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Hierarchical analysis of the relationship between water insecurity and social determinants to household food insecurity in the municipality of Rio de Janeiro, Brazil

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Research Article

Keywords: water insecurity, food insecurity, households, representative survey, Brazil

Posted Date: November 13th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11392912/v1

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Additional Declarations: No competing interests reported.

Abstract

Background

Water and food insecurity are major global development concerns. In Brazil, both have been documented in diverse settings, but the relationship remains underexplored. This study investigates the relationship between inequalities, water insecurity, and household food insecurity in the municipality of Rio de Janeiro.

Methods

This study used data from the Survey on Food and Nutritional Insecurity in the Municipality of Rio de Janeiro, a representative population-based study. Water insecurity was assessed using the 1st Portuguese version of the Water Insecurity Scale, and food insecurity was assessed using the Brazilian Food Insecurity Scale. Associations were estimated using relative risk ratios (RRRs) with 95% confidence intervals, in multinomial logistic regression models with complex survey design adjustment.

Results

Households experiencing low, moderate, and high levels of water insecurity showed higher relative risks of mild food insecurity (RRR 2.3; 95% CI: 1.38, 3.68; RRR 3.0; 95% CI: 1.84, 5.03; and RRR 5.3; 95% CI: 2.14, 13.16, respectively) compared with water-secure households. Stronger associations were observed for moderate/severe food insecurity (RRR 4.2; 95% CI: 2.32, 7.72; RRR 4.7; 95% CI: 2.61, 8.62; and RRR 46.6; 95% CI: 19.93, 109.08), after considering models adjusted for socioeconomic indicators.

Conclusion

These findings indicate that water insecurity constitutes an important structural determinant of food insecurity and highlight the importance of integrated public policies addressing both water access and food security.

Background

Reducing food insecurity (FI) and water insecurity (WI) has been recognised globally as a challenge and occupies a central position on global development agendas. They are present in the 17 Sustainable Development Goals (SDGs) of the 2030 Agenda, among which SDG 2 sets the target of eradicating hunger and malnutrition by 2030, and SDG 6 aims to ensure the availability and sustainable management of water and sanitation for all[1].

The recognition of access to water[2] and adequate food[3] as fundamental rights reinforces the responsibility of governments to ensure their availability, quality and accessibility on an equitable basis. However, these rights are far from being realised: in 2024, around 2.1 billion people still lacked access to safely managed drinking water services[4] and, in 2025, around 2.1 billion people worldwide experienced moderate or severe FI, of whom approximately 645 million suffered from hunger[5].

Water insecurity is defined as the lack of regular access to water in sufficient quantity and quality to meet human needs[6]. FI, in turn, manifests itself from concern about obtaining food to severe restriction of consumption, characterising hunger in its most severe form[7]. The two conditions were originally studied separately and are now being linked in recent studies, which indicate that they may occur simultaneously and, in certain contexts, may reinforce each other[8,9,10,11,12,13,14].

The association between WI and FI has been documented in the global literature. Young et al. (2023) assessed the results of a study based on population samples from 25 countries, indicating that the presence of WI in households more than doubled the odds of simultaneously experiencing the most severe forms of FI. According to the authors, the associations were observed in all the regions analysed, including Latin America, sub-Saharan Africa and Asia[13]. Similarly, a study conducted in 27 low- and middle-income countries showed an association between higher WI scores and worse household FI outcomes[15], which reinforces the link between access to water and food security. These findings show that limitations in access to water may compromise the availability of adequate food.

Studies conducted in Latin America and the Caribbean, in addition to demonstrating the association between WI and FI[13,16,17], indicate an association with indicators of social inequality that may intensify the occurrence and severity of both WI and FI[16]. Broyles et al. (2024) highlighted that the worsening of WI under more economically unequal conditions makes the FI scenario even more severe, even in regions characterised by an abundance of natural water resources[17].

In Brazil, although recent studies have documented the occurrence of WI and FI in different Brazilian contexts[18,19,20], understanding the relationship between these phenomena remains limited. Investigations that analyse the association between these two conditions in an integrated way remain scarce, especially considering the country's marked social inequalities and territorial diversity.

The municipality of Rio de Janeiro, located in south-eastern Brazil, has multiple territorial particularities, among which socioeconomic disparities stand out, directly influencing the availability of and access to adequate food[21]. Despite being the second-ranked Brazilian municipality by Gross Domestic Product (GDP)[22], it is in 59th position in the Brazilian Sanitation Ranking[23], which highlights deficiencies in the provision of essential basic services. These inequalities are also reflected in conditions of access to food: in 2023, around 32.9% of the population of Rio de Janeiro lived with some level of FI, of whom 7.9% experienced severe FI[20]. This scenario reinforces the inequalities that characterise the city, showing that

the municipality's economic power does not necessarily translate into improvements in the population's living conditions.

Thus, the municipality of Rio de Janeiro constitutes a strategic setting for investigating the relationship between WI and FI because of its history of social inequalities, the complexity and vulnerabilities of its water supply system, and the coexistence of areas with high levels of infrastructure and territories marked by precariousness, which affect access to water and adequate food unequally. In this context, the present study aims to analyse the relationship between inequalities, WI and household FI in the municipality of Rio de Janeiro.

