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Prevalence of possible occupational carcinogenic exposures in Brazilian workers: what does the National Health Survey say?

Prevalência de possíveis exposições cancerígenas ocupacionais em trabalhadores brasileiros: o que mostra a Pesquisa Nacional de Saúde?

Abstract

Objective: to estimate the prevalence of possible carcinogenic exposures in Brazilian workers. *Methods*: cross-sectional study, with data from the 2019 National Health Survey. We calculated the prevalences and respective 95% confidence intervals (95%CI) for possible exposure to six occupational carcinogens: solar radiation, chemical substances, mineral dust, radioactive material, night work, and passive smoking at work, according to occupation and sex, considering the complex sample design. *Results*: 44,822 workers were included, 56.33% were male. Reported exposure to at least one carcinogenic agent from group 1, according to the classification of the International Agency for Research on Cancer, 49.0% (95%CI 47.8;50.2) of male workers and 16.9% (95%CI 16.0;17.9) of female workers. Male workers, compared with female workers, had a higher prevalence of exposure to solar radiation (38.1% [95%CI 37.0;39.3] vs 6.6% [95%CI 6.0;7.2]), chemical agents (19.4% [95%CI 18.5;20.5] vs 8.3% [95%CI 7.6;9.1]), mineral dust (18.9% [95%CI 17.9;20.0] vs 3.3% [95%CI 2.9;3.8]), night work (15.5% [95%CI 14.7;16.5] vs 9.4% [95%CI 8.6;10.2]), and passive smoking (14.3% [95%CI 13.3;15.4] vs 8.2% [95%CI 7.6;9.0]). *Conclusion*: the prevalence of exposure to possible occupational carcinogens is high and unequally distributed by sex and occupation. Actions to reduce, replace, and eliminate these carcinogens should be prioritized.

Keywords: health survey; prevalence; occupational health; occupational exposure; cancer.

Resumo

Objetivo: *estimar a prevalência de possíveis exposições cancerígenas em trabalhadores brasileiros.* Métodos: *estudo transversal, com dados da Pesquisa Nacional de Saúde de 2019. Calcularam-se prevalências e respectivos intervalos de confiança de 95% (IC95%) para possível exposição a seis carcinógenos ocupacionais: radiação solar, substâncias químicas, poeiras minerais, material radioativo, trabalho noturno e tabagismo passivo no trabalho, segundo ocupação e sexo, considerando o desenho complexo da amostra.* Resultados: *foram incluídos 44.822 trabalhadores, 56,33% do sexo masculino. Referiram exposição a pelo menos um agente cancerígeno do grupo 1, segundo classificação da International Agency for Research on Cancer, 49,0% (IC95% 47,8;50,2) dos trabalhadores do sexo masculino e 16,9% (IC95% 16,0;17,9) do feminino. Trabalhadores do sexo masculino, em comparação ao feminino, apresentaram maiores prevalências de exposição à radiação solar (38,1% [IC95% 37,0;39,3] vs 6,6% [IC95% 6,0;7,2]), agentes químicos (19,4% [IC95% 18,5;20,5] vs 8,3% [IC95% 7,6;9,1]), poeiras minerais (18,9% [IC95% 17,9;20,0] vs 3,3% [IC95% 2,9;3,8]), trabalho noturno (15,5% [IC95% 14,7;16,5] vs 9,4% [IC95% 8,6;10,2) e tabagismo passivo (14,3% [IC95% 13,3;15,4] vs 8,2% [IC95% 7,6;9,0]).* Conclusão: *a prevalência da exposição a possíveis carcinógenos ocupacionais é elevada e desigualmente distribuída por sexo e ocupação. Ações de redução, substituição e eliminação desses carcinógenos devem ser priorizadas.*

Palavras-chave*: inquérito de saúde; prevalência; saúde do trabalhador; exposição ocupacional; câncer.*

Introduction

Cancer is the second leading cause of death in the world, besides being an important factor in premature deaths in people aged 30 to 69 and a serious global public health issue. Data show that the highest number of deaths from cancer occurs mainly in middle and low-income countries, which face other health difficulties, aggravating their social inequalities and challenging public policies to face health problems, including measures to reduce exposure to risk factors for cancer.[1]

Among the risk factors for cancer, exposure to occupational carcinogens, such as ionizing and non-ionizing radiation, asbestos, silica, pesticides, benzene, formaldehyde, and metals, among others, is internationally recognized as a determinant of work-related cancer diseases and deaths, with its effects increased by individual exposure to other risk factors, such as smoking, excessive alcohol consumption, diets high in fat and red and processed meat, and a sedentary lifestyle.[2]

International studies have shown that 4% to 20% of cancer cases are attributed to exposure to occupational carcinogens, with the percentages varying according to type of cancer and carcinogen, gender, and geographic area. It should be noted that most occupational exposures are avoidable by adopting clean technologies that eliminate the use of those carcinogens in production processes.[3] A substance, combination or mixture of substances is considered potentially carcinogenic when exposure to it in the workplace may cause an increase in the incidence of malignant tumors as well as a significant reduction in the latency period between exposure and the onset of cancer.[4]

According to the International Agency for Research on Cancer (IARC), there are currently 525 agents (chemical, physical or biological) that are carcinogenic to humans. Of those, 79 are present in occupational processes, and 38 types of work-related cancer have been identified.[5]

According to the Brazilian Ministry of Health, work-related cancer is cancer resulting from exposure to carcinogenic agents present in the workplace, even after the end of exposure due to position or job changes or retirement.[4]

In 2018, the World Health Organization estimated a total of 9.6 million cancer deaths worldwide, of which more than 472,000 were attributed to work-related cancer. In that same year, exposure to occupational carcinogens resulted in the loss of nearly 11 million healthy life years due to disability.[6]

In Brazil, the National Cancer Institute (INCA) estimates that for each year of the 2020-2022 period there will be 625 thousand new cases of cancer in the Brazilian population, about 4% to 17% of them attributed to work, that is, between 25 and 100 thousand cases of cancer will be work-related during those three years.[7]

Considering the context above, this study aimed to analyze the prevalence of possible occupational carcinogenic exposures in Brazilian workers in 2019.

