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Original article

Food consumption according to the level of processing and sleep quality during the COVID-19 pandemic



Luiz Antônio Alves de Menezes-Júnior ^{a, b}, Amanda Cristina de Souza Andrade ^c,
 Hillary Nascimento Coletro ^{a, b}, Raquel de Deus Mendonça ^{a, b, d},
 Mariana Carvalho de Menezes ^{a, b, d}, George Luiz Lins Machado-Coelho ^{a, e},
 Adriana Lúcia Meireles ^{a, b, d, *}

^a Postgraduate Program in Health and Nutrition, School of Nutrition, Federal University of Ouro Preto, Ouro Preto, Minas Gerais, Brazil

^b Research and Study Group on Nutrition and Public Health (GPENSC), Federal University of Ouro Preto, Brazil

^c Department of Public Health, Federal University of Mato Grosso, Cuiabá, Mato Grosso, Brazil

^d Department of Clinical and Social Nutrition, School of Nutrition, Federal University of Ouro Preto, Ouro Preto, Minas Gerais, Brazil

^e School of Medicine, Federal University of Ouro Preto, Ouro Preto, Minas Gerais, Brazil

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SUMMARY

Background and aims: Consumption of ultra-processed foods is negatively associated with health outcomes, however, the contribution to sleep quality is limited. Therefore, the objective of this study was to evaluate the association between food intake by frequency and degree of processing and sleep quality in adults during the covid-19 pandemic.

Methods: Population-based survey of adults from October to December 2020 in the Iron Quadrangle region, Brazil. The exposure variable was a food intake score that considered the frequency of consumption and food processing degree. The total score ranged from 0 (best) to 48 points (worst food quality), categorized into quartiles. Furthermore, we also evaluated whether individuals replaced their lunch and/or dinner based mostly on fresh/minimally processed foods for ultra-processed foods, for five or more days in the week. The outcome variable was sleep quality assessed with the Pittsburgh Sleep Quality Index. We constructed a contrasting directed acyclic graph (DAG) model to estimate the adjusted odds ratio of the association between score eating and sleep, by logistic regression.

Results: Most of the 1762 individuals evaluated had poor sleep quality (52.5%). The minimum and maximum food scores were 0 and 30 points (mean 9.16; 95% CI 8.50, 9.81). The higher values of the score corresponded to lower consumption of fresh and minimally processed foods and higher consumption of ultraprocessed foods. In multivariate analysis, individuals in the third food consumption score had 71% greater odds of poor sleep quality (OR = 1.71; 95% CI: 1.03, 2.85) and in the fourth quartile 144% greater odds (OR = 2.44; 95% CI: 1.32, 2.44). Besides, replacing the dinner meal with ultra-processed foods five days or more in the week was also associated with poor sleep quality (OR = 2.01; 95%CI: 1.14, 3.57).

Conclusion: Higher consumption of ultra-processed foods concomitant with lower consumption of fresh and minimally processed foods is associated with a higher chance of poor sleep quality.

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Abbreviations: BMI, Body mass index; CI, Confidence interval; DAG, Directed acyclic graph; DQI-I, Diet Quality Index-International; FFQ, Food frequency questionnaire; GAD-7, Generalized Anxiety Disorder Scale; HEI, Healthy Eating Index; MW, Minimum wage; OR, Odds ratio; PSQI, Pittsburgh Sleep Quality Index; UK, United Kingdom; UPP, Ultra-processed foods.

* Corresponding author. Federal University of Ouro Preto, R. Diogo de Vasconcelos, 122, Ouro Preto - MG, Brazil.

E-mail addresses: luiz.menezes@aluno.ufop.edu.br (L.A.A. Menezes-Júnior), csouza.amanda@gmail.com (A.C.S. Andrade), hillary.coletro@aluno.ufop.edu.br (H.N. Coletro), raquel.mendonca@ufop.edu.br (R.D. Mendonça), mariana.menezes@ufop.edu.br (M.C. Menezes), gmcoelho@ufop.edu.br (G.L.L. Machado-Coelho), adriana.meireles@ufop.edu.br (A.L. Meireles).