Methods

Study design

This was a population-based cross-sectional study that used data from the "First Population Survey on Food Insecurity in the Municipality of Rio de Janeiro" (*I Inquérito populacional sobre a insegurança alimentar no município do Rio de Janeiro*)[20], conducted between November 2023 and January 2024. The survey was coordinated by researchers from the Josué de Castro Institute of Nutrition (*Instituto de Nutrição Josué de Castro*) at the Federal University of Rio de Janeiro (*Universidade Federal do Rio de Janeiro*), in partnership with other higher education institutions in the state of Rio de Janeiro and with financial support from the Rio de Janeiro City Council.

Sample

The municipality of Rio de Janeiro is located in the south-eastern region of Brazil, with a population of 6,211,223 inhabitants according to the 2022 Demographic Census[24], corresponding to a population density of 5,174.6 inhabitants/km². The territory contains 813 favelas and urban communities, and, in these areas, population density reaches approximately 22,983 inhabitants per km².

A representative sample of 2,000 households in the urban area of the municipality was used. Interviews were distributed proportionally across five zones of the city, defined by the municipal government for territorial management and urban planning purposes, which group neighbourhoods with distinct geographical and socioeconomic characteristics. The adult responsible for the household (head of the family or spouse), aged 18 years or over, was asked to answer the questionnaire. The sampling design used a cluster sampling with three selection stages (selection of census tracts from neighborhoods within administrative regions using the probability-proportional-to-size method; random selection of 50 census tracts per zone of the city; and selection of 8 households at systematic intervals).

The questionnaire was developed for the “First Population Survey on Food Insecurity in the Municipality of Rio de Janeiro”[20] and has been used in previous publications from this survey[25,26,27]. Interviewers, trained by the project coordination team, conducted face-to-face interviews using this structured

questionnaire consisting of 80 questions. The questionnaire was organized into thematic modules covering: identification of the household and family; family profile; income over the previous 30 days; the Brazilian Food Insecurity Scale (Escala Brasileira de Insegurança Alimentar, EBIA); the Water Insecurity Scale; social support and food-related issues; perception of the place of residence (neighbourhood); information on food acquisition outlets; and nutritional status.

The Rio de Janeiro Survey was approved by the Research Ethics Committee of the Clementino Fraga Filho University Hospital (*Comitê de Ética em Pesquisa do Hospital Universitário Clementino Fraga Filho*, CEP/HUCFF) in 2021 (CAAE: 54473421.6.0000.5257) and carried out in accordance with the recommendations of National Health Council (*Conselho Nacional de Saúde*, CNS) Resolution No. 510/2016 (Article 2, Subsection XXV). Respondents read and signed the Free and Informed Consent Form drawn up and approved by the CEP/HUCFF, which guaranteed the confidentiality of the information obtained in the interviews.

Water insecurity

WI was measured using the first Portuguese version of the Household Water Insecurity Experiences Scale (HWISE)[28], translated from the original English version. The scale comprises 12 questions covering the dimensions of accessibility, availability, use, acceptability, and reliability of household water over the four weeks preceding the interview. Data was collected using the options 'never' (0 times), 'rarely' (1–2 times), 'sometimes' (3–10 times), 'often' (11–20 times) and 'almost every day' (more than 20 times). In this study, responses were scored dichotomously: never (0 points); rarely, sometimes, often and almost every day (1 point). The use of dichotomous responses to classify households into the four levels of WI follows Bose et al. (2025), who suggest that this is a valid alternative to polytomous response options for measuring the occurrence of WI experiences[26]. The sum of the scores for the categories indicated by the respondent was used to classify households as water secure (0 points), low WI (1–3 points), moderate WI (4–9 points), or high WI (10–12 points)[29].

Food insecurity

FI was assessed using the Brazilian Food Insecurity Scale (*Escala Brasileira de Insegurança Alimentar*, EBIA), which comprises 14 questions for households with members under 18 years of age and 8 questions for adult-only households, with a reference period of the three months preceding the interviews. Response options are dichotomous (yes/no), and each affirmative answer received one point. The total score was used to classify households as food secure (0 points) or into levels of FI severity according to the presence of members under 18 years of age (mild FI = 1–5 points; moderate FI = 6–9 points; severe FI = 10–14 points) or of adults only (mild FI = 1–3 points; moderate FI = 4–5 points; severe FI = 6–8 points)[7].

Other study variables

The sociodemographic profile of households was assessed according to the following: characteristics of the household head (sex of the reference person [male/female]; self-classified race/skin colour according to the IBGE categories [White, Black, Brown or mixed race, Yellow (Asian) or Indigenous], excluding the Indigenous (0.62%) and Yellow (0.45%) categories because the study was conducted in a municipality that lacks representation of ethnic-racial minorities, and analysing the Black and Brown categories grouped together; and schooling in years of study [≤ 8 years/≥9 years]). Information was also collected on the presence of household members under 5 years of age (yes/no); monthly household per capita income, categorised into income terciles (1st/2nd/3rd), considering the monthly wage of R$ 1,320 in 2024 converted at the US dollar exchange rate at the time (US$ 270); type of residence (house, apartment, collective/improvised housing); and number of residents (≤ 4, ≥ 5).

