Brazilian adolescents' dietary environmental footprints: a cross-sectional study with data from the National Students' Health Survey, 2015

Pegadas ambientais da alimentação de adolescentes brasileiros: estudo transversal com dados da Pesquisa Nacional de Saúde do Escolar, 2015

Diôgo Vale [1]

Camila Valdejane Silva de Souza [2]

Natalie Marinho Dantas [3]

Maria Hatjiathanassiadou [4]

Clélia de Oliveira Lyra [5]

Larissa Mont'Alverne Juca Seabra [6]

Angelo Giuseppe Roncalli [7]

[1] PhD in Collective Health, Nutritionist, Instituto Federal de Educação, Ciência e Tecnologia do Rio Grande do Norte, Ceará-Mirim, RN, Brazil
E-mail: diogo.vale@escolar.ifrn.edu.br

[2] PhD in Collective Health, Nutritionist, Prefeitura Municipal de Tangará, Tangará, RN, Brazil
E-mail: camila.valdejane@gmail.com

[3] PhD in Public Health Nutrition, Professor, Universidade de Campinas, Campinas, SP, Brazil
E-mail: ndantas@unicamp.br

[4] Master's in Nutrition, Universidade Federal do Rio Grande do Norte, Natal, RN, Brazil
E-mail: mariahatji@hotmail.com

[5] PhD in Health Sciences, Professor, Universidade Federal do Rio Grande do Norte, Natal, RN, Brazil
E-mail: clelia.lyra@ufrn.br

[6] PhD in Health Sciences, Professor, Universidade Federal do Rio Grande do Norte, Natal, RN, Brazil
E-mail: larissa.seabra@ufrn.br

[7] PhD in Preventive and Social Dentistry, Professor, Universidade Federal do Rio Grande do Norte, Natal, RN, Brazil
E-mail: roncalli@terra.com.br

doi:10.18472/SustDeb.v16n1.2025.57130

Received: 05/02/2025
Accepted: 07/04/2025

ARTICLE- VARIA

ABSTRACT

This study aimed to analyse Brazilian adolescents' dietary environmental sustainability indicators and their associations with socioeconomic factors and nutritional status. This is a cross-sectional study using data from Brazilian adolescents (11-19 years old) from the 2015 National Students' Health Survey. Estimates were made of the environmental footprints of adolescents' diets, including water, ecological, and carbon footprints. Secondary variables were socioeconomic and nutritional status. Correspondence analyses were used to estimate the associative models between the secondary variables and the quintiles of each environmental footprint. The means of the carbon, water, and ecological footprints for the Brazilian adolescents' diet were, respectively, 1206 gCO_2eq/kg (95%CI: 1192-1219), 2760 liters/kg (95%CI: 2730-2789), and 8.07 $g\text{-}m^2/kg$ (95%CI: 7.99-8.16). The lowest quintiles of the environmental footprints of food analysed were associated with dietary patterns characterised by a higher presence of ultra-processed foods and living in more urbanised areas.

Keywords: Adolescent. Sustainable Development Indicators. Social Conditions. Food Consumption. Environmental Impact.

RESUMO

O objetivo deste estudo foi analisar indicadores de sustentabilidade ambiental da alimentação de adolescentes brasileiros e suas associações com fatores socioeconômicos e de estado nutricional. Trata-se de estudo transversal com dados de adolescentes brasileiros (11-19 anos) oriundos da Pesquisa Nacional de Saúde do Escolar, 2015. Estimaram-se as pegadas ambientais semanais (hídrica, ecológica e de carbono) da alimentação de adolescentes. As variáveis secundárias foram do tipo socioeconômicas e de estado nutricional. Análises de correspondência estimaram os modelos associativos entre as variáveis secundárias e os quintis de cada uma das pegadas ambientais. As médias das pegadas de carbono, hídrica e ecológica referentes à alimentação de adolescentes brasileiros foram, respectivamente, 1206 gCO_2eq/kg *(IC95%: 1192-1219), 2760 litros/kg (IC95%: 2730-2789) e 8,07* $g\text{-}m^2/kg$ *(IC95%: 7,99-8,16). Os piores quintis das pegadas ambientais da alimentação analisadas foram associados a padrões alimentares caracterizados pela maior presença de alimentos ultraprocessados e por viver em territórios mais urbanizados.*

Palavras-chave: *Adolescente. Indicadores de Desenvolvimento Sustentável. Condições Sociais. Consumo Alimentar. Impacto Ambiental.*

1 INTRODUCTION

Changes in food systems and dietary patterns with negative repercussions on human health and the environment have been observed globally (RAN *et al.*, 2024). These are partly explained by global food systems primarily based on extensive monoculture, which is characterised by soil depletion, high consumption of water and fuels, use of chemical fertilisers, pesticides, antibiotics, genetically modified seeds, and long-distance transportation. This set of factors leads to environmental degradation and pollution, reduction in biodiversity, and compromise of water, energy, and other natural resource reserves (Belgacem *et al.*, 2021; Çakmakçi *et al.*, 2023; United Nations, 2015).

In 2015, United Nations (UN) member states approved a sustainable development agenda to address this context. This document presents 17 Sustainable Development Goals (SDGs), among which are actions and targets directly related to minimising the impacts of food production and consumption

ISSN-e 2179-9067

on the environment. These include zero hunger and sustainable agriculture (SDG 2); availability and sustainable management of water and sanitation for all (SDG 6); reduction of inequalities (SDG 10); sustainable cities and communities (SDG 11); responsible consumption and production (SDG 12); action against global climate change (SDG 13); life below water (SDG 14); life on land (SDG 15) (European Public Health Association, 2017; United Nations, 2015).

These Sustainable Development Goals (SDGs) directly connect with various food and nutritional issues, encompassing access, production, consumption, and the impact on the entire food system. Specifically, SDG 12 discusses the need for sustainable production and consumption patterns. It emphasises the necessity to "support developing countries in strengthening their scientific and technological capacity to shift towards more sustainable production and consumption patterns" (United Nations, 2015). This goal requires significant consideration in Nutrition and Public Health, including incorporating sustainability in research and management actions related to food and nutrition care (Brazil, 2015). In line with the SDGs, the Strategic Action Plan to Tackle Non-communicable Diseases (NCD) in Brazil, 2021-2030, also envisions promoting healthy and sustainable environments across different strategic action areas for health promotion, prevention, care production, and assistance in addressing risk factors for non-communicable diseases and conditions (Brazil, 2021).

The connections between food, nutrition, and sustainability in the context of health gained increased visibility following the publication discussing "The Global Syndemic," which highlighted interactions among global issues of obesity, undernutrition, and environmental climate disorders (Swinburn *et al.*, 2019). Given this, it is imperative to understand how current food systems interact with food, nutritional, and environmental issues. There is an urgent need for more information and evidence to support collective actions that can transform these systems into more sustainable models. This transformation should focus on promoting health, ensuring the human right to adequate and healthy food, and encouraging positive changes in dietary behaviors among the population (Dixon; Michelsen; Carpenter, 2023).