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1. Introduction

Sleep is vital to the maintenance of physiological parameters and plays an important role in hormone release, cardiovascular activity, and glucose regulation [1]. Several longitudinal studies point to adverse health effects related to a sleep time restriction, including obesity, metabolic disorders, and chronic non-communicable disease risk [2]. Furthermore, sleep is a very critical component in times of pandemic, helping the immune system, and also interfering with the production of antibodies after vaccination or previous contact with the viral agent [3,4].

Sleep is considered one of the three main components of lifestyle, along with diet and physical activity, and is closely linked to health maintenance [5]. Poor sleep quality is often associated with unhealthy habits and lifestyle modifications, such as decreased physical activity and the consumption of high-calorie foods and beverages, and greater fat intake [6,7].

Currently, another important point to consider in dietary practices refers to the degree of food processing. Ultra-processed foods (UPF) are quickly replacing fresh or minimally processed and the traditional cuisine from most countries [8–11].

UPF is related to worse nutritional intake, with high energy density, added sugars, sodium, saturated and trans fats, and refined carbohydrates [9,12,13] encouraging excessive consumption based on characteristics such as convenience and hyper palatability [14] in addition to containing industrial additives linked to inflammation and harmful to health [11,13,15–18].

UPF is defined as industrially manufactured, ready-to-eat, or ready-to-heat formulations made mostly from substances that are derived from foods with little if any, whole foods. Such foods are characterized by the addition of synthetic substances, sugar, salt, fat, and stabilizers [12].

The study of this food group was first documented by Monteiro et al., in 2010, along with the NOVA classification [19], which is an important tool to describe the degree of food processing and its implication on food systems and dietary patterns, and how these may affect health and well-being patterns, and how these may affect health and the risk of disease [20,21]. Now, this classification is considered as the one being most valued in nutritional epidemiology and recommended by the Food and Agriculture Organization of the United Nations [11].

Changes in lifestyle and food consumption patterns have been exacerbated by the covid-19 pandemic, as shown by González-Monroy et al. in a systematic review with only longitudinal studies. González-Monroy noted from the studies that, there was a modification of eating behaviors, characterized by an increased snack frequency and a preference for sweets and ultra-processed food rather than fruits, vegetables, and fresh food after the beginning of the pandemic of covid-19 [22].

High consumption of ultra-processed foods is negatively associated with several health outcomes, including chronic non-communicable diseases, cardiovascular disease, and depression [15,18,23–25]. However, data on the contribution of UPF consumption on sleep quality is still limited in the literature.

Various foods and nutritional supplements have been used to try to benefit sleep [26]. However, the relationship between nutritional components and sleep is complicated. Nutritional factors change significantly with different dietary patterns and depend significantly on the digestive and metabolic functions of each [26,27]. In this regard, it is necessary to assess not only the intake of specific nutrients but also the dietary pattern of consumption.

Therefore, the central hypothesis of this study is that a dietary pattern characterized by high consumption of ultra-processed

foods and low in natural/minimally processed foods is associated with poor sleep quality. To this end, we aimed to determine if the co-occurrence of the food consumption according to the degree of processing was associated with poor sleep quality in adults during the covid-19 pandemic.

2. Methods

2.1. Study design

A population-based serological cross-sectional study was conducted between October and December 2020 in two medium-sized cities in the south-central region of Minas Gerais, known as Iron Quadrangle, one of the largest iron ore producing areas in Brazil. The survey was carried out in three surveys with intervals of 21 days, considering the incubation period of the SARS-CoV-2 virus.

All procedures were adopted according to the Brazilian guidelines and norms for research involving human beings of the Declaration of Helsinki. The study was approved by the Research Ethics Committee (Ethics Submission Certificate No. 32815620.0.1001.5149).

The sample size was calculated using the OpenEpi tool, with the 2019 population estimate by the demographic census 29 for the urban areas, 95% confidence level, design effect equal to 1.5, the estimated proportion of infection, and precision. In addition, it was considered a 20% re-composition percentage for any losses.