Methods

Study design

This is a cross-sectional prevalence study drawing on data from the 2019 edition of the National Health Survey (PNS), a nationwide, household survey carried out by Fundação Oswaldo Cruz and the Brazilian Ministry of Health in partnership with the Brazilian Institute of Geography and Statistics (IBGE).

Sampling plan and study population

The PNS is part of the IBGE Integrated Household Survey System and uses a subset of the IBGE Master Sample, with the same stratification of the primary selection units (UPA), composed of one or more census tracts. Three-stage cluster sampling was used. In the first stage, the UPAs of each stratum were selected. In the second stage, a fixed number of households was randomly selected for each UPA. And, in the third stage, a resident aged 15 or older was randomly selected from each household. Areas with small populations, such as indigenous villages, barracks, military bases, and lodgings, among others, were excluded. A total of 108,525 households were visited and 90,846 residents were interviewed. The non-response rate was 6.4%.[8]

In the reference week for data collection (July 21 to 27, 2019), the employed population of the PNS over the age of 18 consisted of 52,582 individuals.

Variables and measurement

The PNS used three questionnaires: a) household information); b) general characteristics of all household members; and c) individual information of the selected household member.

Occupation was defined by the following question: "What was your occupation (position or function) in this main job?" The PNS considers main job as that with highest number of hours, monthly income, or length of service. The answer sheet provides the occupation codes to be selected, according to the Brazilian Classification

of Occupations (CBO). The CBO describes and orders occupations within a hierarchical structure that makes it possible to gather information about the workforce, distinguishing functions, knowledge, skills, personal attributes, and other requirements of the occupation. The CBO has four hierarchical levels: unit groups or occupational families (UB); minor groups (MiG); sub-major group (SMG), and the major groups (MaG).[9] The last compose the most aggregated level, comprising ten categories grouped by skill level and similarity in the activities performed. The occupational MaG are broken down into forty-three sub-major groups. This work considered all SMG with a minimum sample of 400 workers, with a view to making the analyses more robust. The minimum number of 400 people was established as a criterion assuming a prevalence (P) of 50% with a CI of 95%, totaling 44,852 participants.

For the evaluation of possible carcinogenic occupational exposures, the following question was used: "In your job(s), are you exposed to any of these factors that may affect your health?" The response options include only occupational exposures classified by the International Agency for Research on Cancer (IARC)[10] as carcinogenic to humans, with sufficient and limited scientific evidence, namely: a) handling chemical substances, such as: pesticides, gasoline, diesel, formaldehyde, lead, mercury, chromium, herbal medicines, etc. (yes/no); b) long exposure to solar radiation (yes/no); c) handling of radioactive material during transport, receipt, storage and X-ray work (yes/no); and d) exposure to mineral dust, such as from marble, sand, gravel, glass (silica), asbestos, iron or steel (yes/no).

Information on night shift work, classified by the IARC as a probable occupational carcinogen, was collected through the question: "In your job(s), do you usually work any hours between 8 pm and 5 am (yes/no)?"

Passive smoking at work was determined by the question: "In the last 30 days, has anyone smoked in the same closed environment where you work (yes/no)?"

Exposures to solar radiation, passive smoking, radioactive material, and mineral dust were grouped into a single category (Group 1), considered "carcinogenic exposures with sufficient scientific evidence." In turn, exposures to chemical substances and night shift work were gathered in Group 2, considered "possible carcinogenic exposures" according to the IARC classification.[10]

For the description of the sample of employed workers, the following sociodemographic variables were considered: sex (men, women), age group (18 to 39; 40 to 59; 60 or over), race/skin color (white, black and brown), level of education (no schooling or incomplete primary education; complete primary or incomplete secondary education; complete secondary or incomplete higher education; complete higher education), income (less than one minimum wage, one to two minimum wages, more than two minimum wages) and area of residence (rural, urban).

Statistical analysis

The proportional distribution of the sample was estimated according to the sociodemographic variables, by calculating the percentages and respective confidence intervals.

The percentage of workers exposed to Group 1 and Group 2 was estimated according to the IARC classification, in each main subgroup, with the following categories: no exposure, at least one carcinogenic exposure in Group 1 and at least one carcinogenic exposure in Group 2. An exposure ranking was established for the sub-major goups, based on the percentage in the "no exposure" category. The higher the percentage in this category, the higher the share of those not exposed to occupational carcinogens, and the higher the ranking in "no exposure."

Statistical Package for Social Sciences (SPSS) version 21 was used. The prevalences in the respective 95% Confidence Intervals (95%CI) of occupational exposures were analyzed according to the sub-major groups (SMG) and stratified by sex. All analyses considered the complex sampling design through the complex sample statistical command.

Ethical considerations

The National Health Survey (PNS) was approved on August 23, 2019, by the National Research Ethics Committee (CONEP), under No. 3,529,376. Fieldwork took place between August 2019 and March 2020. All participants signed an informed consent form authorizing their participation in the survey.

Results

A total of 44,822 individuals were included in the study, 56.3% men (n=25,247) and 43.7% women (n=19,575). Most lived in urban areas (83.4% men and 91.4% women); 49.4% of both sexes were aged between 18 and 39; 36.8% of male workers and 42.5% of female workers reported having completed secondary education; 44.8% and 47.0% earn between one and two monthly minimum wages, respectively. Regarding race/skin color, 45.6% of male workers self-declared as brown compared to 42.8% of female workers (**Table 1**).

Table 2 and **Table 3** show the prevalence of types of occupational carcinogenic exposure in male and female workers, respectively. It was observed that, among men, 49% were exposed to at least one

carcinogenic agent from Group 1 and 31.9% to at least one carcinogenic agent from Group 2, against 16.9% and 16.5% for women, respectively. Among men, the major-sub groups "Agricultural, Forestry and Fishery Labourers," "Market-oriented Skilled Agricultural Workers," and "Building and Related Trades Workers (excluding Electricians)" showed the greatest exposure, given the smaller percentages in the "no exposure category" (9.0%, 13.0% and 15.4% respectively).