Within the scope of individual actions related to the consumption dimension, studies indicate that adopting healthy dietary patterns involves using fewer natural resources and lowering emissions of greenhouse gases (GHG) (Grosso *et al.*, 2020). According to the EAT-Lancet Commission, a healthy dietary pattern would include plant-based protein sources, unsaturated fats from plant sources, whole grain carbohydrates, fruits and vegetables, and a moderate, optional consumption of dairy and eggs (Willett *et al.*, 2019).

It is known that adopting healthy dietary habits represents a global health issue and is challenging given the various life contexts. In this regard, adolescents aged 10 to 19 years (WHO, 2005) are characterised by high consumption of ultra-processed products and low intake of fruits and vegetables (Souza *et al.*, 2019). The dietary pattern of Brazilian adolescents follows this trend with higher consumption of processed and ultra-processed foods, of which about 72.3% demonstrate this dietary consumption with greater risk for the health-disease process (Tavares *et al.*, 2014), marked by higher intake of soft drinks, snacks, fried salty foods, and ultra-processed salty snacks (Maia *et al.*, 2018).

Nutrition should be approached based on the concept of "sustainable food," as described by the Food and Agriculture Organization of the United Nations – FAO (FAO, 2010), which considers multidimensional factors in the food production and consumption chain, contemplating the interactions of environmental, economic, social, cultural, and health aspects for the promotion of a diet that is both healthy and sustainable (Harris *et al.*, 2020; Von Koerber *et al.*, 2017).

Assessing the environmental impact of products or productive processes using environmental indicators is important to highlight damages caused by products, processes, and even behavioral patterns. According to Carvalho *et al.* (2010), these indicators can assist in monitoring the operationalisation of sustainable development through the evaluation of the pillars of sustainability (environmental, social, and economic). These indicators are objective parameters in selecting products or adopting practices favourable to the environment. In the context of nutrition, they can guide the choices of foods and diets (Garzillo *et al.*, 2019).

One strategy that can be employed to assess the environmental dimension of sustainable eating is the estimation of environmental indicators such as water, ecological, and carbon footprints. The water footprint (WF) calculates the total amount of freshwater used directly or indirectly by a consumer or producer throughout the entire life cycle, expressed in liters of water used per kilogram of food consumed (liters/kg) (Egan, 2011). The carbon footprint (CF) can be defined as the amount of greenhouse gases expressed in carbon equivalents (CO_2eq) that are emitted into the atmosphere by an individual, product, process, organisation, or event within a specified boundary, considering the entire life cycle (Pandey; Agrawal; Pandey, 2011). The ecological footprint (EF) is a tool that accounts for how much humanity demands from the biosphere's regenerative capacity, considering the demands for producing renewable resources and carbon assimilation. It compares them with the planet's "ecological assets," assessing anthropogenic impacts, typically evaluated separately (carbon emissions, land use change, biodiversity consumption, etc.) (Galli *et al.*, 2011).

Research has shown that dietary patterns with high consumption of animal-sourced foods (Hallström; Carlsson-Kanyama; Börjesson, 2015) and ultra-processed foods have a more significant negative impact on the environment, whereas traditional dietary patterns, such as the Mediterranean diet, showed less impact. This underscores the need for dietary intake changes to preserve human and environmental health (European Public Health Association, 2017).

In Brazil, studies that have estimated the environmental footprints of adolescents with national representation are still scarce. Among them, the result indicating an average water footprint of 2925.9 liters/kg of food and higher averages of this environmental impact marker among adolescents who frequent fast food outlets and live in more urbanised regions stand out (Vale *et al.*, 2021a). Given the above, a knowledge gap has been observed in recognising aspects of the sustainability of adolescent nutrition from environmental indicators.

Considering that this demographic is a foundational audience for sustainable development actions (Sheehan *et al.*, 2017), whose nutritional needs demand larger ecological, water, and carbon footprints (Han; Chai; Liao; 2020), and that the production of information on the subject is fundamental to planning policies and actions geared towards healthy and sustainable nutrition and meeting the SDGs, the development of the present study is justified. Thus, the objective of this study was to analyse environmental sustainability indicators of the diets of Brazilian adolescents and their associations with socioeconomic and nutritional status factors. Finally, it is believed that the findings of this research on adolescent students can generate relevant information to enhance actions promoting healthy eating in schools (Brazil, 2023).

2 METHODS

2.1 STUDY CHARACTERISTICS

This cross-sectional survey-based study utilises "sample 2" data from the 2015 National Survey of School Health (PeNSE). This sample collected data from schoolchildren aged 10 to 19 years, unlike sample 1, which assessed only ninth-grade students, as in the 2009 and 2012 editions of PeNSE. The PeNSE surveys are conducted by the Brazilian Institute of Geography and Statistics (IBGE) in partnership with the Ministry of Health and the Ministry of Education of Brazil.

In 2015, the school-aged adolescent population was expanded compared to the 2009 and 2012 data collections. Therefore, the 2015 dataset was selected for analysis in the present study as it offers an opportunity to initiate the assessment of environmental food indicators representative of the Brazilian school-aged adolescent population (Brazil, 2016). Following the release of this initial dataset with an expanded sample, IBGE published the 2019 data and began collecting data for 2024, which are not yet available to researchers. In the future, the data from these three studies may be compared to evaluate aspects of diet and sustainability related to this population over time.

About ethical considerations, the 2015 PeNSE was approved by the National Committee of Ethics in Research (Conep) on March 30, 2015 (registration no. 1.006.467) (IBGE, 2016). Furthermore, the present study complied with the ethical guidelines for research involving human subjects as outlined in Resolution No. 510 of April 7, 2016, of the National Health Council (Brazil, 2016).

2.2 STUDY VARIABLES

The primary variables were the weekly averages of water footprint (liters/kg), ecological footprint (g-m^2/kg), and carbon footprint (gCO_2e/kg) estimated for each adolescent's diet based on the following these steps: (1) estimation of average footprints for each of the seven food markers from the PeNSE 2015 according to the Garzillo *et al.* (2019) database; (2) estimation of average per capita figures for 2015 for each of these food markers for urban and rural areas across the five Brazilian regions, based on data from the The Consumer Expenditure Survey (POF) of 2009 (IBGE, 2010) and 2018 (IBGE, 2019); (3) development of average weekly footprint factors for water, ecology, and carbon per food marker, day, residence location, and geographical region; and (4) estimation of the water, ecological, and carbon footprints of each adolescent's diet resulting from the product of the footprints of each food marker and their weekly consumption frequency (Vale *et al.*, 2021b).

The secondary variables included sex (male, female), age in years (>15 years; 15 years or older), nutritional status (underweight, normal weight, overweight), dietary pattern (higher nutritional risk; lower nutritional risk), school (public; private), space (urban; rural), Brazil and geographical macro-region (North, Northeast, Southeast, South, and Central-West). Nutritional status was calculated based on the BMI-Age indicator, using data on sex, weight, height, and age. BMI was calculated using the formula [weight (kg) / height^2 (m)], and the data were processed using WHO AnthroPlus software (WHO, 2016).

