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# *Consumption of ultra-processed foods is associated with abdominal obesity in male rotating shift workers*

## Consumo de alimentos ultraprocessados está associado à obesidade abdominal em trabalhadores de turnos alternantes do sexo masculino

### Abstract

*Introduction*: Higher intake of ultra-processed foods (UPF) might be associated with an increased risk of obesity. *Objective*: Our objective was to evaluate the consumption of UPF and their association with nutrient intake and excess body adiposity in shift workers. *Methods*: A cross-sectional study was conducted in 2015 with 238 male rotating shift workers. Dietary data was obtained by the 24-hour recall and classified according to food processing by the NOVA classification system. Body adiposity indicators assessed were waist circumference and body mass index. Logistic regression models were built and adjusted for sociodemographic, lifestyle, and dietary variables. *Results*: UPF represented, on average, 22.3% of the total caloric value of the individual's food consumption, with a maximum value of 66.9%. Participants with the highest consumption of UPF consumed more carbohydrates (57%), protein (35%), total fat (96%), saturated fat (79%), cholesterol (68%), and sodium (44%) compared to the first tercile ($p < 0.001$). The highest frequency of UPF consumed was bread (81.0%), followed by cookies (45.9%), sweetened beverages (45.7%), processed meats (46.8%), and margarine (46.8%). In multivariable analysis, the highest consumption of UPF had 168% higher odds of abdominal obesity (OR = 2.68, 95%CI 1.16-5.68) than the lowest consumption. *Conclusion*: UPF are essential contributors to the energy intake of shift workers, and higher consumption of UPF was associated with abdominal obesity.

Keywords: Minimally processed foods. Ultra-processed food. Shift work schedule. Waist circumference. Nutritive Value.

### Resumo

*Introdução*: A maior ingestão de alimentos ultraprocessados (AUP) pode estar associada a um maior risco de obesidade. *Objetivo*: Nosso objetivo foi avaliar o consumo de AUP e sua associação com a ingestão de nutrientes e o excesso de adiposidade corporal em trabalhadores de turnos. *Métodos*: Um estudo transversal foi realizado em 2015 com 238 trabalhadores de turnos alternantes do sexo masculino. Os dados dietéticos foram obtidos por meio

do recordatório de 24 horas e classificados de acordo com o processamento de alimentos pelo sistema de classificação NOVA. Os indicadores de adiposidade corporal avaliados foram a circunferência da cintura e o índice de massa corporal. Modelos de regressão logística foram criados e ajustados para variáveis sociodemográficas, de estilo de vida e dietéticas. ***Resultados***: Os AUP representaram, em média, 22,3% do valor calórico total do consumo alimentar do indivíduo, com um valor máximo de 66,9%. Os participantes com maior consumo de AUP consumiram mais carboidratos (57%), proteínas (35%), gordura total (96%), gordura saturada (79%), colesterol (68%) e sódio (44%) em comparação com o primeiro tercil ($p < 0,001$). As maiores frequências de AUP consumidos foram pães (81,0%), seguidos por biscoitos (45,9%), bebidas adoçadas (45,7%), carnes processadas (46,8%) e margarina (46,8%). Na análise multivariada, indivíduos com maior consumo de AUPapresentaram uma chance 168% maior de obesidade abdominal (OR = 2,68, IC95% 1,16-5,68) do que aqueles com o menor consumo. ***Conclusões***: Os AUP são contribuintes essenciais para a ingestão calórica dos trabalhadores de turnos, e o maior consumo de AUP foi associado à obesidade abdominal.

**Palavras-chave:** Alimentos Minimamente Processados. Alimentos Ultraprocessados. Horário de Trabalho em Turnos. Circunferência da Cintura. Valor Nutritivo.

## INTRODUCTION

Ultra-processed foods (UPF) are industrial formulations made with ingredients derived from few or no whole foods. They result from a series of industrial processes and use of additives to improve durability, accessibility, convenience, palatability, and readiness for consumption of the final product.[1] The consumption of UPF has increased worldwide in recent decades, especially in low and middle-income countries.[2,3]

In particular, the regions with the highest per capita consumption of UPF are North America, Western Europe, and Latin America. In contrast, Sub-Saharan Africa, South Asia, the Middle East, and North Africa have the lowest consumption.[3] In Latin American countries, the percentage of calories from UPF ranges from 15.9% in Colombia,[4] 21.2% in Mexico[5] and 28.6% in Chile.[6] In Brazil, the percentage of calories from this food group has increased by 56.6% since 1987, according to the Household Budget Survey (HBS).[7]

The most recent HBS (2017-2018) showed that UPF accounted for 19.4% of Brazilians' food consumption caloric value.[7]High consumption of UPF is also observed in countries such as Canada and Sweden.[8,9]

Shift workers, characterized by irregular schedules and reduced access to healthy food options, may be more prone to consuming UPF.[10,11] The unique challenges posed by shift work, including circadian rhythm disruption and alterations in meal timings, can contribute to an increased likelihood of poor dietary choices and abdominal obesity among this population.[10,11] These factors underscore the importance of investigating the consumption of UPF and its association with nutrient intake and excess body adiposity in shift workers.