Information on household access to water was also assessed: main source of water supply (public water supply system or other), availability of a water storage tank (at least one/none), and frequency of water availability (daily or other frequency).

Conceptual model

To evaluate the effect of indicators of social inequality and of WI on FI, a hierarchical model was used, in which the determinants of FI were organised into three levels of determination according to their causal proximity to FI: basic determinants (level 1), intermediate determinants (level 2) and immediate determinants (level 3), as illustrated in Fig. 1. The model was based on the studies by Kepple and Segall-Corrêa (2011)[30], Lignani et al. (2020)[31] and Young (2021)[32].

Basic determinants (level 1) correspond to structural and sociodemographic characteristics that condition, in a more remote way, inequalities in access to food. These factors act as structural markers of social vulnerability, conditioning the subsequent levels of the causal chain. The variables considered were: sex, race/ethnicity, years of schooling, type of residence, number of residents per household, and household members under 5 years of age. The intermediate determinant (level 2), monthly household per capita income, occupies an intermediate position in the model because it represents the mechanism through which structural conditions (level 1) are converted into an effective capacity to access and purchase food.

Immediate determinants (level 3) correspond to conditions directly related to household WI, considered in this model as proximal determinants of FI, given the interdependence between access to water and the production, preparation and consumption of food. The variables considered were: the main source of water supply, water storage tank availability, frequency of water availability, and WI. This hierarchical structure makes it possible to investigate both the direct and indirect effects of structural socioeconomic conditions on FI, contributing to the identification of causal pathways and potential points of intervention at different levels of determination.

Insert Fig. 1. Hierarchical model of determinants of household food insecurity among residents in the Municipality of Rio de Janeiro, Brazil.

Statistical analysis

For the statistical analysis, percentage distributions and the respective 95% confidence intervals (95% CI) were calculated according to the variables and hierarchical level. To analyse the associations between the independent variables and the outcome, multinomial regression was used, estimating Relative Risk Ratios (RRR) and their respective 95% CIs. Initially, bivariate models were fitted for each explanatory variable in relation to the main outcome of the study. Variables with *p-value < 0.20* were selected for inclusion in the multivariable analysis, following a previously established hierarchical model[33]. At each level of the model, variables were retained in the subsequent adjustments if they remained associated with the outcome at the 5% significance level. All analyses incorporated the complex sampling design, applying weights, strata, and clusters, using the SVY commands in Stata version 16.1[34].

Results

The final sample comprised 2,000 households. About half of the household heads were women (51.3%), with a significantly higher proportion of self-declared as Black or Brown (70.9%) and with 9 or more years of schooling (64.6%), and 38.3% of households were in the 1st tertile of monthly household per capita income. Almost all residences were apartments (19.8%) or houses (77.2%), with up to four residents per household (92.8%), predominantly with no members under 5 years of age (88.3%), with a public water supply system (98.9%), a water storage tank (89.1%) and daily water availability (72.2%) (p-value < 0.001). Regarding water access, as assessed by WI, 47.2% of households were water secure, 19.5% with low WI, 26.4% with moderate WI and 6.8% with high WI (p-value < 0.001). Food security was significantly higher among the families assessed (70.1%), whereas moderate/severe FI was present in 14.1% of households (Table 1).

Table 1
Prevalence ratio (%) and 95% confidence intervals (CI) of socio-demographic characteristics, water security and insecurity and food security and insecurity.

Socio-demographic characteristics	Total	
	Proportion (%)	**95% CI**
Head of household characteristic		
Sex (n = 1,980)		
Male	48.7	46.2–51.3
Female	51.3	48.7–53.8
Race/ethnicity (n = 1,975)		
White	29.1	26.9–31.5
Brown/Black	70.9	68.5–73.1
Years of schooling (n = 2,000)		
0 to 8 years	35.4	32.9–37.8
9 years or more	64.6	62.2–67.0
Monthly household *per capita* income[1] (n = 1,778)		
1st tertile	38.3	35.7–40.9
2nd tertile	32.8	30.4–35.4
3rd tertile	28.8	26.6–31.3
Household characteristics		
Type of residence (n = 2,000)		
Apartment	19.8	18.1–21.6
House	77.2	75.4–79.0
Collective or informal housing	3.0	2.3–3.8
Number of residents per household (n = 2,000)		
Up to 4	92.8	91.6–93.9
5 or more	7.2	6.1–8.4

Notes: [1]*Per capita* household income in minimum wages: R$ 1,320.00 Brazilian reals, or US $264.00 (2023–2024); [2]Water security and insecurity according to the Household Water Insecurity Experiences Scale - HWISE (Young et al., 2019); [3]Food security and insecurity according to the Brazilian Household Food Insecurity Scale (Segall-Correa et al., 2014). Data are from the First Survey on Food Insecurity in the Municipality of Rio de Janeiro, Brazil, 2024.