Among women (**Table 3**), the most exposed SGP were: Market-oriented Skilled Agricultural Workers, hunting, and fishing workers, Health Associate Professionals and Health professionals, with prevalences of 30.1%, 34.9% and 57% of no exposure to occupational carcinogens, respectively.

The prevalence of carcinogenic occupational exposures according to sex by occupational SMG is shown in **Table 4** and **Table 5**. Compared to female, male workers had a higher prevalence of exposure to solar radiation (38.1% [95%CI 37.0;39.3] vs 6.6% [95%CI 6.0;7.2]), passive smoking at work (14.3% [95%CI 13.3;15.4] vs 8.2% [95%CI 7.6;9.0]), mineral dust (18.9% [95%CI 17.9;20.0] vs 3.3% [95%CI 2.9;3.8]), chemicals (19.4% [95%CI 18.5;20.5] vs 8.3% [95%CI 7.6;9.1]) and night shift work (15.5% [95%CI 14.7;16, 5] vs 9.4% [95%CI 8.6-10.2]). When analyzing the SMG, male workers showed higher prevalence of exposure to: a) solar radiation, Agricultural, Forestry and Fishery Labourers (87.0%); Market-oriented Skilled Agricultural Workers (82.6%); and Building and Related Trades Workers (excluding Electricians) (65.2%); b) passive smoking at work, in 31.6% of Building and Related Trades Workers (excluding Electricians) and 26.4% Electrical and Electronics Trades Workers; c) mineral dust, in Building and Related Trades Workers (excluding Electricians) (53.3%) and Labourers in Mining, Construction, Manufacturing and Transport (39.8%); d) chemicals, in Metal, Machinery and Related Trades Workers (52.1%); Science and Engineering Associate Professionals (36.2%); and Market-oriented Skilled Agricultural Workers (34.3%); d) night shift work, in 52.3% of Protective Services Workers and 33.3% of personal service workers; and e) radioactive material, Metal, Machinery and Related Trades Workers and 3.3% of Science and Engineering Associate Professionals.

Table 1 Demographic and socioeconomic characteristics of workers by gender, Brazil, 2019.

Variables	*Total*			*Male*			*Female*		
	n	*%*	*95%CI*	*n*	*%*	*95%CI*	*n*	*%*	*95%CI*
Area of residence									
Urban	38950	86.9	86.4;87.4	21064	83.4	82.7;84.1	17886	91.4	90.9;91.9
Rural	5872	13.1	12.6;13.6	4183	16.6	15.9;17.3	1689	8.6	8.1;9.1
Age group (years)									
18-39	22141	49.4	48.5;50.3	12465	49.4	48.2;50.5	9675	49.4	48.2;50.7
40-59	18705	41.7	40.9;42.6	10362	41.0	39.9;42.2	8343	42.6	41.4;43.8
≥ 60	3977	8.9	8.4;9.3	2420	9.6	9.0;10.2	1557	8.0	7.3;8.6
Skin color									
White	19227	43.5	42.6;44.4	10624	42.7	41.6;43.9	8603	44.5	43.3;45.8
Black	5372	12.2	11.6;12.7	2915	11.7	11.1;12.4	2457	12.7	11.9;13.6
Brown	19601	44.3	43.5;45.2	11333	45.6	44.5;46.7	8268	42.8	41.6;44.0
Level of education									
None or incomplete elementary	12412	27.7	26.9;28.5	8173	32.4	31.3;33.4	4239	21.7	20.7;22.7
Complete elementary or incomplete secondary	6968	15.5	15.0;16.1	4398	17.4	16.6;18.3	2570	13.1	12.3;14.0
Complete secondary or incomplete tertiary	17607	39.3	38.5;40.1	9295	36.8	35.7;37.9	8311	42.5	41.2;43.7
Complete tertiary	7835	17.5	16.7;18.3	3381	13.4	12.5;14.4	4454	22.8	21.7;23.9
Monthly income (minimum wages)									
< 1	10162	23.0	22.2;23.7	4577	18.3	17.4;19.2	5586	29	27.8;30.2
1 to 2	20255	45.8	44.9;46.7	11209	44.8	43.6-;6.1	9046	47	45.7;48.4
> 2	13824	31.2	30.4;32.1	9209	36.8	35.7;38.0	4616	24	22.8;25.2
Total	44822	100.0	-	25247	56.3	55.4;57.2	19575	43.7	42.8;44.6

Source: Authors, based on National Health Survey data 2019, IBGE

Table 2 Prevalence (%) of carcinogenic occupational exposure in male workers by exposure groups and main subgroups of the Brazilian Classification of Occupations, Brazil, 2019