The sample was selected in three stages: census sector (probability proportional to the number of households), household (systematic sampling), and resident (randomly). Therefore, for each city, four strata were defined according to the average monthly incomes available in the 2010 demographic census 29, to ensure representativeness of different socioeconomic strata in the sample [28,29]. Based on the sample calculation, 1464 individuals should have been interviewed in the two cities evaluated.

2.2. Data collection

Data collection was performed face-to-face, using an electronic questionnaire with sociodemographic, health status, pandemic, and sleep information by trained interviewers. The health monitoring of the interviewers was conducted through periodic evaluation, before the beginning of each stage of the survey, using health questionnaires associated with the results of serological testing (immunochromatography reaction).

2.3. Sleep quality

The Pittsburgh Sleep Quality Index (PSQI) questionnaire was used to measure the subjects' sleep quality in this study. The Brazilian version of the Pittsburgh Sleep Quality Index had an overall reliability coefficient (Cronbach's α) of 0.82, indicating a high degree of internal consistency [30]. This instrument is composed of 19 questions categorized into seven components, each component scoring from 0 to 3: subjective sleep quality (C1), sleep latency (C2), sleep duration (C3), habitual sleep efficiency (C4), sleep disturbances (C5), use of sleep medication (C6), and daytime dysfunction (C7). The sum of the scores produces an overall score, ranging from 0 to 21, where the highest score indicates the worst sleep quality [31]. In this study, sleep quality was classified as good quality (PSQI score ≤ 5) and poor quality (PSQI > 5). A moderate to severe difficulty in a sleep-specific domain (C1 to C7) was defined as a score of ≥ 2 [31]. Cut-off point also used by Wang et al., 2020 [32].

2.4. Food consumption

Food consumption was assessed using a qualitative food frequency questionnaire (FFQ), referring to consumption for the last three months. The frequency of food consumption was reported on weekdays, considering the answers: i) Never; ii) 1–2 days/per week; iii) 3–4 days/per week; iv) 5–6 days/per week v) Every day including Saturday and Sunday. Participants described the frequency of consumption of 20 food items. However, to meet the objective of this study, we used only 10 food items. The FFQ was analyzed according to the degree of processing [19], and it was assessed by two explanatory variables: fresh/minimally processed foods and ultra-processed food classified according to the Food Guide for the Brazilian Population and the NOVA classification [12,19].

The group of fresh/minimally processed foods was composed of fruits, vegetables, leafy vegetables, milk, and beans, and the ultra-processed group by processed meats, sweets, instant noodles, soft drinks, and snack chips.

To assess the co-occurrence of the consumption of the two groups, a score was calculated according to the degree of processing of each food group as proposed by Francisco et al., 2019 [33]. The score ranged from zero to four points, depending on the food and weekly frequency of consumption. The score was calculated inversely: fresh/minimally processed foods consumed daily, and ultra-processed foods rarely consumed or never received the minimum score (zero). The highest score (four points) was received by the unprocessed and minimally processed foods rarely consumed or never, and by the ultra-processed foods consumed daily (Supplementary Table 1). The total score included the sum of the food items, ranging from 0 (best diet quality) to 40 points (worst diet quality). The total score was categorized into quartiles of the distribution.

Furthermore, we also evaluated whether individuals replaced their lunch and/or dinner, a home-cooked meal, mostly prepared with fresh/minimally processed foods, with ultra-processed foods, for five or more days in the week.

2.5. Co-variables

The questionnaire also included related variables to describe the sample, and for possible confounding controls in the analysis of the association between eating by NOVA classification and sleep quality. The variables evaluated are sex, age (18–34, 35–59 or > 60 years), marital status (married or unmarried), education (0–8, 9–11 or > 12 years), family income (≤ 2 , 2–4 or > 4 minimum wage), and worker (yes or no).

Health variables evaluated were self-reported chronic diseases (high blood pressure, diabetes, asthma, lung disease, chronic kidney disease, depression, anxiety disorder, cancer, heart or thyroid disease), which were dichotomized into morbidity (reporting at least one disease) and without morbidity (no disease).