The cutoff points for nutritional status assessment were the WHO references (2006) (WHO, 2006). The BMI-Age indicator was categorised into underweight (BMI-A < Z-score -2), normal weight (BMI-A ≥ Z-score -2 and < Z-score +1), and overweight (BMI-A ≥ Z-score +1).

The estimation of dietary patterns was conducted using the weekly consumption frequency variables of seven food markers. A non-hierarchical cluster analysis (k-means) was applied to create two clusters named "dietary pattern of higher nutritional risk," characterised by lower weekly consumption of beans, fruits, vegetables, and higher consumption of salty ultra-processed foods, sweets, sodas, and fried snacks; and "dietary pattern of lower nutritional risk," characterised by higher consumption of beans, fruits, vegetables and lower consumption of the other analysed food markers (Vale *et al.*, 2022). Additionally, each footprint (water, ecological, and carbon) was estimated for each food group: beans, fruits, vegetables, salty ultra-processed foods, sodas, sweets, and fried snacks (Vale *et al.*, 2021b).

2.3 STATISTICAL ANALYSIS

Descriptive statistics were utilised to estimate means and confidence intervals (95% CI) for Brazil's water, ecological, and carbon footprints and each secondary variable. These estimates accounted for the sample design effect and the sample expansion factors.

Correspondence analysis was employed to identify associations between the categories of footprints and other variables. This statistical technique produced multidimensional maps from three contingency tables, which were constructed considering the sample design. In these tables, the quintiles of the footprints were compared with the secondary variables. The analyses were conducted using the XLSTAT® software.

3 RESULTS

Among the adolescents surveyed, the majority were male (50.8%), aged 15 years or older (53.9%), attended public schools (74.8%), resided in urban areas (94.8%), and hailed from the Southeast (40.2%) and Northeast (29.5%) regions of Brazil.

Estimates of the average weekly carbon, water, and ecological footprints related to the dietary intake of Brazilian adolescents were, respectively, 1,206 gCO2e/kg (95% CI: 1192-1219), 2,760 liters/kg (95% CI: 2730-2789), and 8.07 g-m²/kg (95% CI: 7.99-8.16). It was noted that estimates were higher among individuals with a dietary pattern of higher nutritional risk and residents of the South and Southeast regions (Table 1).

Table 1 – Descriptive analysis of adolescent diet's weekly water, ecological, and carbon footprints according to secondary variables (n = 16.608). PeNSE, 2015.

Variable	Population	Carbon footprint ($gCO_2e/kg/week$)		Water footprint (liters/kg/week)			Ecological footprint (g-m²/kg/week)		
	%	Mean	CI 95%	Mean	CI 95%		Mean	CI 95%	
Sex									
Male	50,8	1221,1	1201,0-1241,1	2833,5	2789,6	2877,4	8,23	8,10	8,36
Female	49,2	1189,9	1170,5-1209,4	2684,2	2642,9	2725,5	7,91	7,79	8,03
Age									
Under 15	46,1	1178,8	1160,4-1197,2	2776,7	2736,0	2817,5	8,02	7,90	8,14
15 or older	53,9	1228,6	1208,1-1249,2	2745,7	2702,5	2788,9	8,12	7,99	8,25
BMI-for-age									
Thinness	2,7	1285,9	1202,4-1369,3	2777,5	2595,1	2959,9	8,31	7,78	8,83
Eutrophy	70,7	1219,8	1203,1-1236,5	2770,9	2735,3	2806,4	8,13	8,02	8,23
Overweight	26,6	1160,5	1133,9-1187,1	2729,3	2670,7	2787,8	7,91	7,74	8,08
Dietary pattern (DP)									
Lower nutricional risk	61,6	910,1	896,4-923,8	2379,8	2346,4	2413,2	6,56	6,46	6,65
Higher nutritional risk	38,4	1680,2	1660,4-1700,1	3370,0	3319,9	3420,2	10,51	10,37	10,65
School									
Public	74,8	1195,7	1180,4-1211,0	2753,3	2720,8	2785,7	8,03	7,94	8,13
Private	25,2	1270,2	1243,8-1296,6	2802,8	2745,7	2859,8	8,34	8,17	8,50
Area									
Urban	94,8	1235,9	1222,0-1249,9	2837,3	2807,2	2867,4	8,31	8,22	8,39
Rural	5,2	750,4	696,1-804,6	1594,2	1499,6	1688,8	4,57	4,28	4,85

Variable	Population	Carbon footprint (gCO_2e/kg/week)		Water footprint (liters/kg/week)			Ecological footprint (g-m²/kg/week)		
	%	Mean	CI 95%	Mean	CI 95%		Mean	CI 95%	
Dietary pattern (DP)									
North	9,5	865,4	838,5-892,3	1836,6	1788,3	1884,9	5,48	5,33	5,63
Northeast	29,5	1019,2	995,1-1043,4	2103,5	2060,2	2146,9	6,18	6,05	6,31
Southeast	40,2	1341,4	1315,7-1367,1	3185,5	3127,8	3243,3	9,30	9,13	9,46
South	13,2	1513,2	1482,6-1543,8	3565,4	3496,9	3633,8	10,50	10,30	10,70
Central-West	7,7	1104,5	1081,2-1127,7	2807,8	2753,2	2862,4	7,98	7,83	8,14
Brazil		**1205,7**	**1192,0-1219,4**	**2759,9**	**2730,8**	**2789,1**	**8,07**	**7,99**	**8,16**

Source: Authors.

The analysis of factors related to the carbon footprint quintiles among Brazilian adolescents revealed that those associated with the first quintile had a dietary pattern of lower nutritional risk. These adolescents were predominantly residents of the North and Northeast regions and came from rural areas. In contrast, adolescents in the highest quintile of carbon footprint exhibited a dietary pattern with higher nutritional risk and were mainly from the Southern region (Figure 1).