Sub-Major Goups of the Brazilian Classification of Occupations	*n*	*Rank*[a]	*Carcinogenic exposure*					
			None		*At least one of Group 1*[b]		*At least one of Group 2*[c]	
			%	*95%CI*[d]	*%*	*95%CI*[d]	*%*	*95CI%*[d]
Administrative and Commercial Managers (12)	499	3	69.3	61.9;75.8	20.5	15.2;26.9	15.1	10.5;21.2
Production and Specialized Services Managers (13)	402	8	58.1	49.8;66.0	34.9	27.3;43.3	16.3	11.7;22.3
Teaching Professionals (23)	623	4	66.8	60.6;72.4	15.9	11.9;20.9	20.9	16.2;26.5
Business and Administration Professionals (24)	416	1	80.2	72.4;86.3	8.8	5.6;13.4	13.2	8.0;20.9
Legal, Social and Cultural Professionals (26)	583	5	62.7	55.9;69.1	17.7	12.9;23.9	29.2	23.0;36.4
Science and Engineering Associate Professionals (31)	656	17	29.6	24.3;35.5	57.0	50.5;63.2	45.9	39.2;52.8
Business and Administration Associate Professionals (33)	657	6	60.1	53.5;66.3	27.6	22.2;33.8	19.6	14.9;25.3
General and Keyboard Clerks (41)	698	2	74.8	68.5;80.5	13.3	9.5;18.4	14.6	10.1;20.7
Numerical and Material Recording Clerks (43)	471	7	58.9	50.3;67.0	22.0	16.0;29.5	28.0	21.3;35.9
Personal service workers (51)	1,306	10	51.5	45.4;57.6	18.5	15.1;22.5	39.1	33.6;44.9
Sales Workers (52)	2,715	9	56.9	53.9;59.8	29.4	26.7;32.2	22.7	20.2;25.4
Protective Services Workers (54)	884	15	33.3	27.9;39.1	30.4	25.6;35.8	55.3	49.6;60.9
Market-oriented Skilled Agricultural Workers (61)	2511	21	13.0	11.3;14.8	83.8	81.9;85.6	37.2	34.0;40.5
Building and Related Trades Workers (excluding Electricians) (71)	2,499	22	15.4	13.1;18.1	80.5	77.6;83.1	23.4	20.4;26.7
Metal, Machinery and Related Trades Workers (72)	1,526	20	21.2	17.7;25.1	51.9	47.2;56.5	58.3	53.4;63.1
Electrical and Electronics Trades Workers (74)	679	13	40.2	29.0;52.5	52.5	41.4;63.3	21.2	14.7;29.5
Food Processing, Woodworking, Garment and Other Craft and Related (75)	702	11	49.2	42.5;56.0	25.7	19.9;32.5	39.4	32.8;46.4
Stationary Plant and Machine Operators (81)	750	12	40.8	33.9;48.1	35.8	29.4;42.9	40.5	33.5;48.1
Drivers and Mobile Plant Operators (83)	2,808	14	33.8	30.9;36.9	50.7	47.4;54.1	37.5	34.3;40.8
Domestic and Office Cleaners and Helpers (91)	746	16	31.2	26.1;36.8	55.8	49.4;61.9	32.9	27.3;39.0
Agricultural, Forestry and Fishery Labourers (92)	1,024	23	9.0	7.2;11.3	88.5	85.9;90.7	32.2	26.6;38.4
Labourers in Mining, Construction, Manufacturing and Transport (93)	1,664	18	25.5	21.6;30.0	65.9	61.1;70.3	23.5	19.5;28.0
Garbage Collectors and other Other Elementary Workers (96)	429	19	21.8	16.5;28.2	64.4	55.6;72.4	29.0	21.1;38.3
Total (n > or = 400)	25,247	-	37.1	36.0;38.2	49.0	47.8;50.2	31.9	30.7;33.1

a) Rank refers to the ordered ranking of an ascending numeric sequence, from lowest to highest carcinogenic exposure. Therefore, rank 1 means classification of the SMG in the "no exposure" category.
b) Group 1- Category in which occupational exposures are recognized as carcinogenic to humans with sufficient scientific evidence, according to the International Agency for Research on Cancer (IARC, 2020).
c) Group 2- Category in which occupational exposures are recognized as probable/possible carcinogens for humans, with limited scientific evidence, according to the International Agency for Research on Cancer (IARC, 2020).
d) 95%CI: 95% Confidence Interval
Source: Authors, based on National Health Survey data 2019, IBGE

Table 3 Prevalence (%) of carcinogenic occupational exposure in female workers by exposure groups and sub-major groups of the Brazilian Classification of Occupations, Brazil, 2019

Sub-major groups (SMG)	*n*	*Rank*[a]	*Carcinogenic exposure*					
			None		*At least one of Group 1*[b]		*At least one of Group 2*[c]	
			%	*95%CI*[d]	*%*	*95%CI*[d]	*%*	*95%CI*[d]
Health professionals (22)	637	12	57.0	50.1;63.5	22.1	17.2;27.8	35.0	29.2;41.3
Teaching Professionals (23)	1,828	2	83.6	80.5;86.3	9.0	6.9;11.6	9.1	7.2;11.5
Legal, Social and Cultural Professionals (26)	470	5	79.1	73.5;83.8	9.9	6.5;14.8	13.7	10.2;18.0
Health Associate Professionals (32)	821	13	34.9	29.6;40.6	41.2	35.5;47.2	41.6	36.0;47.4
Business and Administration Associate Professionals (33)	516	4	78.7	72.7;83.8	14.4	10.2;20.0	10.3	7.1;14.7
General and Keyboard Clerks (41)	1,484	1	85.2	81.4;88.3	9.1	6.5;12.5	8.1	5.9;11.0
Customer Services Clerks (42)	823	3	82.5	77.4;86.6	7.2	4.8;10.8	12.2	8.7;16.9
Personal service workers (51)	2,143	11	61.2	57.4;64.8	14.5	12.2;17.2	30.0	26.5;33.7
Sales Workers (52)	3,725	6	74.7	72.0;77.3	16.5	14.6;18.7	11.2	9.3;13.4
Personal care workers (53)	1,161	10	68.4	62.9;73.4	16.4	12.5;21.2	20.1	16.2;24.7
Market-oriented Skilled Agricultural Workers (61)	583	14	30.1	25.6;35.0	67.4	62.4;71.9	18.4	14.9;22.5
Food Processing, Woodworking, Garment and Other Craft and Related (75)	958	8	73.2	68.2;77.7	10.2	7.7;13.3	18.5	14.4;23.6
Stationary Plant and Machine Operators (81)	582	7	73.9	66.6;80.1	12.9	8.6;19.0	18.5	13.0;2573
Domestic and Office Cleaners and Helpers (91)	3,844	9	73.3	70.7;75.7	17.6	15.6;19.7	12.5	10.6;14.8
Total (n > or = 400)	19,575	-	71.1	69.8;72.3	16.9	16.0;17.9	16.5	15.5;17.6

a) Rank refers to the ordered ranking of an ascending numeric sequence, from lowest to highest carcinogenic exposure. Therefore, rank 1 means classification of the SMG in the "no exposure" category".
b) Group 1- Category in which occupational exposures are recognized as carcinogenic to humans with sufficient scientific evidence, according to the International Agency for Research on Cancer (IARC, 2020).
c) Group 2- Category in which occupational exposures are recognized as probable/possible carcinogens for humans, with limited scientific evidence, according to the International Agency for Research on Cancer (IARC, 2020).
d) 95%CI: 95% Confidence Interval