Socio-demographic characteristics	Total	
	Proportion (%)	95% CI
Household members under 5 years (n = 2,000)		
None	88.3	86.9–89.6
At least one child under 5 years	11.7	10.4–13.2
Main source of water supply (n = 1,997)		
Public water supply system	98.9	98.4–99.3
Other	1.1	0.7–1.6
Water storage tank availability (n = 1,998)		
At least one	89.1	87.7–90.4
None	10.9	9.6–12.3
Frequency of water availability (n = 1,965)		
Daily	72.2	70.1–74.1
Other frequency	27.8	25.9–29.9
Water Insecurity[2] (n = 1,992)		
Water security	47.2	44.7–49.8
Low water insecurity	19.5	17.5–21.7
Moderate water insecurity	26.4	24.2–28.8
High water insecurity	6.8	5.6–8.2
Food insecutiry[3] (n = 1,996)		
Food security	70.1	68.1–72.1
Mild food insecurity	15.8	14.2–17.4
Moderate/severe food insecurity	14.1	12.6–15.7

Notes: [1]*Per capita* household income in minimum wages: R$ 1,320.00 Brazilian reals, or US $264.00 (2023–2024); [2]Water security and insecurity according to the Household Water Insecurity Experiences Scale - HWISE (Young et al., 2019); [3]Food security and insecurity according to the Brazilian Household Food Insecurity Scale (Segall-Correa et al., 2014). Data are from the First Survey on Food Insecurity in the Municipality of Rio de Janeiro, Brazil, 2024.

Insert Table 1

Figure 2 shows the prevalence of WI by food security and FI level. The proportion of food-secure households decreased with increasing WI severity: the highest proportion of food security was observed among water-secure households (85.3%, 95%CI = 82.5, 87.8) and the lowest (17.5%; 95% CI = 11.6, 25.7) among those with high WI. Among households with mild FI, the proportion was significantly higher in the presence of water security, low WI and moderate WI. For moderate/severe FI, the proportions enhanced with increasing WI severity, being lowest among water-secure households (5.1%; 95% CI = 3.7, 7.1) and highest among those with high WI (63.8%; 95% CI = 53.8, 72.7) (p-value < 0.001).

Insert Fig. 2. Prevalence of water insecurity according to household food security and food insecurity levels.

In the assessment of the relationship between the hierarchical determinants and FI levels, among the basic determinants, female sex, Black or Brown race/ethnicity, 0 to 8 years of schooling, collective or informal housing, 5 or more residents per household and at least one child under 5 years were significantly associated with greater FI severity (p-value < 0.001). Regarding the intermediate determinant, lower monthly household per capita income was significantly associated with FI (p-value < 0.001). Regarding the immediate determinants, no water storage tank availability, no daily water availability and WI were also significantly associated with FI (p-value < 0.001) (Table 2).

Table 2
Proportion (%) and 95% confidence intervals (CI) for food security and food insecurity levels according to sociodemographic characteristics.

Figure 2. Prevalence of water insecurity[1] according to household food security and food insecurity levels[2].

Notes: [1]Water security and insecurity according to the Household Water Insecurity Experiences Scale - HWISE (Young et al., 2019); [2]Food security and insecurity according to the Brazilian Household Food Insecurity Scale (Segall-Correa et al., 2014). Data are from the First Survey on Food Insecurity in the Municipality of Rio de Janeiro, Brazil, 2024.

Insert Table 2

Considering the hierarchical model (Fig. 1) used to evaluate the effect of the study variables on the different levels of FI severity, the results of the bivariate analyses showed that, among the basic determinants, female sex, 0 to 8 years of schooling, type of residence, 5 or more residents per household and at least one child under 5 years were significantly associated with both mild FI and moderate/severe FI. Black or Brown race/ethnicity, in turn, was significantly associated only with moderate/severe FI. Monthly household per capita income, considered an intermediate determinant in the proposed hierarchical model, was also associated with both outcomes. Among the immediate determinants, main source of water supply, water storage tank availability and frequency of water availability were associated with both mild FI and moderate/severe FI, as were all levels of WI, which showed a significant association with a higher risk of mild FI and moderate/severe FI in all the strata analysed (Table 3).

Table 3
Relative Risk Ratio (RRR) and 95% confidence intervals (CI) of the association between hierarchical levels and food insecurity1 (FI).

Socio-demographic characteristics	Food Security[3]		Mild FI[3]		Moderate/Severe FI[3]		
	Proportion (%)	95% CI	Proportion (%)	95% CI	Proportion (%)	95% CI	*p*[4]
1st level							
Sex (n = 1,980)							< 0.001
Male	73.9	70.4–77.0	13.1	10.8–15.9	13.0	10.7–15.8	
Female	60.3	56.7–63.8	20.7	17.9–23.9	19.0	16.2–22.1	
Race/ethnicity (n = 1,975)							< 0.001
White	75.2	70.8–79.2	15.5	12.2–19.4	9.4	6.9–12.5	
Brown/Black	64.0	60.9–66.9	17.2	15.0-19.7	18.8	16.5–21.5)	
Years of schooling (n = 2,000)							< 0.001
0 to 8 years	50.1	45.7–54.4	22.0	18.6–25.9	27.9	24.1–32.1	
9 years or more	76.5	73.6–79.2	24.1	12.0-16.5	9.4	7.6–11.5	
Type of residence (n = 2,000)							< 0.001
Apartment	80.7	75.6–84.9	12.1	8.8–16.5	7.2	4.7–11.0	
House	65.0	62.1–67.7	17.5	15.4–19.9	17.5	15.3–19.9	