The high consumption of UPF harms health, as most are high in sodium, saturated fat, trans fat, sugar, and high energy density.[12,13] Consumption of UPF is associated with poor diet quality,[14] and increased consumption of UPF is associated with lower fiber intake, micronutrients, and phytochemicals.[15,16] Moreover, consumption of UPF has been linked to increased risk of obesity, diabetes, cardiovascular diseases, and some types of cancer, as well as adverse effects on the immune system, the microbiota, and the epigenome.[17,18]

To address these concerns, this study aims to evaluate the consumption of UPF and its relationship with nutrient intake and excess body adiposity among shift workers, shedding light on potential dietary factors contributing to health outcomes in this population.

## METHODS

### Study Design and Population

A cross-sectional study was conducted in 2015 with a male rotating shift worker population of an iron ore extraction company in the region of Iron Quadrangle, Minas Gerais, Brazil. The time for rotating shifts was six hours, followed by 12 hours of rest, from 7 pm to 1 am, 1 pm to 7 pm, 7 am to 1 pm, and 1 am to 7 am. After completing the four-shift cycle, the workers had a day off.

The participants were previously evaluated in a screening study conducted by the Federal University of Ouro Preto to identify the prevalence of cardiovascular risk factors in shift workers.[19] This study is part of a larger project carried out in 2012, 2015, and 2018, but only the workers from 2015 were evaluated for the present study, as this was when the 24-hour recall (24HR) assessed food consumption. The initial sample of the larger project consisted of 952 workers invited to participate in the research in 2012. However, in 2015, only 366 workers were initially asked, of which 55 did not complete the questionnaire, 18 did not answer the 24HR, and 55 did not have complete food data, such as quantity or type of food consumed, resulting in a final sample of 238 individuals.

## Data collection and analysis

Data collection was performed at the company's outpatient clinics by teams previously trained to apply and assess anthropometric and food survey data. The sociodemographic variables evaluated were sex, age, self-reported skin color, marital status, and education. Age was categorized as < 30 years, 30-39 years, and 40 years or more; the self-declared skin color was categorized as white, black, brown, yellow, or indigenous; marital status was categorized as single or married; education was categorized up to high-school graduate, and technical or university education. Life style evaluation used a questionnaire about tobacco consumption, alcohol consumption, and physical activity. Tobacco consumption was classified as non-smokers, those who had never smoked or had quit smoking more than six months ago, and smokers, those who currently smoked or had quit smoking less than six months ago.[20] Alcohol consumption was classified as yes or no. The instrument used to assess the level of physical activity was the International Physical Activity Questionnaire (IPAQ) version 8 - long form. The workers were classified as having high physical activity $\geq$ 600 measure total energy - min/week.[21]

In the collection of anthropometric data, weight was measured on the portable TANITA® model BC558 body composition monitor, with a maximum capacity of 150 kg and an accuracy of 0.1 kg (Tanita Corporation of America, Inc., Arlington Heights, Illinois, USA) and the height on the AlturExata® portable stadiometer with centimeter-scale and one-millimeter accuracy (AlturExata, Belo Horizonte, Minas Gerais, Brazil). In both procedures, the subjects were evaluated in an upright anatomical position with a fixed point in front, barefoot, and correctly positioned feet in the center of the platform according to the instruction manual. Waist circumference (WC) was measured in triplicate with a simple, inelastic tape measure at the midpoint between the iliac crest and the last coastal arch.[22] Values of WC $\geq$ 90.0 cm were classified as abdominal obesity.[23] BMI was calculated from the formula "weight (kg) / height (m)$^2$",and BMI values $\geq$ 25.0 kg/m$^2$ were considered indicative of excess weight.[22]

The food survey was conducted through a single 24HR for each participant, referring to the day before the interview. To reduce the biases of memory and estimation of food intake, we used the multiple-pass method, which asks detailed questions about each meal and snack performed on the previous day, including time, place, type, amount, and brand of foods and beverages consumed. We also used a photographic record to estimate the size of the portions of foods and utensils used to serve them, such as spoons, knife tips, cups, and glasses, among others. The book *Food Consumption: Viewing Portions*, with illustrative photos of various food portions, was also used to help individuals determine their intake.[24] These procedures were performed to increase the accuracy and validity of the 24HR. Dietary data were converted to grams and milliliters to enable a chemical analysis of food intake. They were later included in the Virtual Nutri Plus version 2.0 nutritional analysis program that provided the food's total energy intake, macros, and micronutrients. After the converted data, the energy density of the food was calculated by dividing the total calories (kcal) per gram (g) of food for further analysis.