Source: Authors, based on National Health Survey data 2019, IBGE

Table 4 Prevalence (%) of carcinogenic occupational exposure in male workers by exposure groups and sub-major groups of the Brazilian Classification of Occupations, Brazil, 2019

Sub Major-Groups of the Brazilian Classification of Occupations	n	Carcinogenic exposure (Group 1) [a]						Possible carcinogenic exposure (Group 2) [b]					
		Solar Radiation		Radioactive Material		Passive Smoking		Mineral Dust		Night Shift Work		Chemicals	
		%	95%CI[c]	%	95%CI[c]	%	95%CI[c]	%	95%CI[c]	%	95%CI[c]	%	95%CI[c]
Administrative and Commercial Managers (12)	499	10.5	6.8;15.9	0.1	0.0 – 0.4	10.9	6.8;16.9	8.8	5.3;14.2	6.4	4.0;10.0	9.0	5.3;15.0
Production and Specialized Services Managers (13)	402	27.1	19.8;36.0	1.0	0.3;3.6	3.8	2.0;7.3	11.9	7.4;18.7	7.2	4.3;11.8	9.8	6.6;14.2
Teaching Professionals (23)	623	7.9	5.2;11.9	0.2	0.0;1.2	4.5	2.8;7.2	4.6	2.4;8.8	17.9	13.4;23.4	4.8	2.7;8.5
Business and Administration Professionals (24)	416	3.4	1.8;6.4	0.2	0.1;1.2	3.3	1.7;6.4	3.0	1.3;7.0	7.5	4.5;12.2	6.0	2.4;14.5
Legal, Social and Cultural Professionals (26)	583	5.9	3.4;10.1	1.7	0.5;6.1	10.9	6.9;16.7	4.1	2.1;8.0	25.0	19.1;32.0	8.0	4.4;13.9
Science and Engineering Associate Professionals (31)	669	35.8	29.4;42.6	3.3	1.1;9.5	11.4	7.5;17.0	34.3	28.1;41.0	18.1	13.2;24.4	36.2	29.8;43.2
Business and Administration Associate Professionals (33)	660	19.4	14.7;25.2	0.5	0.2;1.4	9.9	6.9;14.0	6.1	3.6;10.2	16.4	11.9;22.1	7.2	4.1;12.4
General and Keyboard Clerks (41)	734	8.4	5.2;13.2	0.8	0.2;3.0	5.0	2.8;8.7	3.7	2.1;6.4	7.8	5.0;11.8	7.4	3.9;13.6
Numerical and Material Recording Clerks (43)	473	9.3	5.3;15.7	1.2	0.4;3.2	7.4	4.1;13.0	10.9	7.2;16.1	16.2	10.8;23.7	14.2	9.8;20.0
Personal service workers (51)	1,313	10.0	7.6;13.2	0.3	0.1;0.6	9.3	6.9;12.4	5.1	3.3;7.9	33.3	28.2;38.9	8.1	5.9;11.0
Sales Workers (52)	2,764	18.3	16.0;20.8	0.5	0.3;0.9	13.2	11.1;15.7	6.4	5.0;8.1	14.6	12.5;17.0	10.3	8.6;12.3
Protective Services Workers (54)	884	19.5	15.1;24.7	1.4	0.6;3.2	19.4	14.3;25.8	7.7	5.5;10.7	52.3	46.7;57.9	8.6	5.2;13.8
Market-oriented Skilled Agricultural Workers (61)	2,572	82.6	80.6;84.4	0.1	0.0;0.2	11.1	7.7;15.5	10.2	8.4;12.4	5.6	4.0;7.9	34.3	31.3;37.4
Building and Related Trades Workers (excluding Electricians) (71)	2,503	65.2	61.8;68.4	1.2	0.6;2.7	31.6	27.7;35.7	53.3	51.6;59.0	4.9	3.6;6.5	19.8	17.0;23.0
Metal, Machinery and Related Trades Workers (72)	1,548	27.0	22.9;31.5	3.9	2.0;7.4	17.7	14.1;21.9	31.8	27.7;36.3	13.4	10.2;17.3	52.1	47.4;56.9
Electrical and Electronics Trades Workers (74)	681	36.6	27.4;47.0	1.4	0.6;3.1	26.4	17.4;37.9	19.5	13.2;27.8	9.2	5.2;15.7	12.5	8.3;18.4
Food Processing, Woodworking, Garment and Other Craft and Related (75)	702	9.8	6.1-15.3	0.4	0.1-1.3	9.5	6.2-14.4	13.1	9.4-17.9	18.2	13.2-24.6	24.1	18.2-31.1
Stationary Plant and Machine Operators (81)	768	15.6	10.9-21.9	1.8	0.9-3.5	11.9	8.0-17.4	19.6	14.9-25.4	24.4	18.4-31.7	26.1	19.9-33.5
Drivers and Mobile Plant Operators (83)	2811	42.9	39.5-46.4	1.1	0.6-2.1	11.1	8.3-14.7	16.8	14.0-20.1	25.4	22.8-28.3	16.6	14.5-19.0
Domestic and Office Cleaners and Helpers (91)	749	46.1	39.8-52.5	1.5	0.7-3.2	17.0	11.8-23.9	15.4	11.1-21.0	11.1	7.0-17.2	24.4	19.7-29.9
Agricultural, Forestry and Fishery Labourers (92)	1081	87.0	84.2-89.4	0.1	0.0-0.5	15.5	6.6-32.1	16.0	11.9-21.3	3.1	2.0-4.9	29.9	24.3-36.3
Labourers in Mining, Construction, Manufacturing and Transport (93)	1713	51.7	46.8-56.6	0.7	0.3-1.4	22.8	16.1-31.4	39.8	34.7-45.1	11.3	8.6-14.7	14.2	10.9-18.2
Garbage Collectors and Other Elementary Workers (96)	447	58.2	49.5-66.3	1.0	0.4-2.4	15.8	8.2-28.4	14.8	11.0-19.6	14.5	9.6-21.3	16.0	9.5-25.7
TOTAL (n > or = 400)	25247	38.1	37.0-39.3	1.0	0.8-1.3	14.3	13.3-15.4	18.9	17.9-20.0	15.5	14.7-16.5	19.4	18.5-20.5

a) Group 1- Category in which occupational exposures are recognized as carcinogenic to humans with sufficient scientific evidence, according to the International Agency for Research on Cancer (IARC, 2020).
b) Group 2- Category in which occupational exposures are recognized as probable/possible carcinogens for humans, with limited scientific evidence, according to the International Agency for Research on Cancer (IARC, 2020).
c) 95%CI: 95% Confidence Interval
Source: Authors, based on National Health Survey data 2019, IBGE