Notes: [1]Per capita household income in minimum wages: R$ 1,320.00 Brazilian reals, or US $264.00 (2023–2024); [2]Water security and insecurity according to the Household Water Insecurity Experiences Scale - HWISE (Young et al., 2019); [3]Food security and insecurity according to the Brazilian Household Food Insecurity Scale (Segall-Correa et al., 2014); [4]P values refer to the $\chi 2$ test for differences in proportions; Data are from the First Survey on Food Insecurity in the Municipality of Rio de Janeiro, Brazil, 2024.

Socio-demographic characteristics	Food Security[3]		Mild FI[3]		Moderate/Severe FI[3]		
	Proportion (%)	95% CI	Proportion (%)	95% CI	Proportion (%)	95% CI	*p*[4]
Collective or informal housing	53.5	39.6–67.0	25.0	14.5–39.5	21.5	12.3–34.9	
Number of residents per household (n = 2,000)							< 0.001
Up to 4	69.0	66.4–71.4	15.2	13.3–17.2	15.8	13.9–18.0	
5 or more	39.7	30.4–49.7	42.6	32.8–53.1	17.7	11.2–26.7	
Household members under 5 years (n = 2,000)							< 0.001
None	69.2	66.6–71.7	16.2	14.3–18.4	14.6	12.7–16.7	
At least one child under 5 years	51.3	43.8–58.8	22.0	16.2–29.2	26.6	20.2–34.2	
2nd level							
Monthly household *per capita* income[1] (n = 1,778)							< 0.001
1st tertile	37.8	33.6–42.2	29.4	25.4–33.8	32.8	28.7–37.2	
2nd tertile	72.3	67.9–76.3	16.4	13.2–20.2	11.3	8.6–14.7	
3rd tertile	93.6	90.5–95.7	3.9	2.4–6.4	2.4	1.2–4.9	
3rd level							

Notes: [1]Per capita household income in minimum wages: R$ 1,320.00 Brazilian reals, or US $264.00 (2023–2024); [2]Water security and insecurity according to the Household Water Insecurity Experiences Scale - HWISE (Young et al., 2019); [3]Food security and insecurity according to the Brazilian Household Food Insecurity Scale (Segall-Correa et al., 2014); [4]P values refer to the $\chi 2$ test for differences in proportions; Data are from the First Survey on Food Insecurity in the Municipality of Rio de Janeiro, Brazil, 2024.

Socio-demographic characteristics	Food Security[3]		Mild FI[3]		Moderate/Severe FI[3]		
	Proportion (%)	95% CI	Proportion (%)	95% CI	Proportion (%)	95% CI	*p*[4]
Main source of water supply (n = 1,997)							0.039
Public water supply system	67.6	65.1–70.0	16.7	14.8–18.7	15.7	13.9–17.8	
Other	38.2	18.6–62.5	31.4	13.9–56.5	30.4	13.5–55.1	
Water storage tank availability (n = 1,998)							< 0.001
At least one	70.3	67.7–72.7	16.6	14.6–18.8	13.1	11.3–15.2	
None	41.0	33.6–48.8	19.1	13.9–25.8	39.9	32.3–48.0	
Frequency of water availability (n = 1,965)							< 0.001
Daily	75.3	72.5–77.9	14.0	11.9–16.3	10.7	8.9–12.9	
Other frequency	49.8	45.1–54.6	22.7	18,8–27.0	27.5	23.3–32.1	
Water Insecurity[2] (n = 1,992)							< 0.001
Water security	85.3	82.5–87.8	9.6	7.6–12.0	5.1	3.7–7.1	
Low water insecurity	63.9	57.8–69.6	19.4	15.0-24.8	16.7	12.5–21.9	
Moderate water insceurity	50.8	45.7–55.9	26.9	22.6–31.6	22.3	18.3–27.0	
High water insecurity	17.5	11.6–25.7	18.7	11.9–28.0	63.8	53.8–72.7	

Notes: [1]Per capita household income in minimum wages: R$ 1,320.00 Brazilian reals, or US $264.00 (2023–2024); [2]Water security and insecurity according to the Household Water Insecurity Experiences Scale - HWISE (Young et al., 2019); [3]Food security and insecurity according to the Brazilian Household Food Insecurity Scale (Segall-Correa et al., 2014); [4]P values refer to the $\chi 2$ test for differences in proportions; Data are from the First Survey on Food Insecurity in the Municipality of Rio de Janeiro, Brazil, 2024.

After adjustment in the hierarchical model, mild FI remained significantly associated among families when the reference person was a woman, had lower schooling and when the household had more than five residents (p-value < 0.05). Households in the lowest tertile of monthly per capita income had an adjusted RRR of 12.2 for mild FI compared with food-secure households (95% CI = 6.4, 23.4). Regarding the association between WI and mild FI, the ajusted RRR increased with increasing WI severity, such that households with high WI had an ajusted RRR of 5.3 for mild FI compared with food-secure households (p-value < 0.001). (Table 3).