## Food Classification

All reported foods were classified using the NOVA classification according to nature, extent, and purpose of food processing. Essentially, foods were divided into three main groups according to the NOVA food classification.[25] The first group includes unprocessed or minimally processed foods such as fresh vegetables, fruits, grains, roots, and tubers. The second group is processed culinary ingredients such as salt, oil, butter, and vinegar, obtained directly from group 1 foods or nature by pressing, refining, grinding, or milling. The third group is processed foods such as canned or bottled vegetables and fruits in brine or syrup; salted or cured meat and fish such as ham, bacon, smoked fish; cheese; and freshly made bread. These foods are obtained by adding edible substances from group 2 to group 1 food, using preservation methods such as salting, sugaring, smoking, curing, or fermenting. The fourth group is ultra-processed foods such as chips, many

kinds of sweets, fatty or salty snacks, ice cream, chocolates, hamburgers, hot dogs, sausages, nuggets, and other reconstituted meat products; bread with a long shelf life; cookies; cakes; breakfast cereals; cereal bars; fruit drinks; soft drinks; energy drinks; and others. These foods are formulations of low-cost substances derived from group 1 foods with little to no whole foods; they always contain edible substances not used in home kitchens (such as protein isolates, modified starches, hydrogenated oils) and/or cosmetic additives (such as flavors, flavor enhancers, colors, emulsifiers).[1,26] Our study did not differentiate between the culinary ingredients (oils and salt) used to prepare unprocessed and minimally processed foods. Therefore, we considered unprocessed and minimally processed foods and the culinary ingredients used in their preparation for this group, except for sugar, which was not grouped in this group. The supplementary table lists all the foods reported by the participants and their respective NOVA groups.

**Supplementary Table 1.** Classification of foods in the 24-hour recall according to the extent and purpose of processing NOVA

| Food Group | Foods |
|---|---|
| Fresh and minimally processed foods + Culinary ingredients[a] | Cereals: rice, corn, oats; Legumes: beans, chickpeas; Roots and tubers: cassava, yams, potatoes and others; Flour: cassava flour, corn flour, wheat flour, tapioca flour and others; Meats: Beef steak, beef in cubes or pieces, pork, chicken with or without skin, salmon and other fish, shrimp and shellfish; Eggs: chicken egg, quail egg and others; Milk and dairy products: whole, skim or semi-skim milk and others; Fruits: banana, orange, apple, avocado, pineapple, acai, acerola, guava, kiwi, papaya, mango, watermelon, melon, strawberry, peach, grapes, and other tropical fruits such as pitanga, graviola, umbu, cupuaçu, and others; Vegetables: Lettuce, chard, watercress, kale, arugula, spinach, squash, zucchini, chayote, eggplant, beets, carrots, cauliflower, cabbage, cucumber, peppers, tomatoes, and others; Mushrooms: Fresh or dried mushrooms; Dried fruits: raisins, apricots, plums, dates, figs, and others; Oilseeds: nuts, walnuts, unsalted peanuts, and others; Pasta: fresh pasta such as macaroni, gnocchi, and others. Culinary ingredients: Olive oil, soybean oil, sunflower oil, canola oil, corn oil, pork fat, and salt. |
| Processed foods | Meats: dried meat, ham, bacon, sausage, sausage, salami, and other sausages with no added... Cheese: fresh Minas cheese, Pratocheese, mozzarella cheese, and other cheeses with salt; Bread: French bread, homemade bread, and other bread with yeast and salt, with no added additives; Fruit: fruits in syrup or candied fruits or jams; Vegetables: pickled vegetables such as cucumber, carrot, corn, beets and others; Beverages: pasteurized or concentrated fruit juices, beer and wine; Others: tomato extract or sauce, fruit jellies, natural yogurt and other products with added sugar, salt or vinegar. |
| Ultra-processed foods | Beverages: soft drinks, artificial juices, energy drinks, distilled alcoholic beverages, and others; Dairy products: regular or light cream cheese, whole or skimmed/light yogurt with added sugar or sweeteners, ultra-processed cheeses, and others; Meats: mortadella, salami, full-fat ham, turkey breast/chester, sausage, frankfurter/ sausage, bacon/ bacon and other sausages with chemical additives; Breads and cookies: flat bread, toast, industrialized cheese bread, sweet bread, whole wheat bread with chemical additives, stuffed or cream cracker cookies, and others; Cereals and pasta: sugary or chemical additive breakfast cereal, cereal bar with sugar or sweeteners, instant or precooked noodles, and others; Fats: regular or light margarine, regular or light mayonnaise, and others; Sweets and desserts: regular or light ice cream with chemical additives, soy milk with sugar or sweeteners, milk or white chocolate with chemical additives, chocolates and other industrialized candies, powdered or liquid chocolate with sugar or sweeteners, pudding/ambrosia/sweet pudding/sweet rice pudding/flan and other ready-made desserts; Snacks and snacks: frozen or pre-prepared pizza, hot dogs/beefburgers/chicken and other industrialized sandwiches, fried snacks (drumstick/pastry/risole/croquettes) and other ready-to-fry or bake snacks, cakes/pastries/quiche and other ready-to-bake pies, microwave popcorn or popcorn with chemical additives, industrialized chips or corn snacks; Sauces and seasonings: industrialized tomato extract or sauce with chemical additives, fruit jellies with sugar or sweeteners, mustard and other ready-made sauces with chemical additives, ultra-processed vegetables such as soup powder, instant mashed potatoes and others. |