Anxiety symptoms were assessed by the Generalized Anxiety Disorder Scale (GAD-7), and a cut-off score of 10 was considered to determine symptoms of a generalized anxiety disorder [34]. Alcohol consumption and smoking were evaluated by self-report (yes or no). Nutritional status was evaluated by the body mass index (BMI) from self-reported weight and height, and classified as underweight, eutrophic, or excess weight [35,36].

2.6. Statistical analysis

A theoretical causality model based on a directed acyclic graph (DAG) was elaborated with exposure (food consumption score), outcome (sleep quality), and confounding variables, using the

online software Dagitty, version 3.2 [37]. Causal connections represented by arrows were established among the variables (Supplementary Figure 2). Each variable in the DAG was represented by a rectangle and the colors had different meanings: green was the exposure variable; blue circled by black was the response variable; variables considered to be potential confounders were included, in blue are the antecedents of the outcome variable, and those in red are antecedents of the outcome and exposure variables. To avoid unnecessary adjustments, spurious associations, and estimation errors, the backdoor criterion was used to select a minimum set of confounding variables to fit the analyses [38]. The model was adjusted by the following minimum set of variables: age, sex, family income, marital status, and anxiety symptoms.

Unadjusted and adjusted logistic regression for the variables indicated by the DAG were conducted. Furthermore, linear trend tests were performed for each logistic regression model. Categorical variables were described as relative frequencies and 95% confidence interval (CI), and continuous variables were described as means and standard deviations (SD). Statistical analyses were performed considering the weighting factors of sampling using the svy command of Stata® software, version 15.0. The level of significance was set at 0.05.

3. Results

3.1. Characteristics of study participants

Table 1 shows the sociodemographic characteristics and health conditions of the study participants. Of the participants, 51.9% were women, the most prevalent age group was 35–59 years (45.6%), most were married (53.2%), had from 9 to 11 years of education (39.7%), and had a family income equal or less than two minimum wage (41.1%). About work-related variables, 52.5% of the evaluated individuals were active workers.

Concerning health conditions, more than half of the individuals had at least one chronic disease (52.3%), consumed alcohol at least once a month (58.2%), and were overweight (61.4%). Furthermore, 20.6% of the subjects had symptoms of an anxiety disorder (Table 1).

3.2. Distribution of sleep and food consumption score

The distribution of the PSQI and food consumption score is shown in Fig. 1. The PSQI had a mean score of 6.32 (95% CI 6.03–6.62) (Fig. 1), and the prevalence of poor sleep quality was 52.5% (Table 1). Evaluating the food consumption score, the mean score obtained was 9.16 (95% CI 8.50–9.81), with a minimum value of 0 and a maximum value of 30 (see Fig. 2).

Besides, Fig. 3 shows the distribution of the food consumption score by moderate to difficult sleep subdomains, by PSQI. Individuals in the third and fourth quartile of the food consumption score had a 30% higher prevalence of moderate to difficult sleep latency (36.7% vs. 47.8%; $p = 0.003$), 28% higher moderate to difficulties sleep disturbances (26.4% vs. 33.8%; $p < 0.001$), and 68% higher moderate to difficulties daytime dysfunction (9.1% vs. 15.3%; $p = 0.001$) when compared with individuals in the first and second quartile (Fig. 3).

3.3. Food consumption score and poor sleep quality

Table 2 shows the association between sleep quality and diet quality according to the food consumption score. Individuals in the first quartile had the lowest frequency of ultra-processed food consumption and the highest frequency of fresh/minimally processed food consumption. And individuals in the fourth quartile

Table 1
Sociodemographic and health conditions in adults during the covid-19 pandemic.