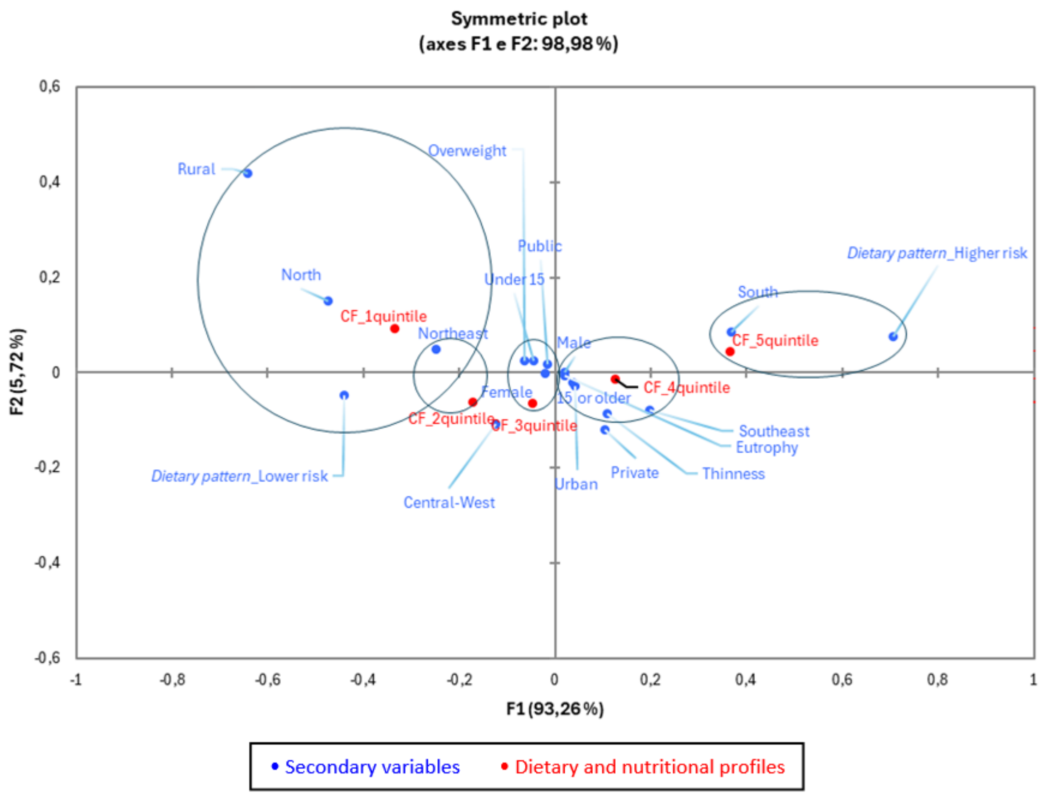

Figure 1 – Correspondence Analysis Applied to the Carbon Footprint (CF) of Diet and Secondary Variables Among Adolescents in Brazil. PeNSE, 2015.

Source: Authors

Lower water footprints were also identified in adolescents with a dietary pattern of lower nutritional risk from rural areas and the North and Northeast regions. In contrast, those with a dietary pattern of higher nutritional risk and residing in the South and Southeast were associated with the last quintile of this footprint (Figure 2).

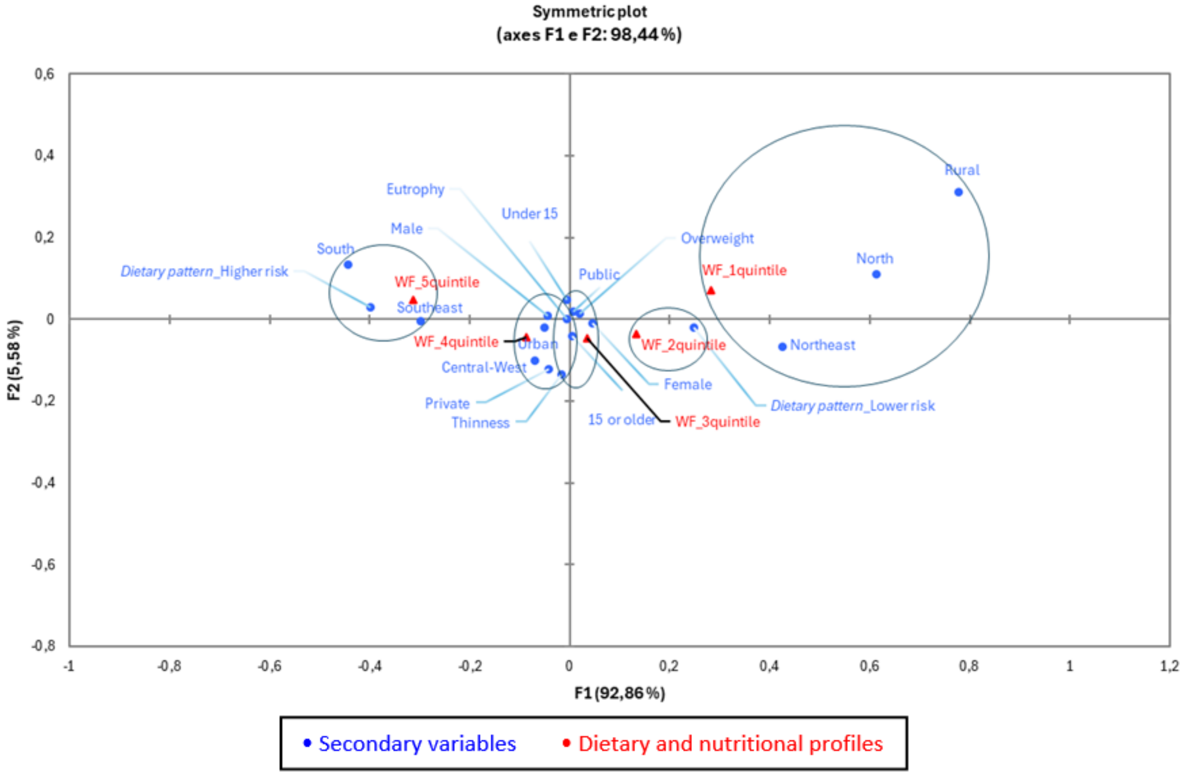

Figure 2 – Correspondence Analysis Applied to the Water Footprint (WF) of Diet and Secondary Variables Among Adolescents in Brazil. PeNSE, 2015.

Source: Authors

For the first and last quintiles of ecological footprints, identical associations to those found in water footprint analyses were identified (Figure 3). As for the intermediate quintiles for all three footprints, there appears to be a trend where urban individuals, those with underweight or normal weight, from private schools, and aged 15 or older, are clustered in the worst sustainability strata, that is, higher water, ecological, and carbon footprints.