[a]This group includes unprocessed and minimally processed foods, and culinary ingredients (oils and salt) that are used to prepare the foods in this group. Sugars were not included in this group.

We calculated the percentage of workers that consume UPF (%), mean caloric contribution (kcal/day), and percentage (%) of total energy intake (kcal/day) for all UPF in the 24HR to identify the types of ultra-processed foods consumed by the participants. For descriptive purposes, we present the data for consumed UPF, categorized into distinct groups based on food type.

To analyze the consumption of UPF, we calculated the percentage of the caloric value (kcal) of UPF in the total caloric value [(kcal of UPF / total kcal of the diet) x 100]. We then sorted this percentage into three equally sized groups called terciles. Tertile 1 (T1) contained the workers with the lowest percentages of UPF in their diet, ranging from 0% to 14.2%. Tertile 2 (T2) contained the workers with intermediate percentages of UPF in their diet, ranging from 14.3% to 27.7%. And tertile 3 (T3) contained the workers with the highest percentages of UPF in the diet, ranging from 27.7% to 66.9%. Furthermore, we presented the median and interquartile range (IQR) of the total percentage of the caloric value (% kcal of UPF/day) for each tertile of UPF consumption.

## Statistical analysis

Shapiro Wilk test was used to assess the normality of the data, and data were described as the median and interquartile range (IQR), for caloric value (% kcal of UPF/day) and nutrient intake per tertile of UPF percentage, as shown in Table 3. Categorical variables were presented with absolute (n) and relative (%) frequency values. To compare the variables with the UPF percentage terciles, Pearson chi-squared, Kruskal-Wallis test, and post hoc Dunn Bonferroni were used.

Binary logistic regression models assessed the association between UPF consumption and excess weight or abdominal obesity. The first (lowest) tercile was considered as reference and odds ratios (OR), and their 95% confidence intervals (CI) were obtained. We built two logistic regression models with consecutive adjustment levels: model 1 was adjusted for age, education, and skin color; model 2 was adjusted as in model 1 plus physical activity, alcohol, tobacco consumption, and the day of the week of the recall, to account for potential biases related to typical and atypical days of consumption. Furthermore, linear trends across terciles were tested by modeling the median value of each tercile as an ordinal variable.

Sampling power (a posteriori) was performed using the OpenEpi program version 3.1.9.2 and data on proportions and sample sizes of the explanatory and outcome variables. This was performed for the whole sample, with an estimated power of 0.99. For all tests, a significance level of 5% was adopted. The analyses were performed with STATA software version 15.0 for Windows (StataCorp LP, College Station, TX, USA).

## Ethical issues

This study was conducted according to the guidelines in the Declaration of Helsinki. All procedures involving human subjects were approved by the Research Ethics Committee of the Federal University of Ouro Preto (CAAE: 39682014.7.0000.5150). Written informed consent was obtained from all topics. This study followed reported guidelines dictated by the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE).