As for moderate/severe FI, after hierarchical adjustment, households headed by people of Black or Brown race/ethnicity and with lower schooling remained significantly associated with a higher risk of the severe forms of FI, as did households with lower per capita household income (p-value < 0.001). The severity of WI levels remained significantly and directly associated with moderate/severe FI. Households experiencing high WI had and ajusted RRR of 46.6 for moderate/severe FI compared with water-secure households (p-value < 0.001). (Table 3).

Insert Table 3

Discussion

This study evaluated the relationship between WI and FI in the urban area of Rio de Janeiro, a city characterised by marked social and territorial inequalities, and by inequalities in access to basic services. As expected, factors of social inequality that are described in the literature as associated with FI, such as gender, racial and income inequalities, remained significantly related to increases in the severe forms of FI. It is noteworthy that, after adjustment in the hierarchical model, the study revealed that WI remained associated with both mild and moderate/severe FI. Households experiencing high WI had and ajusted RRR of 46.6 for moderate/severe FI compared with water-secure households. This may indicate that WI represents another dimension of social vulnerability, in which families experience restrictions in access to water and food in adequate quantity and quality.

The findings of the present study corroborate previous evidence of an association between WI and FI in international studies, especially in contexts of socioeconomic vulnerability[10,12,15], given that households experiencing WI may have a reduced capacity to ensure food security[35] and to guarantee the human right to adequate and healthy food.

The central issue highlighted by the present study was the strong relationship between the severity of WI, measured by the first Portuguese version of a scale for assessing household WI in Brazil, and FI. The results indicated a significant association between these two indicators of social inequality in population-based studies, that is, FI and WI. One possible explanation for the relationship between WI and FI is that water is an essential element for the preparation, cleaning and preservation of food[8], especially unprocessed or minimally processed foods such as leafy greens, fruits, grains and

vegetables[36]. Thus, the absence or irregularity of water directly compromises the availability and quality of the families' food[37].

In addition, WI is associated with the consumption of alternative sources of hydration, including sugar-sweetened beverages such as artificial fruit drinks and soft drinks[34], which may aggravate the guarantee of healthy and adequate food and increase the risk of obesity[38,39]. In a qualitative study conducted in Brazil[40], families who took part in focus groups reported that WI led to significant changes in food preparation. In the face of water shortages, families opted for simpler meals that require fewer utensils to wash afterwards. These meals were generally characterised by the absence of vegetables, leafy greens, pulses and other preparations that require water. The families also reported having to resort to ready-to-eat foods and meals, in addition to replacing water with soft drinks, owing to uncertainty about the quality of the water available[40].

In addition to affecting food preparation, WI also aggravates FI by reducing households' capacity to produce and acquire food, limiting food choices[8] and altering the household budget through additional water-related expenses that could otherwise be spent on food[41]. The diversion of financial resources intended for buying food towards the purchase of drinking water and/or water treatment technologies results in a smaller quantity and diversity of food for consumption[42], especially in households whose income is already restricted.

Furthermore, inadequate access to water can make food biologically unsafe for consumption due to poor hygiene and preparation conditions[8], which accounts for its association with health outcomes such as diarrhoea and dehydration[38].

These mechanisms are reinforced by the fact that WI, as captured by measurement scales such as the one used in the present study, is determined by structural factors such as infrastructure limitations in households and territories, economic affordability and the occurrence of extreme weather events[37]. Since these factors are also recognised as determinants of FI, this reinforces the interrelated nature of the two conditions.

Another important finding of the present study was that, although frequency of water availability was not associated with increased FI in the adjusted model, the absence of water storage tanks was associated with moderate/severe FI. This may be explained by the fact that water storage tanks make it possible to store water during periods of supply interruption or irregularity. In this regard, Brewis et al. (2025) pointed out that intermittent water supply is an important mechanism aggravating FI, since it limits the preparation of unprocessed foods, may induce greater consumption of ultra-processed foods and increases household costs of obtaining water, reducing the resources available for buying food[43]. Corroborating this finding, previous studies have shown that in some households, even when there was enough food, the lack of adequate water for its preparation resulted in changes in the recipes, reduced meal portions or skipped meals[44].

As for the socioeconomic indicators assessed, the study reiterates the greater vulnerability of households headed by a woman, by a Black or Brown person and by a person with lower schooling, factors that contributed to a higher risk of moderate/severe FI when compared with the other food-secure households[45,46,47,48,49,50]. In addition, larger households also have greater difficulty in guaranteeing the human right to adequate food and food and nutrition security, as captured by the FI indicator[31,35].

The associations observed in this study indicated the importance of government policies, at both federal and municipal levels, aimed at reducing the social inequities that sustain inadequate access to food and, consequently, an increased risk of moderate/severe FI in populations such as the one assessed. Câmara et al.[48] (2026) assessed racial issues related to geographical distribution in the same study that gave rise to the present work. According to the authors, FI was more prevalent in regions that have historically had lower levels of social investment and a greater concentration of the Black population, emphasising that FI in the municipality reflects structural racial and territorial inequities that go beyond poverty[26].