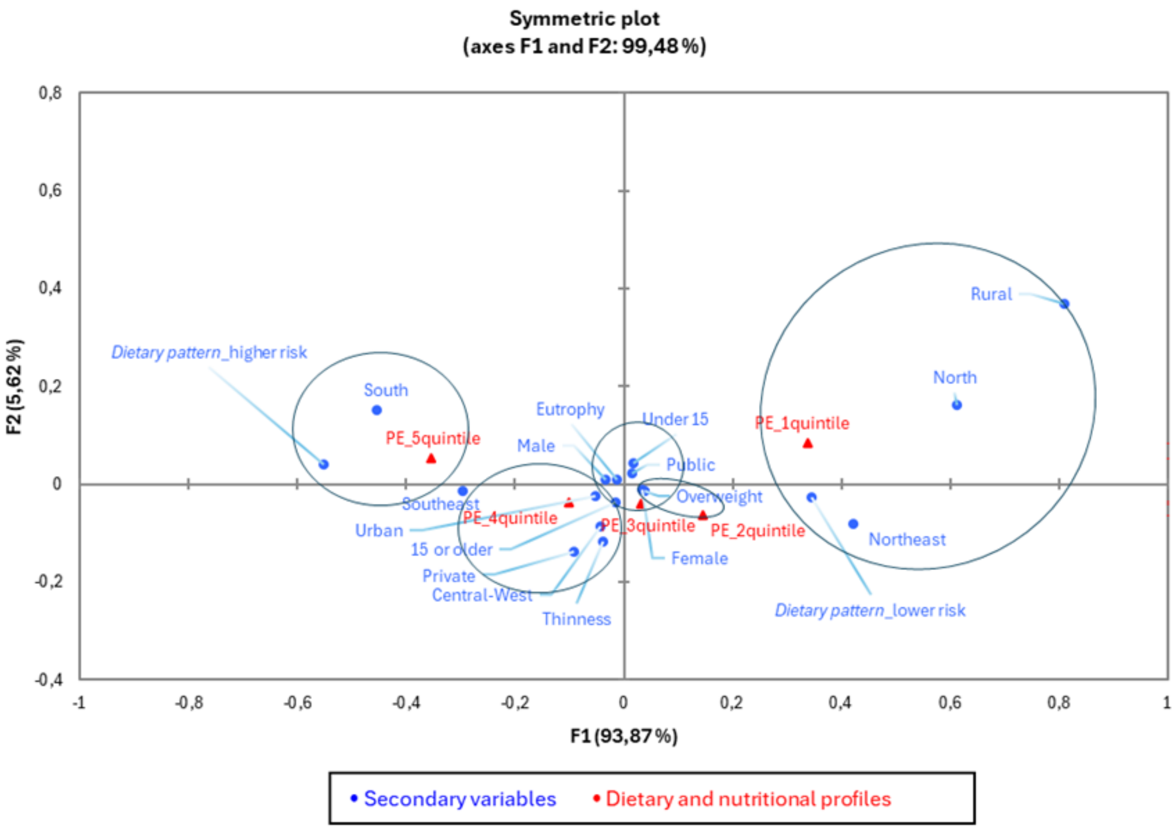

Figure 3 – Correspondence Analysis Applied to the Ecological Footprint (EF) of Diet and Secondary Variables Among Adolescents in Brazil. PeNSE, 2015.

Source: Authors

4 DISCUSSIONS

The current study's findings underscored that the most negative sustainability markers in diets were identified among adolescents with higher nutritional risk dietary patterns and from Brazil's Southern and Southeastern regions. Conversely, the lowest water, ecological, and carbon footprint values were observed in individuals with lower nutritional risk dietary patterns from the Northern and Northeastern regions. These results demonstrate the strong association of ultra-processed foods (such as snacks and soft drinks) with a more significant negative environmental impact. Consequently, they stimulate discussion on the increased consumption of ultra-processed foods and their greater nutritional and environmental impact, presenting as one of the challenges for healthy and sustainable eating.

Similarly, Andrade *et al.* (2023) identified a high percentage of ultra-processed foods in the diets of French children and adolescents (44.2% and 44.5% of total energy intake, respectively). Furthermore, a study with Lebanese adolescents noted a significant increase in environmental footprints with increased consumption of meat products and sugary drinks (Naja *et al*., 2020).

Studies involving adult participants, who also employed food frequency questionnaires to evaluate dietary intake, have shown that diets high in animal-sourced and ultra-processed foods had a greater negative environmental impact. In contrast, Mediterranean dietary patterns exhibited a lesser impact, demonstrating that dietary changes are necessary to preserve human and environmental health (Grosso *et al.*, 2020).

Current food systems are considered one of the leading causes of the Global Syndemic. This process is characterised by changes in dietary patterns and increased consumption of processed and ultra-processed foods. Although these foods meet energy needs, they are defined by their low nutritional quality linked to production processes with direct negative effects on the environment, such as the use of high-demand natural resources, waste generation, greenhouse gas emissions, deforestation, soil degradation, and biodiversity loss, thereby being considered as the driving force of the syndemic (Gebhardt *et al*., 2020; Swinburn *et al*., 2019).

The research identified a less sustainable dietary intake among adolescents from the South and Southeast regions. These regions have the highest proportions of territories with outlets selling ultra-processed foods (Caisan, 2018). This dietary profile correlates with a higher negative environmental impact in areas with greater biodiversity scarcity, such as these highly urbanised macro-regions. It is important to highlight that the environmental impact of this dietary consumption not only affects these areas, as food production occurs in different territories, typically with lower urban development, following the logic of export monocultures, which do not promote short production and consumption circuits.

For instance, the growth of agriculture in Brazil threatens ecosystem functions and mega-biodiversity essential for agricultural production (Martinelli; Filoso, 2009). Therefore, the dietary consumption of a population in a territory affects not only the food systems coexisting in that space; this negative practice demands natural resources available in that immediate environment and from other spaces involved in food production to disposal.

Identifying ultra-processed food products and their environmental impacts on territories and planetary health, not merely as foods with negative effects on individual health, is an interesting strategy for adolescent nutritional education. A study on food consumers concerned with sustainability found that these individuals tended to be "open to experiences" (Feil *et al*., 2020). It is known that this is a typical social profile among people in adolescence, during biological and psychosocial changes and identity formation (Alonso-Stuyck, 2020).

It is argued that improving diet sustainability without drastic changes to eating habits, even in non-vegetarian patterns, is possible. Many of these patterns demonstrate good compatibility with nutritional, environmental, accessibility, and acceptability dimensions (Perignon *et al*., 2017).

Given this possibility, efforts in adolescent nutritional education can be intensified, focusing on sustainability and agroecology (Ronto *et al*., 2016). Education for sustainability should focus on building a socio-ecological culture that aims to protect both human beings and nature (Pereira; Calgaro, 2019), as well as overall sustainability (Boff, 2017). These issues are increasingly discussed with adolescents in school (Derqui; Grimaldi; Fernandez, 2020) and family environments (Queiroz *et al*., 2020), and should positively impact planetary health.

In this context, the Brazilian framework for nutritional education outlines its first two structuring principles as social, environmental, and economic sustainability and a comprehensive approach to the food system (Brazil, 2012). These are points promoted by various Sustainable Development Goals (SDGs), such as SDG 13: "Improve education, enhance awareness and human and institutional capacity on climate change mitigation, adaptation, impact reduction, and early warning" (United Nations, 2015).

Schools can be ideal settings for discussions about food and sustainability among adolescents. In these environments, themes related to environmental changes and their impacts are often addressed. However, conversations about food typically focus on food waste. This presents an opportunity to explore issues regarding food systems and sustainability in their environmental, economic, and social dimensions (Brazil, 2012). Consequently, this facilitates the promotion of proper nutrition and dietary practices among adolescents in alignment with the Sustainable Development Goals (SDGs).

In Brazil, this discussion was integrated into the Dietary Guidelines for the Brazilian Population (Brazil, 2014) and in the actions of the National School Feeding Program (Pnae) (Brazil, 2020). Nevertheless, the dissolution of the National Council for Food Security and Nutrition (Consea) in 2018 undermined the Food Security System, halting various initiatives (Castro, 2019). These efforts were only resumed in 2023. Changes in dietary habits are closely linked to people's life realities, which in Brazil are marked by social inequities that hinder the realisation of the human right to adequate and healthy food.