## RESULTS

The total sample consisted of 238 workers aged 26 to 60 years, with a median age of 38 years (IQR: 9.0). Consumption of UPF contributed with a mean of 22.3% (± 15.2) of the individuals' total calorie diet, with

a minimum value of 0 for those who did not consume UPF and a maximum value of 66.9%. Those who did not consume UPF were 0.06% of the sample studied. Approximately two in three workers were overweight (BMI ≥ 25.0 kg/m²) or abdominal obese (WC ≥ 90 cm) (Table 1).

**Table 1.** Characteristics of rotating shift workers in the Iron Quadrangle, Brazil, 2015.

| | **Total** (n=238) |
|---|---|
| Age, n (%) | |
| < 30 years | 19 (8.0%) |
| 30-39 years | 129 (54.2%) |
| 40-60 years | 90 (37.8%) |
| | |
| Skin color, n (%) | |
| White | 89 (37.4%) |
| Brown | 117 (49.2%) |
| Black | 32 (13.4%) |
| | |
| Marital status, n (%) | |
| Married | 192 (80.7%) |
| Not Married | 46 (19.3%) |
| | |
| Education, n (%) | |
| High-school graduate | 135 (56.7%) |
| Technical or University education | 103 (43.3%) |
| | |
| Tobacco consumption, n (%) | |
| Smokers | 170 (71.4%) |
| Non-smoker | 68 (28.6%) |
| | |
| Alcohol consumption, n (%) | |
| Yes | 154 (64.7%) |
| No | 84 (35.3%) |
| | |
| Physical activity[a], n (%) | |
| High | 71 (29.8%) |
| Low/moderate | 167 (70.2%) |
| | |
| Nutritional status, n (%) | |
| Excess weight (BMI ≥ 25.0 kg/m²) | 170 (71.4%) |
| Abdominal obesity (WC ≥ 90.0 cm) | 169 (71.0%) |

BMI: Body mass index; WC: Waist circumference
[a] Physical Activityevaluated by IPAQ.
The other values are presented as absolute (n) and relative frequency (%) values

The highest frequencies of UPF consumed were bread (81.0%), followed by cookies (45.9%), sweetened beverages (45.7%), processed meats (46.8%), and margarine (46.8%). Of these, the highest caloric contribution in the total daily energy value (% of energy) was from ultra-processed bread (10.9% of energy), cookies (5.2% of energy), and sweetened beverages (3.7% of energy) (Table 2).

Table 2. Characterization of the ultra-processed foods consumed by rotating shift workers in the Iron Quadrangle, Brazil, 2015.

| Foods | Percentage of workers that consume (%) | Caloric contribution (kcal/day) | Percentage (%) of total energy intake (kcal/day) |
|---|---|---|---|
| Ultraprocessed breads[1] | 81.0 | 243.4 | 10.9 |
| Ultraprocessed meat[2] | 46.8 | 89.0 | 2.1 |
| Margarine | 46.8 | 131.5 | 1.7 |
| Cookies | 45.9 | 251.3 | 5.2 |
| Sweetened beverages[3] | 45.7 | 157.6 | 3.7 |
| Cake and bakery UPF | 21.6 | 299.5 | 2.7 |
| Dairy drinks | 13.4 | 203.4 | 1.5 |
| Ultraprocessed cheese | 7.6 | 116.2 | 0.4 |
| Ready sauces[4] | 6.7 | 172.9 | 0.6 |
| Vegetable-based UPF[5] | 3.1 | 51.6 | 0.1 |

The ultra-processed foods considered here refer to foods that undergo a high degree of industrial processing, including adding artificial or extracted ingredients, such as emulsifiers, colorings, flavorings, and hydrogenated fat.
For descriptive purposes, we present only the most frequent UPF, not all of those consumed
[1] Including light bread, white/pita bread, whole grain/rye bread, Brazilian cheese bread
[2] Including soft drinks, processed juice, and artificial juice
[3] Including sausage/chorizo/Vienna sausage, hamburger (beef), ham/mortadella/salami.
[4] Including mayonnaise, ketchup, and mustard.
[5] Including instant mashed potatoes, soup powder, tomato sauce with artificial additives, and ready-to-eat meats (burgers, meatballs, and others) of vegetable origin

The consumption of UPF ranged from 7.8% (1st tercile) to 34.8% (3rd tercile) of total energy intake. The macronutrient intake of participants was assessed according to terciles of percentage of UPF intake (Table 3). There was a higher mean intake of carbohydrates, proteins, total fat, saturated fat, cholesterol, and sodium between the 1st and 3rd tertile of consumption of the percentage of UPF in the diet ($p < 0.001$).