It should be noted that the city of Rio de Janeiro presents socio-spatial inequalities, expressed in the higher prevalence of FI in the Central, North and West Zones[21,26]. These territories, marked by a historical lack of investment, concentrate peripheral neighbourhoods with a larger number of favelas and areas of informal occupation by families, such as occupations of high-risk areas and disorganised land invasions. These factors hinder access to basic sanitation and water supply, and may compromise the guarantee of water security. In this regard, one study highlighted that the patterns of inequalities between territories in Rio de Janeiro were evident in differences in household access to water, reinforcing that WI was unevenly distributed across the municipality evaluated in this manuscript[27].

It is worth considering that intermittent water supply is common in the economically more unequal territories of Rio de Janeiro[21], with limited access to infrastructure and low water quality[51]. This way, situations of social vulnerability are perpetuated, compromising the guarantee of the human right to access to water, which is closely linked to the guarantee of the human right to adequate food and to food and nutrition security.

This study has limitations that need to be considered. Because of its cross-sectional design, it is not possible to make causal inferences and, therefore, to establish the temporal direction between WI and FI, nor to rule out reverse causality or the influence of unmeasured factors. However, given the studies that point to a relationship between the vulnerability captured by the WI indicator and food preparation, as presented in this study, and given the strength of the association observed between high WI and moderate/severe FI (RRR = 46.6; 95% CI: 19.9, 109.1), it is unlikely that the inverse relationship, that is, FI leading to WI, explains the results of this study.

Future research should employ longitudinal or qualitative methods to deepen understanding of the dynamics between WI and FI, and should be specifically designed and powered to assess the role of WI in FI. In addition, they should consider broadening the scope to rural areas, assessing the impact of

interventions and public policies, and investigating additional determinants that may influence access to water and food, contributing to more equitable and effective solutions.

Conclusion

The results of this study showed that WI was associated with FI in households in the municipality of Rio de Janeiro, over and above indicators of social inequality. This finding contributes to the understanding that impairments in access to water may directly affect households' capacity to ensure adequate food.

Over the last 20 years, mainly through the use of FI measurement instruments such as the EBIA, the relationships between social inequalities and FI have been corroborated in the literature. However, research on WI as an explanatory factor for FI is more recent, and most studies still treat these conditions dichotomously, considering only presence or absence, without exploring differences between their levels of severity.

In this regard, the relevance of the present study lies in assessing not only the association between WI and FI but also the association between their respective levels of severity. The results showed that increasing WI severity was associated with an increased risk and severity of FI, which reinforces the hypothesis that WI is not merely an isolated deprivation but an additional dimension of social vulnerability, capable of aggravating household FI.

In view of these findings, it is recommended that strategies to tackle FI also include access to water, recognising the interdependence between these conditions. Incorporating WI into food and nutrition security policies may help to identify the most vulnerable groups and guide intersectoral actions aimed at guaranteeing the human right to adequate food and access to water.

Abbreviations

FI – food insecurity

WI – water insecurity

SDG - Sustainable Development Goals

Gross Domestic Product (GPD)

EBIA -Brazilian Food Insecurity Scale / Escala Brasileira de Insegurança Alimentar

CEP - Research Ethics Committee / Comitê de Ética em Pesquisa

HUCFF - Clementino Fraga Filho University Hospital / Hospital Universitário Clementino Fraga Filho

HWISE - Household Water Insecurity Experiences Scale

IBGE - Brazilian Institute of Geography and Statistics / Insituto Brasileiro de Geografia e Estatística

CI – confidence interval

RRR - Relative Risk Ratios

Declarations

Human Ethics and Consent to Participate declarations

This study was conducted in accordance with the relevant guidelines and regulations, including the principles of the Declaration of Helsinki and Brazilian National Health Council Resolution No. 510/2016. It was approved by the Research Ethics Committee of Clementino Fraga Filho University Hospital (HUCFF), Federal University of Rio de Janeiro, in May 2022 (CAAE: 54473421.6.0000.5257). Informed consent was obtained from all participants before their participation in the study. Prior to the interviews, all participants were informed about the research objectives and confidentiality procedures, and signed the Free and Informed Consent Form approved by the HUCFF Research Ethics Committee. The form ensured that participants were aware of the study details and that the confidentiality of the information collected during the interviews would be maintained.

Consent for publication

Not Applicable.

Availability of data and materials

Data cannot be shared publicly because of confidentiality. Data are available for researchers who participated in the “First Survey on Food and Nutritional Insecurity in the Municipality of Rio de Janeiro”.

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Clinical trial number

Not applicable.

Funding

This research project was supported by National Council for Scientific and Technological Development/CNPq (grant number Edital Universal 403264/2023-5); Rio de Janeiro State Research Support Foundation/FAPERJ (grant number Edital APQ1 E26/210365/2024); Câmara Municipal do Rio de Janeiro, through the “First Survey on Food and Nutritional Insecurity in the Municipality of Rio de Janeiro” (grant number 04560/21). R.S-C was supported partially by the Brazilian National Research

Council (grant no. 311060/2023-4), CNPq (grant no. 311060/2023-4) and Rio de Janeiro State Research Support Foundation/FAPERJ (grant number Edital CNE E-26/200.023/2026).