With the resumption of national social control bodies for food security and nutrition, it is essential to prioritise specific public health actions in public agendas to address these unjust inequalities. This includes promoting themes of sustainability and agroecology within Brazil's National Policy on Food and Nutrition (2013). It also involves developing effective food labeling programs that may incorporate sustainability indicators alongside nutritional information. Additionally, there will be public support for creating sustainable and resilient food systems, as well as implementing taxes on the production and sale of ultra-processed foods in Brazil (Mendoza-Velázquez; Aguirre Sedeno, 2019; Ribal; Sanjuán, 2020). In this context, it is noteworthy that sustainability assessment spans various political and social aspects that clearly cannot be reduced to the dichotomy of production and consumption (Hatjiathanassiadou; Rolim; Seabra, 2023; Triches; Schneider, 2015).

Finally, it is important to note some limitations of this study. The first is the non-assessment of total food consumption. The evaluation relied on only seven weekly dietary markers and did not include animal protein sources, such as meat and dairy, whether raw or minimally processed. It is known that these foods significantly contribute to environmental indicators (Notarnicola *et al*., 2017). However, the inclusion of the category of salty ultra-processed foods, which are made with ingredients of animal origin, enabled the examination of the effects of some of these foods in their most critical forms (i.e., processed meats, canned goods, and ready-to-eat frozen products) (Garzillo *et al*., 2022).

Secondly, the data collection year of 2015 does not accurately reflect the current reality, as Brazil is experiencing an increase in the prevalence of overweight and obesity, along with a rise in the consumption of ultra-processed food products. Therefore, it is crucial to conduct future studies using more recent data to better understand the potential associations with the nutritional transition, which indicates a growing nutritional risk and sustainability challenges related to the actions of the agri-food industry in Brazil (Hassan *et al*., 2025). It is likely that when the results of PeNSE 2024 (post-pandemic) are made available, a worsened situation will be identified regarding the sustainability landscape related to food among this age group, associated with the increased marketing and consumption of ultra-processed foods.

While it is uncommon to include environmental impacts in dietary recommendations for children and adolescents within the scientific literature, it is essential to integrate these considerations into public policy agendas. This integration can help raise awareness about how diets affect health and the environment (Hollis *et al*., 2020). Thus, initiatives targeting adolescents can contribute more effectively to promoting adequate, healthy, and sustainable eating by considering multidimensional contexts (Kenny *et al*., 2023) associated with dietary patterns based on ultra-processed foods and food environments in more urbanised territories.

5 CONCLUSIONS

Based on the 2015 survey data, it is evident that the most negative sustainability indicators among Brazilian adolescents were linked to dietary patterns, including consuming ultra-processed foods and living in more urbanised areas. This scenario underscores the importance of recognising food environments as influential factors in shaping individual choices and the environmental impact of dietary practices. Consequently, the present study's findings should inform the surveillance and management of care for Brazilian adolescents, ensuring that food and nutrition security initiatives are aligned with sustainability principles. From this perspective, public actions within health and education institutions can play a vital role in shaping the food environments that adolescents frequent, such as schools, restaurants, and public spaces, ultimately promoting healthier and more sustainable food systems that support health enhancement.

REFERENCES

ALONSO-STUYCK, P. Parenting and healthy teenage lifestyles. **International Journal of Environmental Research and Public Health**, v. 17, p. 1-15, 2020. Available in: https://doi.org/10.3390/ijerph17155428

ANDRADE, G. C. et al. Ultra-processed food consumption and NCD-related dietary nutrient profile in a national sample of French children and adolescents. **J Public Health**, v. 31, p. 1547–1557, 2023. Available in: https://doi.org/10.1007/s10389-022-01693-4

BELGACEM, W. et al. Changing dietary behavior for better biodiversity preservation: a preliminary study. **Nutrients**, v. 13, n. 2076, 2021. Available in: https://doi.org/10.3390/nu13062076

BOFF, L. **Sustentabilidade**: o que é, o que não é. Petrópolis, RJ: Vozes, 2017.

BRASIL. Ministério do Desenvolvimento Social e Combate à Fome. Secretaria Nacional de Segurança Alimentar e Nutricional. **Marco de Referência de Educação Alimentar e Nutricional para as Políticas Públicas**. MDS, 2012. Available in: https://www.mds.gov.br/webarquivos/publicacao/seguranca_alimentar/marco_EAN.pdf

BRASIL. Ministério da Saúde. Secretaria de Atenção à Saúde. **Política Nacional de Alimentação e Nutrição**. Ministério da saúde, 2013. Available in: https://bvsms.saude.gov.br/bvs/publicacoes/politica_nacional_alimentacao_nutricao.pdf

BRASIL. Ministério da Saúde. Departamento de Atenção Básica. **Guia Alimentar para a População Brasileira.** Ministério da Saúde, 2014. Available in: https://bvsms.saude.gov.br/bvs/publicacoes/guia_alimentar_populacao_brasileira_2ed.pdf

BRASIL. Ministério da Saúde. Secretaria de Atenção à Saúde. **Marco de Referência da Vigilância Alimentar e Nutricional na Atenção Básica**. Ministério da Saúde, 2015. Available in: https://bvsms.saude.gov.br/bvs/publicacoes/marco_referencia_vigilancia_alimentar.pdf

BRASIL. Ministério da Saúde. Conselho Nacional de Saúde. **Resolução n. 510, de 07 de abril de 2016.** Brasília: Planalto, 2016. Available in: https://www.gov.br/conselho-nacional-de-saude/pt-br/acesso-a-informacao/legislacao/resolucoes/2016/resolucao-no-510.pdf/view

BRASIL. Ministério da Educação. Fundo Nacional de Desenvolvimento da Educação. Conselho Deliberativo. **Resolução n. 06, de 08 de maio de 2020.** Brasília: Planalto, 2020.

BRASIL. Ministério da Saúde. Secretaria de Vigilância em Saúde. Departamento de Análise em Saúde e Vigilância de Doenças Não Transmissíveis. **Plano de Ações Estratégicas para o Enfrentamento das Doenças Crônicas e Agravos não Transmissíveis no Brasil 2021-2030.** Brasília: Ministério da Saúde, 2021. Available in: https://www.gov.br/saude/pt-br/centrais-de-conteudo/publicacoes/svsa/doencas-cronicas-nao-transmissiveis-dcnt/09-plano-de-dant-2022_2030.pdf/view

BRASIL. Decreto n. 11.821, de 12 de dezembro de 2023. Dispõe sobre os princípios, os objetivos, os eixos estratégicos e as diretrizes que orientam as ações de promoção da alimentação adequada e saudável no ambiente escolar. **Diário Oficial da União**, Brasília, 13 dez. 2023. Available in: https://www.planalto.gov.br/ccivil_03/_ato2023-2026/2023/decreto/d11821.htm.