Table 3. Consumption of nutrient intake according to the terciles of ultra-processed foods consumption by rotating shift workers in the Iron Quadrangle, Brazil, 2015.

| | Total | Terciles of ultra-processed foods consumption (% kcal/day) | | | |
|---|---|---|---|---|---|
| | | 1st Tercile | 2nd Tercile | 3th Tercile | *p* |
| UPF (kcal/day) | 365.6 (486.1) | ≤ 233.9 | 240.0-566.6 | 566.7-2142.1 | - |
| % of energy from UPF | 22.3 (15.2) | 7.8 (10.6)[a] | 19.7 (10.9)[b] | 34.8 (15.9)[c] | **≤ 0.001** |
| Total energy intake (kcal) | 1852.0 (906.9) | 1515.0 (801.6)[a] | 1767.7 (691.6)[b] | 2406.5 (892.1)[c] | **≤ 0.001** |
| The energy density (kcal/g) | 1.2 (0.3) | 1.1 (0.3)[a] | 1.2 (0.2)[b] | 1.3 (0.3)[c] | **≤ 0,001** |
| Carbohydrate (g) | 240.7 (137.8) | 198.8 (109.9)[a] | 229.1 (112.3)[b] | 312.5 (124.1)[c] | **≤ 0.001** |
| Protein (g) | 78.7 (45.0) | 70.5 (41.1)[a] | 78.5 (38.9)[b] | 95.2 (54.5)[c] | **≤ 0.001** |
| Total fat (g) | 60.1 (45.7) | 44.0 (32.6)[a] | 57.1 (27.2)[b] | 86.4 (44.8)[c] | **≤ 0.001** |
| Saturated fat (g) | 13.1 (12.3) | 10.2 (10.2)[a] | 12.8 (9.7)[b] | 18.3 (17.4)[c] | **≤ 0.001** |
| Total fibers (g) | 17.1 (10.9) | 16.4 (10.7)[a] | 16.5 (10.4)[a] | 17.6 (11.2)[a] | 0.433 |
| Cholesterol (mg) | 176.6 (188.2) | 151.3 (118.6)[a] | 176.1 (171.7)[a] | 255.1 (227.8)[b] | **≤ 0.001** |
| Sodium (mg) | 2350.4 (1359.7) | 1934.2 (1052.0)[a] | 2250.8 (1333.3)[b] | 2789.1 (1848.4)[c] | **≤ 0.001** |

Data are shown as the median and interquartile range (IQR). Kruskal Wallis and post hoc Dunn Bonferroni were performed to compare the medians.

Crude and adjusted analyses of the association between the dietary contribution of UPF and adiposity are shown in Table 4. No association was observed for excess weight; excess weight was similar across terciles. For abdominal obesity, the univariate analysis showed that the highest consumption of UPF had 118% higher odds of abdominal obesity (OR= 2.18; 95%CI: 1.12-4.39) compared with the lowest consumption. In multivariable analysis, after adjustments for sociodemographic and life style variables (model 2), the magnitude of the association increased and remained significant for 2nd tercile (OR= 2.57; 95%CI: 1.13-5.36) and 3rd tercile (OR= 2.68; 95%CI: 1.16-5.68) (Table 4).

**Table 4.** Association of excess body adiposity according to the terciles of ultra-processed foods consumption by rotating shift workers in the Iron Quadrangle, Brazil, 2015

| | Terciles of ultra-processed food consumption (% kcal/day) | | | |
|---|---|---|---|---|
| Body adiposity | 1stTercile | 2ndTercile | 3thTercile | |
| Excess weight (BMI ≥ 25.0kg/m²) | Reference | OR (95% CI) | OR (95% CI) | p for trend[a] |
| Univariate | 1.00 | 1.16 (0.58-2.33) | 1.22 (0.61-2.43) | 0.578 |
| Model 1 | 1.00 | 1.22 (0.60-2.48) | 1.23 (0.60-2.50) | 0.421 |
| Model 2 | 1.00 | 1.41 (0.66-3.01) | 2.19 (0.89-4.23) | 0.274 |
| Abdominal obesity (WC ≥ 90.0 cm) | Reference | OR (95% CI) | OR (95% CI) | p for trend[a] |
| Univariate | 1.00 | 1.44 (0.72-2.87) | **2.18 (1.12-4.39)*** | **0.042** |
| Model 1 | 1.00 | 1.20 (0.61-2.35) | **2.47 (1.16-5.23)*** | **0.021** |
| Model 2 | 1.00 | **2.57 (1.13-5.36)*** | **2.68 (1.16-5.68)**** | **0.011** |