Authors' contributions

J.C.B. contributed to the concept and design of the study, participated in all phases of the study, performed the formal data analysis, wrote the manuscript, and had primary responsibility for the final content. C.C.S.C. contributed to the study design and methodology, supervised the data analysis, critically reviewed the manuscript for intellectual content, and approved the final version to be published. T.F.L.R. undertook the literature review and collaborated on the final manuscript revision. L.S.S. undertook the literature review and collaborated on the final manuscript revision. J.S.S.J. undertook the literature review and collaborated on the final manuscript revision. R.S-C. secured funding, contributed to the methodology, supervised the data analysis, reviewed for intellectual content and edited the final manuscript, and approved the final version to be published.

Acknowledgements

Special thanks to the Coordination for the Improvement of Higher Education Personnel (CAPES), which awarded the master’s degree scholarship that led to this article.

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Figures

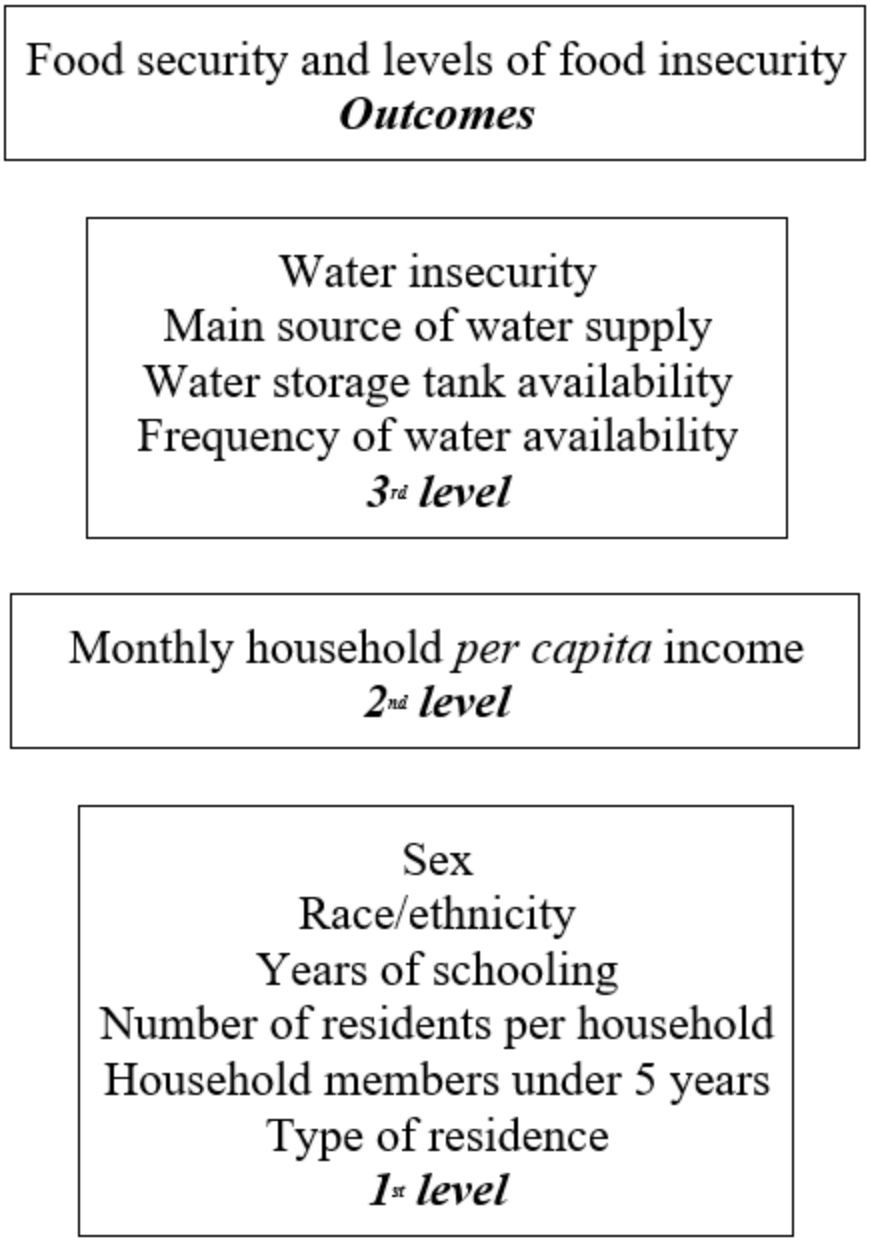


Figure 1

Hierarchical model of determinants of household food insecurity among residents in the Municipality of Rio de Janeiro, Brazil.

Notes: The hierarchical model includes three levels of explanatory variables. The first level comprises sociodemographic and household characteristics; the second level includes monthly per capita household income; and the third level includes water insecurity and water access and storage characteristics. Household food security status is the outcome.