CÂMARA INTERMINISTERIAL DE SEGURANÇA ALIMENTAR E NUTRICIONAL. **Estudo Técnico**: mapeamento dos desertos alimentares no Brasil. Brasília: Secretaria-Executiva da Câmara Interministerial de Segurança Alimentar e Nutricional do Ministério do Desenvolvimento Social, 2018. Available in: https://aplicacoes.mds.gov.br/sagirmps/noticias/arquivos/files/Estudo_tecnico_mapeamento_desertos_alimentares.pdf.

CARVALHO, J. R. M. C. et al. Proposta e validação de indicadores hidroambientais para bacias hidrográficas: estudo de caso na sub-bacia do alto curso do Rio Paraíba, PB. **Sociedade & Natureza**, v. 23, n. 2, 2011. Available in: https://doi.org/ 10.1590/S1982-45132011000200012

CASTRO, I. R. R. A extinção do Conselho Nacional de Segurança Alimentar e Nutricional e a agenda de alimentação e nutrição. **Cadernos de Saúde Pública**, v. 35, 2019. Available in: https://doi.org/10.1590/0102-311X00009919

ÇAKMAKÇI, R.; SALIK, M. A.; ÇAKMAKÇI, S. Assessment and Principles of Environmentally Sustainable Food and Agriculture Systems. **Agriculture**, v. 13, n. 5, p. 1073, 2023. Available in: https://doi.org/10.3390/agriculture13051073

DERQUI, B.; GRIMALDI, D.; FERNANDEZ, V. Building and managing sustainable schools: the case of food waste. **Journal of Cleaner Production**, v. 243, 2020. Available in: https://doi.org/10.1016/j.jclepro.2019.118533

DIXON, K. A.; MICHELSEN, M. K.; CARPENTER, C. L. Modern Diets and the Health of Our Planet: an investigation into the environmental impacts of food choices. **Nutrients**, v. 15, n. 3, 2023. Available in: https://doi.org/10.3390/nu15030692

EGAN, M. The Water Footprint Assessment Manual. Setting the Global Standard. **Social and Environmental Accountability Journal**, v. 31, 2011. Available in: https://waterfootprint.org/resources/TheWaterFootprintAssessmentManual_English.pdf

EUROPEAN PUBLIC HEALTH ASSOCIATION. **Healthy and Sustainable Diets for European Countries**. 2017. Available in: https://eupha.org/repository/advocacy/EUPHA_report_on_healthy_and_sustainable_diets_20-05-2017.pdf

FEIL, A. A. et al. Profiles of sustainable food consumption: consumer behavior toward organic food in southern region of Brazil. **Journal of Cleaner Production**, v. 258, 2020. Available in: https://doi.org/10.1016/j.jclepro.2020.120690

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS. Sustainable Diets and Biodiversity: directions and solutions for policy, research and action. **Proc. Int. Sci. Symp**. 2010. Available in: https://www.fao.org/4/i3004e/i3004e.pdf. Access at: 17 jul. 2024.

FORERO-CANTOR, G.; RIBAL, J.; SANJUÁN, N. Levying carbon footprint taxes on animal-sourced foods. A case study in Spain. **Journal of Cleaner Production**, v. 243, 2020. Available in: https://doi.org/10.1016/j.jclepro.2019.118668

GALLI, A. et al. Integrating Ecological, Carbon and Water footprint into a “footprint Family” of indicators: definition and role in tracking human pressure on the planet. **Ecological Indicators**, v. 16, n. 4, 2012. Available in: https://doi.org/10.1016/j.ecolind.2011.06.017

GARZILLO, J. M. F. et al. **Pegadas dos alimentos e das preparações culinárias consumidos no Brasil**. São Paulo: Faculdade de Saúde Pública da USP, 2019. Available in: https://www.livrosabertos.abcd.usp.br/portaldelivrosUSP/catalog/view/393/345/1602

GARZILLO, J. M. F. et al. Ultra-processed food intake and diet carbon and water footprints: a national study in Brazil. **Revista de Saúde Pública**, v. 28, n. 56, 2022. Available in: https://doi.org/10.11606/s1518-8787.2022056004551

GEBHARDT, B. et al. Assessing the sustainability of natural and artificial food colorants. **Journal of Cleaner Production**, v. 260, 2020. Available in: https://doi.org/10.1016/j.jclepro.2020.120884

GROSSO, G. et al. Environmental impact of dietary choices: role of the mediterranean and other dietary patterns in an Italian cohort. **International journal of environmental research and public health**, v. 17, 2020. Available in: https://doi.org/10.3390/ijerph17051468

HALLSTRÖM, E.; CARLSSON-KANYAMA, A.; BÖRJESSON, P. Environmental impact of dietary change: a systematic review. **Journal of Cleaner Production**, v. 91, 2015. Available in: https://doi.org/10.1016/j.jclepro.2014.12.008

HAN, A.; CHAI, L.; LIAO, X. Demographic Scenarios of Future Environmental Footprints of Healthy Diets in China. **Foods**, v. 9, n. 8, 2020. Available in: https://doi.org/ 10.3390/foods9081021

HARRIS, F. et al. The Water Footprint of Diets: a global systematic review and meta-analysis. **Advances in nutrition**, v. 11, 2020. Available in: https://doi.org/ 10.1093/advances/nmz091

HASSAN, B. K. et al. Disputes over the agenda to promote adequate and healthy eating: how the agri-food sector interfered in the Brazilian tax reform. **Social Science & Medicine**, v. 371, 2025. Available in: https://doi.org/10.1016/j.socscimed.2025.117747.

HATJIATHANASSIADOU, M.; ROLIM, P. M.; SEABRA, L. M. A. J. Nutrition and its footprints: using environmental indicators to assess the nexus between sustainability and food. **Frontiers in Sustainable Food Systems**, v. 6, 2023. Available in: https://doi.org/10.3389/fsufs.2022.1078997

HOLLIS, J. L. et al. Defining healthy and sustainable diets for infants, children and adolescentes. G**lobal Food Security**, v. 27, p. 100401, 2020. Available in: https://doi.org/10.1016/j.gfs.2020.100401

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. **Pesquisa de Orçamentos Familiares 2008-2009**: aquisição alimentar domiciliar per capita. IBGE, 2010.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. **Síntese de indicadores sociais**: uma análise das condições de vida da população brasileira 2015. Rio de Janeiro: IBGE, 2015. 132 p. Available in:http://www.ibge.gov.br/home/estatistica/populacao/condicaodevida/indicadoresminimos/sinteseindicsociais2015/default.shtm. Access at: 12 ago. 2024.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. Coordenação de População e Indicadores Sociais. **Pesquisa Nacional de Saúde do Escolar**: 2015. IBGE, 2016.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. Diretoria de Pesquisas. Coordenação de População e Indicadores Sociais. **Pesquisa de Orçamentos Familiares**: 2017 – 2018. Primeiros Resultados. IBGE: 2019.