Table 5 Prevalence (%) of carcinogenic occupational exposure in female workers by exposure groups and sub-major groups of the Brazilian Classification of Occupations, Brazil, 2019

Sub-major groups of the Brazilian Classification of Occupations	*n*	*Carcinogenic exposure (Group 1)* [a]								*Possible carcinogenic exposure (Group 2)* [b]			
		Solar Radiation		*Radioactive Material*		*Passive smoking*		*Mineral dust*		*Chemicals*		*Night shift work*	
	n	*%*	*95%CI*[c]	*%*	*95%CI*[c]	*%*	*95%CI*[c]	*%*	*95%CI*[c]	*%*	*95%CI*[c]	*%*	*95%CI*[c]
Health professionals (22)	637	2.0	1.1;3.6	17.5	13.2;22.8	3.7	2.1;6.4	1.8	0.9;3.8	22.0	17.3;26.7	18.1	14.0;23.0
Teaching Professionals (23)	1,828	1.7	1.1;2.6	0.6	0.3;1.4	3.6	2.4;5.6	4.5	3.0;6.5	2.0	1.2;3.5	7.5	5.9;9.6
Legal, Social and Cultural Professionals (26)	470	4.5	2.3;8.3	0.1	0.0;0.5	6.0	3.3;10.5	0.5	0.2;1.3	1.5	0.5;4.1	12.7	9.4; 16.9
Health Associate Professionals (32)	821	17.5	13.8;22.0	17.8	13.5;23.0	8.9	5.3;14.5	4.2	2.8;6.3	24.2	19.6;29.5	25.8	21.1;31.1
Business and Administration Associate Professionals (33)	516	5.8	3.4;9.6	1.1	0.5;2.6	6.5	3.7;11.4	4.2	2.1;8.4	2.3	1.2;4.3	8.4	5.5;12.7
General and Keyboard Clerks (41)	1,484	2.3	1.3;4.2	1.1	0.6;2.2	4.1	2.5;6.5	3.3	1.8;6.0	3.9	2.3;6.4	4.4	3.0;6.5
Customer Services Clerks (42)	823	1.1	0.6;2.0	1.3	0.5;3.2	4.1	2.1;7.8	1.2	0.6;2.6	2.3	1.4;3.8	10.0	6.6;14.8
Personal service workers (51)	2,143	3.6	2.5;5.2	1.2	0.4;3.1	11.5	9.4;14.0	1.7	0.9;3.0	19.0	16.0;22.4	12.9	10.7;15.5
Sales Workers (52)	3,725	8.2	6.8;10.0	0.1	0.1;0.2	8.7	7.2;10.4	3.2	2.5;4.1	2.6	1.9;3.6	9.1	7.3;11.3
Personal care workers (53)	1,161	2.2	1.2;3.9	0.9	0.4;1.9	11.0	7.9;15.1	4.2	2.1;8.4	5.8	3.6;9.1	15.6	12.2;19.7
Market-oriented Skilled Agricultural Workers (61)	583	65.7	60.7;70.4	0.1	0.0;0.7	11.1	5.5;20.9	7.4	4.1;13.1	17.6	14.1;21.7	2.1	1.2;3.9
Food Processing, Woodworking, Garment and Other Craft and Relate (75)	958	2.7	1.5;4.6	0.0	0.0;0.1	6.2	4.4;8.8	2.4	1.2;4.5	6.4	3.6;11.0	12.5	9.5;16.3
Stationary Plant and Machine Operator (81)	582	3.1	1.5;6.6	2.2	0.5;9.1	8.3	4.9;13.7	3.5	1.9;6.6	8.2	4.4;14.8	10.4	6.7;15.9
Domestic and Office Cleaners and Helpers (91)	3,844	4.4	3.3;5.9	0.4	0.0;0.7	11.8	10.1;13.6	3.7	2.9;4.7	9.6	8.1;11.4	3.3	2.3;4.8
TOTAL (n > or = 400)	19,575	6.6	6.0;7.2	1.9	1.6;2.3	8.2	7.6;9.0	3.3	2.9;3.8	8.3	7.6;9.1	9.4	8.6;10.2

a) Group 1- Category in which occupational exposures are recognized as carcinogenic to humans with sufficient scientific evidence, according to the International Agency for Research on Cancer (IARC, 2020).
b) Group 2- Category in which occupational exposures are recognized as probable/possible carcinogens for humans, with limited scientific evidence, according to the International Agency for Research on Cancer (IARC, 2020).
c) 95%CI: 95% Confidence Interval
Source: Authors, based on National Health Survey data 2019, IBGE

Among female workers (**Table 5**), the highest prevalences were: a) exposure to solar radiation in Market-oriented Skilled Agricultural Workers (65.7%) and Health Associate Professionals (17.5%); b) passive smoking in Domestic and Office Cleaners and Helpers (11.8%) and personal service workers (11.5%); c) mineral dust Market-oriented Skilled Agricultural Workers (7.4%); d) handling chemicals in Health Associate Professionals and the like (24.2%) and health professionals (22.0%); e) night shift work in Health Associate Professionals (25.8%) and health professionals (18.1%); and f) radioactive material in Health Associate Professionals (17.8%) and health professionals (17.5%).

Discussion

This study revealed that almost two thirds of male workers and one third of female workers reported exposure to some carcinogenic agent, in either Group 1 or Group 2, according to the IARC classification. It should be noted that different patterns of exposure to occupational carcinogens were observed between the genders, regarding both type of exposure and carcinogen per occupation. Male workers were markedly more exposed than female workers to all evaluated agents, except for radioactive material.