Characteristics	Total % (95%CI)	PSQI ≤5 % (95%CI)	PSQI >5 % (95%CI)	p-value*
Sociodemographic				
Sex				
Male	48.1 (41.0–55.2)	52.9 (44.7–60.9)	43.9 (36.3–51.8)	0.011
Female	51.9 (44.7–59.0)	47.1 (39.0–55.3)	56.1 (48.2–63.6)	
Age				
18–34 years	35.6 (31.1–40.3)	39.3 (30.8–48.4)	32.4 (26.2–39.2)	0.405
35–59 years	45.6 (41.1–50.2)	43.6 (36.0–51.6)	47.3 (39.7–55.0)	
≥ 60 years	18.8 (15.5–22.7)	17.1 (12.6–22.6)	20.3 (16.1–25.3)	
Marital status^a				
Married	53.2 (47.2–59.2)	57.5 (50.3–64.4)	49.6 (41.5–57.6)	0.105
Not married	46.8 (40.8–52.8)	42.5 (35.6–49.7)	50.4 (42.4–58.5)	
Education				
0–8 years	31.2 (26.7–36.0)	76.5 (69.7–82.2)	62.2 (54.1–69.6)	0.009
9–11 years	39.7 (35.6–43.9)	23.0 (17.3–29.8)	35.0 (27.4–43.5)	
≥ 12 years	29.1 (23.8–35.1)	0.5 (0.2–1.3)	2.8 (1.2–6.1)	
Family Income^b				
≤ 2 MW	41.1 (35.6–46.8)	37.9 (29.3–47.2)	43.8 (34.9–53.1)	0.450
> 2 to ≤ 4 MW	32.0 (26.9–37.5)	31.6 (24.7–39.5)	32.3 (26.1–39.1)	
> 4 MW	26.9 (22.0–32.5)	30.5 (22.0–40.6)	23.9 (17.8–31.3)	
Working^c				
Not workers	47.5 (42.7–52.3)	43.8 (36.1–51.9)	50.7 (43.8–57.7)	0.233
Active workers	52.5 (47.7–57.3)	56.2 (48.1–63.9)	49.3 (42.3–56.2)	
Health conditions				
Chronic diseases				
No	47.7 (41.3–54.2)	53.8 (44.7–62.7)	42.4 (35.4–49.8)	0.020
Yes	52.3 (45.8–58.7)	46.2 (37.3–55.2)	57.6 (50.2–64.6)	
Chronic pain				
No	65.7 (61.4–69.7)	74.6 (66.3–81.4)	58.0 (50.4–65.3)	0.013
Yes	34.3 (30.3–38.6)	25.4 (18.6–33.7)	42.0 (34.7–49.6)	
Anxiety symptoms^d				
Minimal	47.6 (43.6–51.7)	63.8 (56.0–70.9)	33.7 (26.6–41.6)	<0.001
Mild	29.0 (23.9–34.7)	22.3 (17.4–28.2)	34.8 (28.2–42.0)	
Moderate	15.6 (12.1–19.8)	11.4 (5.3–22.8)	19.2 (14.7–24.7)	
Severe	7.8 (6.2–9.8)	2.5 (1.5–4.2)	12.3 (9.6–15.7)	
Depression symptoms^e				
Minimal	61.1 (55.9–66.1)	83.1 (77.2–87.6)	61.1 (55.9–66.1)	<0.001
Mild	23.1 (19.0–27.9)	14.2 (9.9–20.0)	23.1 (19.0–27.9)	
Moderate	9.7 (7.2–12.8)	1.9 (1.1–3.3)	9.7 (7.2–12.8)	
Moderate to severe	4.3 (2.6–6.9)	0.7 (0.1–1.4)	4.3 (2.6–6.9)	
Severe	1.8 (1.2–2.8)	0.1 (0.1–0.2)	1.8 (1.2–2.8)	
Smoking				
No	83.0 (78.6–86.7)	81.6 (73.8–87.4)	84.3 (78.7–88.6)	0.530
Yes	17.0 (13.3–21.4)	18.4 (12.6–26.2)	15.7 (11.4–21.3)	
Alcohol consumption				
No	41.8 (36.0–47.9)	36.8 (31.1–42.9)	46.1 (38.4–53.9)	0.016
Yes	58.2 (52.1–64.0)	63.2 (57.0–68.9)	53.9 (46.1–61.6)	
Nutritional status				
Eutrophic	36.0 (30.7–41.7)	39.6 (32.0–47.6)	39.7 (32.2–47.7)	0.899
Underweight	2.6 (1.8–3.6)	2.2 (1.3–3.7)	2.7 (1.5–4.7)	
Excess weight	61.4 (55.6–66.9)	58.2 (50.1–65.9)	57.6 (49.6–65.3)	

MW: Minimum wage.

