigation conducted by Oliveira et al.[24] with physical activities coachers indicate the prevalence of direct solar exposure of 64.2% and 13% for partial exposure. The prevalence of sun exposure in labourers of activities of art, culture, sport and recreation was 13.2% (Table 2).

Meyer et al.[25] while investigating labourers of the coastal community of Natal, capital of Rio Grande do Norte, noticed prevalence of 56% for those who are exposed for more than 6h/day and 33% between 3 and 6h/day. 77.1% of labourers of agriculture, livestock, forest, fishing and aquaculture activities were exposed to solar radiation, similar to the results of the study of Peters et al.[26] in Canada where the highest prevalence was found in agriculture, construction and landscaping.

The findings of the Australian Work Exposures Study (AWES) about workers exposed to solar radiation in Australia have also shown high prevalence in men than in women for all economic activities with higher proportions for farmers, heavy duty trucks, painters, plumbers and livestock farmers[27]. The results are consistent with the present article, since painters and plumbers are classified as construction workers.

The present findings confirm that the frequency of the distribution of solar radiation is heterogeneous by economic sectors. Most likely, the workers are exposed to different levels of solar radiation with different risks of sickening associated with UVA/UVB radiation. A German study conducted between 2014 and 2019 revealed that the amount of exposure to UV radiation varies significantly for the same profession, and the main determinant factor is the profile of tasks performed by each professional[28].

Regarding the factors associated with long-term work exposure for the total population of workers (Table 5), the likelihood of high exposure occurs in workers living in the rural area in the Northeast and Southeast regions, low education level, working outdoor or in mixed environments and work shift greater than 40h/week. Men with low education with informal jobs were positively associated with solar radiation at work and similar association was also found for 30-39 years old women with complete high-school due to long-term solar radiation. Most likely, sex differences reflect the work inequalities in relation to the profile, function and activities performed[29-31].

Quite often, informal workers have low education level, worst working conditions and are more exposed to hazardous agents[32], which possibly justifies the positive association between the informality and high likelihood of solar radiation exposure in men.

The highest prevalence for male workers exposed to solar radiation was found for informal and low qualified jobs in agriculture, construction, waste management and collection, power and gas. Corroborating these findings, Dielh et al.[33] evaluated solar protection practices and attitudes at work and concluded that more than 50% of outdoor workers have completed high school and 36% had informal jobs.

Climate changes affect the health of outdoor workers as they provoke frequent heat waves and higher levels of UVA/UVB solar radiation, making them more vulnerable to prolonged sun exposure related harms[34]. A systematic review conducted by the World Health Organization (WHO) and ILO concluded that solar radiation exposure increases the risk of skin malignant tumors in 45% of outdoor workers. In this same study, the cancer burden attributable to ultraviolet radiation occupational exposure was the third highest among occupational carcinogens, behind only asbestos and silica[10].

In Brazil, melanoma and non-melanoma skin cancer of the lips and eyes were included as occupational diseases in the National List of Work-Related Diseases and Harms revised in 2023 and acknowledging solar radiation as occupational carcinogen[35] which reinforces the necessity of estimating the national prevalence and characterize occupational exposure to solar radiation to identify groups of more vulnerable workers and prioritize health protective actions.

Experts recommend a legal framework to prevent solar radiation occupational exposure and protect the workers health[8]. The existing ruling norm (NR) 15 establishes daily exposure limits for levels of occupational exposure to ionizing and non-ionizing radiations in working environments, but excludes ultraviolet solar radiation (natural source), neglecting the surveillance of outdoor workers exposure[36].

Additionally, they recommend continuous monitoring activities of outdoor workers through skin clinical tests

to identify precursor lesions of skin cancer, health professionals training and workers exposed and utilization of individual protective measures as sun blockers, UVA/UVB protective clothing, wide brim hats while performing outdoor activities[37].

PNS is not an investigation on work health and safety, a potential limitation of the study. The questionnaire utilized was not specific to evaluate work-related occupational hazards. Other factors that affect occupational exposure levels to solar radiation were not addressed as days worked per week, duration of outdoor work, hours of exposure to solar radiation, seasons of the year when work activities are performed and protective personal equipment.

According to Modenese et al.[5], environmental and individual factors influence acute and cumulative solar exposure of outdoor workers. The working environment may contain reflective surfaces as water for sea workers or glass and metal for construction workers that intensify the exposure. In addition, it is possible that workers have to perform their activities as in agriculture and construction around noon and/or during the hottest seasons of the year. The areas of the body more exposed reflect the worker's attitude further to the use of individual eye and skin protection.

According to Gobba et al.[38], the evaluation of solar radiation exposure is underreported due to possible legal consequences because few investigations collect detailed data. The authors recommend the utilization of individual evaluation to measure more accurately the exposure to UV radiation.

A possible bias of sample size may have occurred since even very small differences in large populations may be statistically significant.

CONCLUSION

Exposure to solar radiation of Brazilian workers is high, unevenly distributed by economic sectors and more accentuated in men. Protective measures against occupational exposure to solar radiation and skin cancer surveillance should prioritize outdoor and mixed environments workers, living in rural areas and low education-level for more than 40 hours/week.

CONTRIBUTIONS

All the authors contributed to the study design, acquisition, analysis and interpretation of the data, wording and critical review. They approved the final version for publication.

DECLARATION OF CONFLICT OF INTERESTS

There is no conflict of interests to declare.

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