The prevalence of exposure to occupational carcinogens in a representative sample of the

population of Brazilian workers had not been previously disclosed. Attempts to estimate prevalence in specific surveys using a Job-Exposure Matrix – JEM can be mentioned. This method was used to estimate the population exposed to benzene[11] and silica.[12] For other carcinogens, there is an effort by the Ministry of Health, the National Cancer Institute (INCA), the Ministry of Labor and Social Security (Fundacentro) and universities to estimate the population exposed to some agents, following the Carex (CARcinogen EXposure) international methodology implemented in countries in Europe, North America and, more recently, Latin America and the Caribbean, including Brazil.[4]

The prevalence of exposure to occupational risk factors for cancer, such as solar radiation, handling of chemicals, mineral dust, radioactive material, night shift work and passive smoking at work, in the Brazilian working population, can be calculated from data of the National Health Survey that, since 2013, has inserted questions about such exposures in its questionnaires.[13] It should be noted that exposure to occupational carcinogens is a result of the work process and, in most cases, workers are not given or offered options or means to reduce or avoid it.[14]

It is perceived that gender inequalities in the Brazilian labor market affect the access of women to some economic sectors (such as civil and mechanical construction, manufacturing, metallurgy, and mining), and they enjoy a greater participation in the service sector. Therefore, male workers are more susceptible to exposure to dangerous and potentially carcinogenic agents, especially in activities related to farming, construction and manufacturing, while women are the majority in personal care and service occupations.[15] International studies revealed a higher prevalence of occupational carcinogens in men compared to women,[16] mainly for: welding fumes, herbicides, wood dust, solvents and night shift work.[17]

As for occupational exposure to solar radiation, the most significant prevalences occurred in workers in the farming and fishing sectors – for both sexes – and in construction – for male workers. That is, occupations characterized by the execution of outdoor activities and, consequently, with greater exposure to the solar radiation. Similar prevalences were observed in the study by Peters et al.[18] in Canada for men in the agricultural sector (80%), and slightly higher prevalences for construction workers (75%). In Australia, the country with the highest skin cancer rates in the world, Carey et al.[19] detected a percentage of 87.6% of men and 12.4% of women occupationally exposed to solar radiation, figures close to our results. The most exposed groups of workers were: farmers, painters, plumbers, heavy vehicle drivers, horticultural workers, animal caretakers, construction workers and artisans. Exposure to solar radiation is recognized worldwide as the main risk factor for melanoma and non-melanoma skin cancer, and lip and eye cancer. In Brazil, non-melanoma skin cancer is the most frequent in the adult population, with an estimated 650,000 new cases for the three-year period of 2020-2022.[7]

Regarding exposure to chemicals, the data in the PNS is aggregated, making it impossible to investigate each chemical substance individually. However, it should be noted that, most of the time, workers are occupationally exposed to a variety of chemicals with carcinogenic potential in work processes which are difficult to measure in health surveys. The sharp growth of chemical industries in the world economy has introduced new toxic agents, resulting in new exposures at work with which satisfactory mechanisms for regulating exposure and protecting the health of workers cannot keep up. According to the International Labor Organization (ILO),[20] only a limited number of chemical exposures are considered and monitored with proper regulations for work environments, which makes us believe that data on the global burden of diseases attributed to chemicals are often absent or severely underestimated.

In this study, we observed greater exposure to chemicals among men, in Machinery and Related Trades Workers (52.1%), in Metal, Science and Engineering Associate Professionals (36.2%) and Market-oriented Skilled Agricultural Workers (34.3%). Cogliano et al.[2] showed various occupational carcinogens used in civil and mechanical construction, metallurgy and the electrical and electronics sector, such as: benzene, benzidine, 1-3 butadiene, 2, 3,7,8-tetrachlorodibenzo-p-dioxin, bischloromethyl ether, methyl chloride, diesel gasoline, among others, which are strongly associated with the occurrence of leukemia, lymphomas, multiple myelomas, and lung and bladder cancer. In agricultural workers, the greater exposure to chemical compounds is due to the use in Brazil of pesticides with carcinogenic potential, such as glyphosate, diazinone, malathion, 2,4 D and chlorothalonil.[21] Exposure to those chemicals increases the risk of non-Hodgkin's lymphoma, leukemia, cancer of the lung, liver and bile ducts, testis, prostate, and other unspecified solid tumors.[22,23]

Among female workers, the highest rates of exposure to chemicals were for Health Associate Professionals, as well as health professionals, reaching almost a quarter of workers in those occupational groups. It is likely that the administration and

handling of drugs and medications are the main activities that contribute to higher exposure in these subgroups. However, it should be noted that most drugs are not carcinogenic, except for antineoplastic agents. International organizations recommend prioritizing the surveillance and monitoring of occupational exposure to the following chemicals: heavy metals, solvents, dyes, and pesticides.[20]

As for exposure to mineral dust, the analysis of PNS data does not allow us to distinguish between the types of mineral dust to which workers are exposed. We identified that, among male workers, the most exposed are Building and Related Trades Workers (excluding Electricians) (53.3%), and Labourers in Mining, Construction, Manufacturing and Transport (39.8%), while for female workers it was Market-oriented Skilled Agricultural Workers (7.4%). A previous study in Brazil in 2001 showed higher prevalences than ours of exposure to silica mineral dust in employed workers: 65% in construction, 59% in stone extraction, 55% in the non-metallic mineral industry and 24% in the metallurgical industry.[12] In a survey carried out in Costa Rica, prevalence of exposure to mineral dust was significantly lower: 2.1% for silica, 0.5% for glass fibers and 0.02% for ceramic fibers in the occupied population.[24] For 2012, the International Agency for Research on Cancer (IARC) lists the following groups as most exposed to mineral dust: farmers, miners and construction and quarry workers, as well as those who use or manipulate sand or other products containing silica in processes related to foundry, installation and repair of ovens, sandblasting and production of glass, ceramics, abrasives, cement and marble. The mineral dusts of greatest interest for cancer in humans are silica and asbestos,[25] which are produced in drilling, mining and mineral extraction activities, explosions, stone crushing and in the construction sector. Occupational exposure to silica may cause lung cancer, and exposure to asbestos may causer mesothelioma and lung, larynx, ovary, colon and rectum, pharynx, and stomach cancer.[1]