*p-value of Pearson's chi-square test.

^a Not married: Widowed, divorced, single.^b Minimum wage value: BRL 1045.00 ≈ USD 194.25 (1 USD = 5.3797 BRL).^c Not workers: Unemployed, pensioner, retiree.^d Anxiety symptoms evaluated by Generalized Anxiety Disorder Scale-7.^e Depression symptoms evaluated by Patient Health Questionnaire-9.

represent the highest frequency of consumption of ultra-processed foods and the lowest frequency of consumption of fresh/minimally processed foods. In adjusted analysis, the individuals in the third quartile were 71% more likely to have poor sleep quality (OR = 1.71; 95%CI: 1.03–2.85), and those in the fourth quartile, had a 144% greater chance of having poor sleep quality (OR = 2.44; 95%CI: 1.32–4.50).

Furthermore, 10.8% and 14.6% of the individuals replaced their lunch and dinner, a home-cooked meal mostly prepared with fresh/minimally with ultra-processed foods, for five or more days of the

week, respectively (Table 2). In adjusted analysis, the individuals who reported replacing dinner in the evening period with UPF were 101% more likely to have poor sleep quality (OR = 2.01; 95%CI: 1.14–3.57) (Table 2).

4. Discussion

To our knowledge, this is the first study that evaluated the association between the frequency of food consumption, according to the NOVA classification, and sleep quality in adults. Our main