OR: Odds ratio; 95% CI: confidence interval of 95%; BMI: body mass index. WC: waist circumference.
[a]Based on the consumption of ultra-processed food as a continuous variable.
Model 1: adjusted for age, education, and skin color. Model 2: adjusted as in model 1 plus physical activity, alcohol, tobacco consumption, and the day of the week of the recall to account for potential biases related to typical and atypical days of consumption
* p-value ≤ 0,05; ** p-value ≤ 0,01

## DISCUSSION

The consumption of UPF contributed about 22.3% of caloric intake among rotating shift workers in an iron ore mining company. Workers with a higher percentage consumption of UPF were more likely to have abdominal obesity and higher mean intake of carbohydrates, protein, total fat, saturated fat, cholesterol, and sodium intake.

The consumption of UPF by rotating shift workers in the present study was 13.2% higher than that found in the Brazilian population (19.7%).[27] A study that analyzed the data from the HBS 2008-2009 and 2017-2018 showed that the consumption of UPF was higher in urban areas than in rural areas and that the increase in consumption over time was more pronounced in rural areas (+2.43 percentage points) than in urban areas

(+0.86 percentage points).[28] The present study also observed a high consumption of UPF, suggesting that the consumption of UPF by male shift workers living in small cities may be similar to or even higher than that of male populations in large urban centers.This is a concerning finding, considering that the Pan American Health Organization (PAHO/WHO) has shown a 48.0% increase in sales of UPF and beverages in Latin America between 2000-2013. In Brazil, this growth reached 29.7%.[29] One possible explanation for this trend is that large urban centers have a higher supply and availability of UPF than small cities,[30] which may influence consumers' food choices and preferences. However, the present study also observed a high consumption of UPF by shift workers in small cities, suggesting that the consumers' location may not limit this consumption. UPF consumption may harm both populations of shift workers in the long term, regardless of their location.

To our knowledge, no studies in the literature have evaluated the consumption of UPF, with the NOVA methodology, in shift workers. However, in a paper evaluating food consumption from the Nurses' Health Studies (NHS), most women were highly exposed to work in rotating shifts.[31] In this study, the authors did not present the percentage of calorie intake coming from UPF, but from a list of 205 foods consumed by shift workers, 36.1% were identified as ultra-processed.[32] Besides, shift workers are likelier to change eating patterns by omitting meals and consuming more foods at non-conventional times, especially quick-to-prepare foods, such as ultra-processed, since they are easy to consume.[10]

The most frequently consumed UPF among rotating shift workers included ultra-processed bread, crackers, sugary drinks, ultra-processed meats, and margarine. These results are similar to that found by Simões et al.,[33] who evaluated the contribution of UPF to total calorie intake using baseline data from the Longitudinal Study of Adult Health-Brazil (ELSA-Brazil 2008-2010) in actives and retired civil servants aged 35-74 years from six higher education institutions of Brazil. A total of 14,378 participants were evaluated, and the most consumed UPF were ultra-processed bread (3.8%), sweets and treats (3.1%), cakes and sweet biscuits (2.7%), soft drinks, processed juice, and artificial juice (2.3%).[33] However, when we evaluated the percentage of caloric contribution of these foods, we observed that shift workers in our study have a higher caloric contribution of ultra-processed bread (+7.1%), cookies, and bakery products (+5.1%) when compared to ELSA-Brazil study.[33] The percentage of calorie contribution from processed meats, yogurt, sausage meat, and sweetened beverages was similar to our study.[33]

Obesity is a multifactorial disorder, with individual, sociocultural, and environmental contributors.[22] Among the determinants of obesity, high consumption of UPF has been associated with greater chances of increased body adiposity.[9]

In this study, we observed that more than 70% of the shift workers evaluated were overweight or had abdominal obesity. Furthermore, when assessed for consumption of UPF, workers in the highest tercile of consumption (2$^{nd}$ and 3$^{rd}$ terciles) were more likely to have abdominal obesity, even controlling for sociodemographic, lifestyle, and dietary variables. These results are corroborated by other studies, as Canhada et al.[34] demonstrated in the ELSA-Brazil longitudinal study, in which 11,827 individuals were evaluated. The authors found that the highest quartile of UPF intake had 27 and 33% increased risk of weight and WC increase (RR= 1.27; 95%CI: 1.07-1.50 and RR= 1.33; 95%CI: 1.12-1.58, respectively). Besides, approximately 15.0% of cases of overweight and abdominal obesity could be attributed to consumption higher than 17.8% of energy from UPF.[34] Similar results were found in a meta-analysis of observational studies.[35] Evaluating 12 studies, they found that consumption of UPF was associated witha 36.0% greater chance of being overweight (OR= 1.36; 95% CI: 1.14, 1.63; I2= 73%) and a 41% greater chance of abdominal obesity (OR= 1.41; 95% CI: 1.18, 1.68; I2= 62%).[35] There are no results in the literature on the consumption of UPF in rotating shift workers. However, an analysis of three American cohorts of nursing professionals, who usually work rotating shifts, showed that consuming foods such as sweets, processed meats, French fries,