KENNY, T. A. et al. Consumer attitudes and behaviors toward more sustainable diets: a scoping review. **Nutrition reviews**, v. 81, n. 12, 2023. Available in: https://doi.org/10.1093/nutrit/nuad033

LANHAM, A. R.; POLS, J. C. V. Toward Sustainable Diets-Interventions and Perceptions Among Adolescents: a scoping review. **Nutrition reviews**, v. 0, p. 1-17, 2024. Available in: https://doi.org/10.1093/nutrit/nuae052

MAIA, E. G. et al. Dietary patterns, sociodemographic and behavioral characteristics among Brazilian adolescents. **Revista Brasileira de Epidemiologia**, v. 21, 2018. Available in: https://doi.org/10.1590/1980-549720180009.supl.1

MARTINELLI, L. A.; FILOSO, S. Balance between food production, biodiversity and ecosystem services in Brazil: a challenge and an opportunity. **Biota Neotropica**, v. 9, 2009. Available in: https://doi.org/10.1590/S1676-06032009000400001

MENDOZA-VELÁZQUEZ, A.; AGUIRRE SEDEÑO, D. Impuesto especial a alimentos y bebidas y su impacto en la inflación en México: dinámica, persistencia y cambio de régimen. **Revista Panamericana de Salud Pública**, v. 43, n. 1, 2019. Available in: https://doi.org/10.26633/RPSP.2019.88

MOTA, J. C.; VASCONCELOS, A. G. G.; ASSIS, S. G. Análise de correspondência como estratégia para descrição do perfil da mulher vítima do parceiro atendida em serviço especializado. **Revista Ciência e Saúde Coletiva**, v. 12, 2007. Available in: https://doi.org/10.1590/S1413-81232007000300030

NAJA, F. et al. Changes in Environmental Footprints Associated with Dietary Intake of Lebanese Adolescents Between the Years 1997 and 2009. **Sustainability**, v. 12, 2020. Available in: https://doi.org/10.3390/su12114519

NOTARNICOLA, B. et al. Environmental impacts of food consumption in Europe. **Journal of Cleaner Production**, v. 140, 2017. Available in: https://doi.org/10.1016/j.jclepro.2016.06.080

PANDEY, D.; AGRAWAL, M.; PANDEY, J. S. Carbon footprint: current methods of estimation. **Environmental Monitoring and Assessment**, v. 178, 2011. Available in: https://doi.org/10.1007/s10661-010-1678-y

PEREIRA, A. O. K.; CALGARO, C. Os danos socioambientais na sociedade moderna consumocentrista: a continuação do antropocentrismo em desfavor a uma cultura socioecológica expressa pelos direitos da natureza. **Revista de Direito e Sustentabilidade**, v. 5, 2019. Available in: https://doi.org/10.26668/IndexLawJournals/2525-9687/2019.v5i2.5785

PERIGNON, M. et al. Improving diet sustainability through evolution of food choices: review of epidemiological studies on the environmental impact of diets. **Nutrition Reviews**, v. 75, 2017. Available in: https://doi.org/10.1093/nutrit/nuw043

QUEIROZ, P. et al. Self and nature: parental socialization, self-esteem, and environmental values in Spanish adolescents. **International journal of environmental research and public health**, v. 17, 2020. Available in: https://doi.org/10.3390/ijerph17103732

RAN, Y. et al. Environmental assessment of diets: overview and guidance on indicator choice. **The Lancet Planetary Health**, v. 8, n. 3, 2024. Available in: https://doi.org/10.1016/S2542-5196(24)00006-8

RONTO, R. et al. Adolescents' perspectives on food literacy and its impact on their dietary behaviours. **Appetite**, v. 107, 2016. Available in: https://doi.org/10.1016/j.appet.2016.09.006

SHEEHAN, P. et al. Building the foundations for sustainable development: a case for global investment in the capabilities of adolescents. **The Lancet**, v. 390, 2017. Available in: https://doi.org/10.1016/S0140-6736(17)30872-3

SOUSA, J. G. et al. Atividade física e hábitos alimentares de adolescentes escolares: pesquisa nacional de saúde do escolar (Pense), 2015. **Revista Brasileira de Nutrição Esportiva**, v. 13, 2019. Available in: https://www.rbne.com.br/index.php/rbne/article/view/1259

SWINBURN, B. A. et al. The Global Syndemic of Obesity, Undernutrition, and Climate Change: the lancet commission report. **The Lancet**, v. 393, 2019. Available in: https://doi.org/10.1016/S0140-6736(18)32822-8

TAVARES, L. F. et al. Dietary patterns of Brazilian adolescents: results of the Brazilian National School-Based Health Survey (PeNSE). **Cadernos de Saúde Pública**, v. 30, 2014. Available in: https://doi.org/10.1590/0102-311X00016814

TRICHES, R. M.; SCHNEIDER, S. Alimentação, sistema agroalimentar e os consumidores: novas conexões para o desenvolvimento rural. **Cuadernos Desarrollo Rural**, v. 12, n. 21, 2015. Available in: https://doi.org/10.11144/Javeriana.cdr12-75.asac

UNITED NATIONS. **Transforming our world**: the 2030 agenda for sustainable development. 2015, A/RES/70/1. Available in: https://www.unsdsn.org/resources/transforming-our-world-interdisciplinary-insights-on-the-sustainable-development-goals/?gad_source=1&gclid=Cj0KCQjwna6_BhCbARIsALId2Z0mDisrv0xG8Em6MouRhUrNT3h7Swsl_Zg2L0UzM446act5JZxwZKIaAk3nEALw_wcB

VALE, D. et al. Water footprint of the diet of adolescents in Brazil: relationships with fast food consumption and place of residence. **Research, Society and Development**, v. 10, n. 12, 2021a. Available in: https://doi.org/10.33448/rsd-v10i12.20597

VALE, D. et al. Food and nutrition surveillance of Brazilian adolescents: possibilities with PeNSE data. **Research, Society and Development**, v. 10, n. 11, 2021b. Available in: https://doi.org/10.33448/rsd-v10i11.19818

VALE, D. et al. Dietary and Nutritional Profiles among Brazilian Adolescents. **Nutrients**, v. 14, 2022. Available in: https://doi.org/10.3390/nu14204233

VON KOERBER, K.; BADER, N.; LEITZMANN, C. Wholesome Nutrition: an example for a sustainable diet. **The Proceedings of the Nutrition Society**, v. 76, 2017. Available in: https://doi.org/10.1017/S0029665116000616

WILLETT, W. et al. Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. **The Lancet**, v. 393, 2019. Available in: https://doi.org/10.1016/S0140-6736(18)31788-4

WORLD HEALTH ORGANIZATION. **Nutrition in adolescence**: issues and challenges for the health sector. Issues in adolescent health and development. Geneva: World Health Organization, 2005. Available in: https://www.who.int/publications/i/item/9241593660

WORLD HEALTH ORGANIZATION. **Child Growth Standards**: length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age. Methods and development. In Proceedings of the Geneva, WHO; 2006. Available in: https://www.who.int/publications/i/item/924154693X

WORLD HEALTH ORGANIZATION. **WHO AnthroPlus**. [computer program]. 2016. Available in: https://www.who.int/tools/child-growth-standards/software