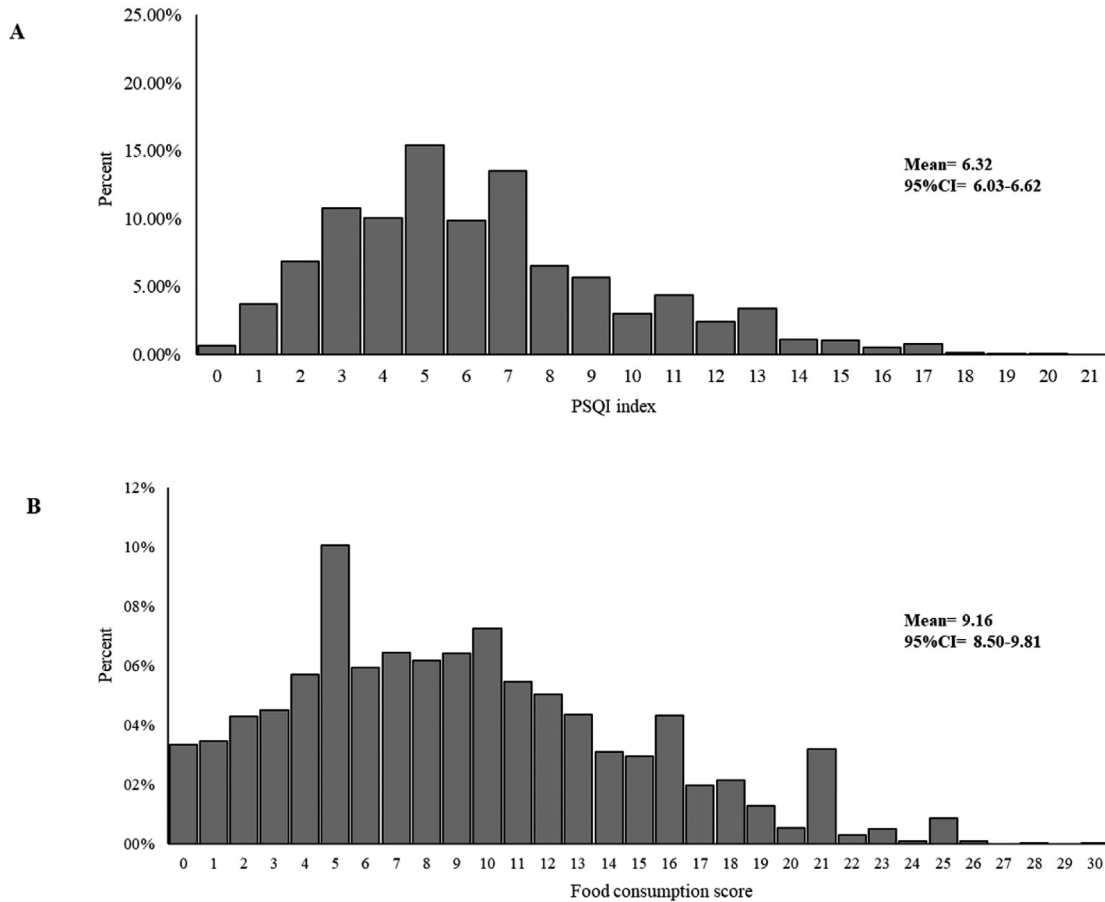


Fig. 1. Frequency distribution of PSQI score (A) and food consumption score (B).

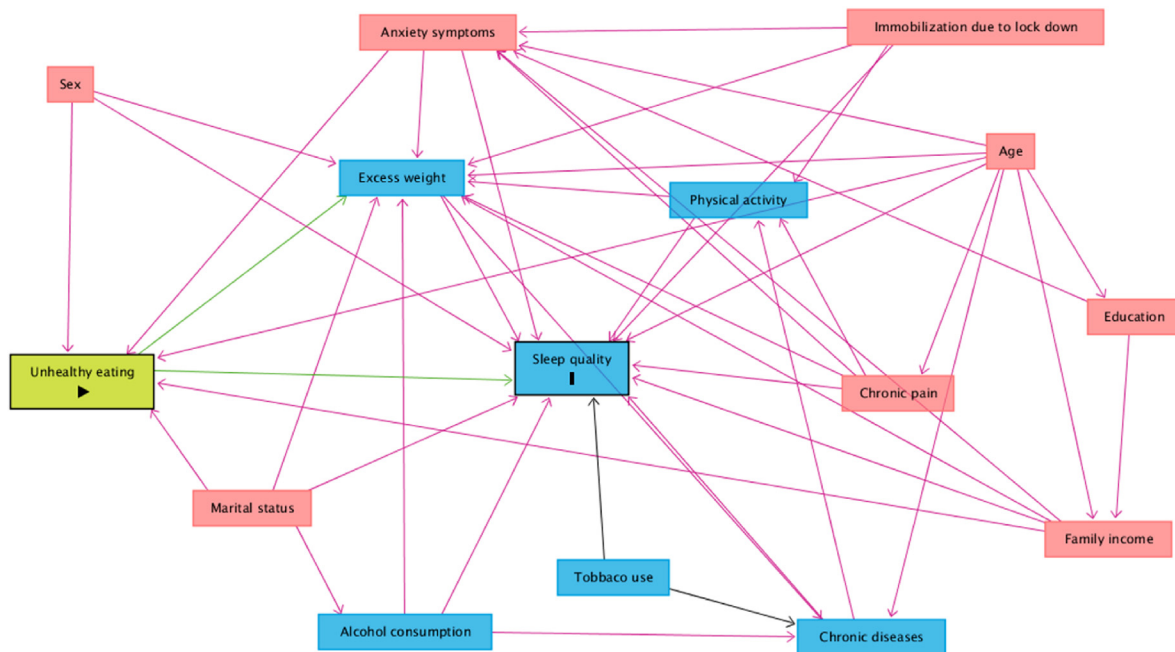


Fig. 2. Directed acyclic graph (DAG) on unhealthy eating score according to food processing level and sleep quality in adults during the covid-19 pandemic. Legend: The variable in green and with the "►" symbol inside the rectangle was the exposure variable; those in blue and with the letter "I" inside the rectangle were the response variables; variables in blue are the antecedents of the outcome variable; and those in red are antecedents of the outcome and exposure variables.