and sugary drinks was strongly associated with weight gain in American adults.[36] However, the relationship between the consumption of foods classified according to their degree of processing (i.e., UPF) and overweight has been examined by several studies, showing a consistent positive association, as shown in a systematic review and meta-analysis of observational studies found that higher consumption of UPF was associated with a 28% increased risk of overweight and a 32% increased risk of obesity.[37] However, these findings still need to be verified in alternating shift workers.

Analyzes of the Brazilian food consumption survey conducted in 2008-2009 showed that the UPF set has 2.5 times more energy per gram than the fresh, minimally processed food set and culinary preparations based on these foods.[16] Therefore, although most studies do not evaluate the relationship between ultra-processed consumption and indicators of adiposity, studies show in shift workers a significantly increased risk of being excess weight [Pooled OR: 1.32 (95% CI: 1.15, 1.51)] and abdominal obesity [Pooled OR: 1.35 (95% CI: 1.13, 1.61)].[38] Moreover, shift workers have increased consumption of foods rich in simple carbohydrates, fat, and other inadequate components due to working hours,[39] which may negatively impact shift workers' health. This may be related to increased satiety or decreased food intake after fiber intake, with stomach distension, fermentation, and changes in intestinal hormones as possible appetite control mechanisms.[40] Higher fiber and whole-grain intake are associated with lower BMI and weight gain prevention compared to low-fiber and whole-grain diets.[41]

Our study also found a significant result: the intake of carbohydrates, protein, total fat, saturated fat, cholesterol, and sodium increased significantly with ultra-processed food consumption when comparing the terciles of ultra-processed food consumption. No significant relationship was found with fiber consumption but fibers are below the recommended levels in all terciles. This finding is consistent with a study that showed that UPF consumption was inversely associated with dietary fiber intake in Brazil and that most Brazilians had an insufficient fiber intake.[42] Furthermore, Bielemann et al.,[43] in a cohort study, found a significant relationship between increased intake of UPF with lower dietary fiber intake and higher sodium intake.[43] Louzada et al.[44] demonstrated that increased consumption of UPF was associated with increased saturated fat, trans fat, and free sugar and inversely associated with fiber and protein content.[44] The authors also noted that only 20% of Brazilians who least consume these foods had a diet that meets or approaches World Health Organization (WHO) recommendations for preventing NCDs, like cardiovascular diseases, cancers, chronic respiratory diseases, and diabetes.[44]

The study's limitations include possible biases in food-related questionnaires, such as memory errors, underreporting, and conscious or subconscious modification of food consumption patterns. To minimize these biases, the data collection team received training and a manual for consultation, and the instruments used were pre-tested. Another possible limitation of our study was the evaluation of food intake by a single 24-hour food recall; due to the logistics of the workers, it was not possible to evaluate it for more than one day, which may not represent the usual food intake. However, it should be noted that most of the food consumed by the workers, especially the UPF, was offered by the employer.

Our study has strengths. We are the first to evaluate the consumption of UPF and the association with abdominal obesity in rotating shift workers. The evaluation of food intake by the NOVA system in these workers is relevant. Strategies to reduce consumption of this food group should be encouraged as preventive approaches to obesity. These strategies should involve not only individual actions, such as maintaining a traditional food culture and improving a diet based on fruits, vegetables, and legumes but also public health actions, such as taxation of ultra-processed foods, fiscal subsidies for natural and minimally processed foods to make them more accessible to the population, regulation of ultra-processed food marketing, among others. However, further studies with this population of workers are needed to confirm our findings.

## CONCLUSION

The consumption of UPF contributes significantly to the energy intake of rotating shift workers. It has an unbalanced nutritional profile, with excess carbohydrates, proteins, fats, cholesterol, and sodium and a fiber, vitamins, and minerals deficiency. In addition, high consumption of UPF increases the chance of abdominal obesity. Further studies with this population of workers are needed to confirm our findings.

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## Contributors

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