Night shift work was classified by IARC[26] as a probable carcinogen in humans, associated with breast, prostate, colon, and rectum cancer. Changes in serum melatonin and in the expression of central circadian genes seem to be the mechanisms of carcinogenesis present in exposed populations.[27] In our study, we found night shift work prevalences in 15.5% of men and 9.4% of women, with greater predominance in service sectors, reaching 52.3% of men in protection and security services and 25.8% of women in Health Associate Professionals. The population survey on work and income carried out in Canada in 2011[28] showed that 12% of the occupied population was exposed to night shift work, 45% of whom were women. In the same study, the highest prevalences occurred among professional categories similar to our results: security professionals (37%), healthcare professionals (35%) and machine operators and assemblers (24%). In China, data from the baseline of a cohort with 3,871 workers from different economic sectors (nuclear power plant, semiconductors, steel, brewery, and graphics) showed 45.4% of exposure to night shift work, significantly higher than the prevalence found in our study.[29] Such divergences may occur due to different criteria for defining exposure to night shift work and the occupation categories included in the analysis.

Regarding exposure to radioactive material, in general, prevalences were relatively low, but more pronounced in female workers (1.9%) than in male workers (1.0%). Health Associate Professionals (17.8%) and health professionals (17.5%) stood out, with prevalences well above the average for women. The study carried out by Piwowarska-Bilska et al.[30] in Poland, in a nuclear medicine environment, also demonstrated that technical-level professionals are more exposed than other members of the hospital staff. Major occupational sources of ionizing radiation include hospitals and practices; nuclear power plants and their supporting facilities; production of nuclear weapons; industrial operations; research labs; air and space travel and transportation operations; and workplaces with high levels of naturally occurring radioactive materials such as radon.[31] There are several tumor locations related to exposure to ionizing radiation: cancer of the lung, liver, pancreas, breast, uterus, bladder, ovary, brain, bones, nasal cavity and paranasal sinuses, thyroid and prostate, as well as leukemia and lymphomas. In Brazil, there are radiological protection standards establishing limits and parameters for monitoring the occupationally exposed population, with special attention to pregnant women and workers under the age of 18. The aim is to restrict the amount of effective dose received, considering the uncertainties and harmful effects on health, especially among pregnant women and workers under the age of 18.[32]

In Brazil, initiatives by the National Tobacco Control Policy, introduced in 2005, enabled a 37% reduction in passive smoking at work between 2013 (13.4%) and 2019 (8.4%).[33] However, this study found prevalences above the national average when stratified by SMG. For men, the highest rates were found among Building and Related Trades Workers (excluding Electricians) (31.6%) and Electrical and Electronics Trades Workers (26.4%). For women, in turn, Domestic and Office Cleaners and Helpers (11.8%) and personal service workers (11.5%) had a higher prevalence of exposure to passive smoking. In an evaluation of 6,996 Italian workers, Ruscitti

et al.[34] observed groups with greater exposure to passive smoking at work that are different from ours: artisans, skilled workers, and farmers. Data from the European cohort study that monitored 14,590 individuals in three periods (1990-1995, 1998-2003 and 2010-2014) showed a significant drop in passive smoking in workplaces, reaching only 2.5% of the employed population in the last year,[35] a significantly lower prevalence compared to ours. These findings indicate the need to intensify efforts to adopt institutional policies for smoking cessation in the workplace and for smoke-free indoor environments, as established by Decree 8262, dated May 31, 2014.[36]

This study estimated the prevalence of exposure to possible occupational carcinogens in a representative sample of the Brazilian population with more than 40,000 individuals. The first step to start monitoring exposure to occupational carcinogens in the employed population is to identify the occupational categories with the highest exposure and suggest actions to prevent them, in order to avoid the occurrence of work-related cancer in this population. Health surveys, when carried out regularly – such as the National Health Survey, which introduced specific sections on working conditions and occupational exposures – make it possible to assess the success achieved by workers' health policies and programs in Brazil.

As a limitation, the analyzed data on occupational exposures are based on self-reporting, which makes the collected information prone to response bias, resulting in under or overestimation of percentages. In addition, the occupational exposure to chemicals collected by the PNS does not inform the chemical substance handled during work activities. This limitation was also found in other population surveys in countries in Latin American and the Caribbean.[37] In this sense, we cannot state that the prevalence found for occupational exposure to chemicals is indeed carcinogenic. We can only qualitatively assess the possible carcinogenic chemicals that would be present in the occupational categories analyzed, according to the scientific literature. Another consideration to be made is the lack of information about the time and intensity of exposure, as well as the use of personal protective equipment during routine work, which are important factors in determining exposure to occupational carcinogens. Future specific surveys with the working population incorporating this information would strengthen the field of studies on workers' health in Brazil, contributing to unravel the relationship between health and work.

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Author contributions

Nogueira FAM took part in all stages of manuscript preparation, in its conception, writing, analysis, data interpretation, conclusion and approval of the final version. Damacena GN comntributed to the study design, survey, analysis and interpretation of data and approval of the final version. Otero UB participated in the preparation of the manuscript, its critical review and approval of the final version. Madeira CSP and Souza HP contributed to the preparation of the manuscript and approval of the final version. Szwarcwald CL participated in the study design, survey, analysis, interpretation of data and approval of the final version. All authors assume responsibility for the published content and for all aspects of the survey, ensuring that those related to the accuracy or completeness of any part of the study have been appropriately investigated and resolved.

Data Availability

The entire anonymized dataset that supports the results of this study is available at: Instituto Brasileiro de Geografia e Estatística - Microdados PNS 2019. https://www.ibge.gov.br/estatisticas/sociais/saude/29540-2013-pesquisa-nacional-de-saude.html?edicao=9177&t=microdados. Access in Feb 2, 2022.

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