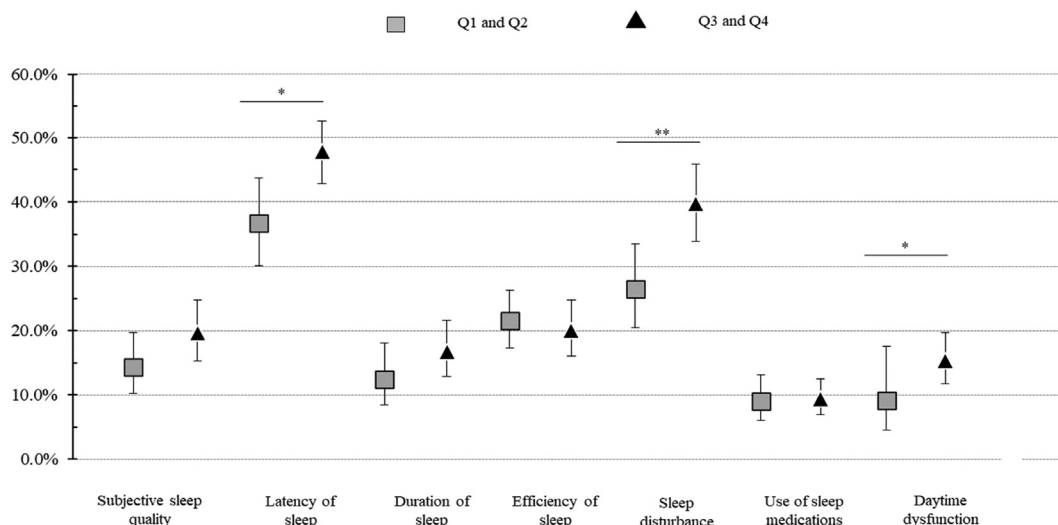


Fig. 3. Prevalence of moderate to difficulties Pittsburgh Sleep Quality Index subdomains^a by quartiles of food consumption score distribution. Legend: ^aScore for each domain ranges from 0 to 3 (no difficulty to severe difficulty), and a domain score ≥ 2 indicates moderate to difficulties sleep in the domain. Performed chi-squared analysis; * p-value < 0.05; ** p-value < 0.001.

Table 2
Association between unhealthy eating by NOVA system and sleep quality in adults during the covid-19 pandemic.

Food consumption score	Min. and max. values	Frequency (95% CI)	Unadjusted analysis			Adjusted analysis ^c		
			OR	95% CI	p-trend ^d	OR	95% CI	p-trend ^d
Quartile score^a								
Q1	0–4	21.4 (17.7–25.5)	1.00	–	0.056	1.00	–	0.013
Q2	5–8	28.6 (23.8–33.9)	1.43	0.82–2.49		1.54	0.82–2.87	
Q3	9–12	24.1 (20.2–28.6)	1.44	0.92–2.24		1.71	1.03–2.85	
Q4	13–30	25.9 (21.3–31.1)	2.01	1.09–3.73		2.44	1.32–4.50	
Replaced lunch or dinner for UPF^b								
Not replace lunch		98.9 (98.1–99.4)	1.00	–		1.00	–	
Replace lunch with UPF		1.1 (0.6–1.9)	2.07	0.72–5.92		1.45	0.42–5.01	
Not replace dinner		85.4 (81.9–88.4)	1.00	–		1.00	–	
Replace dinner with UPF		14.6 (11.6–18.2)	2.15	1.27–3.46		2.01	1.14–3.57	

UPF: Ultra-processed foods.

^a Quartiles of food consumption score distribution. Q1 are the lowest values of the score, characterized by the highest consumption of fresh and minimally processed foods and highest consumption of ultra-processed foods. Q4 are the highest values of the score, characterized by the lowest consumption of fresh and minimally processed foods and the highest consumption of ultra-processed foods.

^b Replaced lunch and/or dinner, a home cooked meal, mostly prepared with fresh/minimally processed foods, to ultra-processed foods, for five or more days in the week.

^c Adjusted analysis by the following minimum set of variables: age, sex, family income, marital status, and anxiety symptoms.

^d Linear trend tests.

findings were that the higher frequency of consumption of ultra-processed foods and the lower frequency of consumption of fresh and minimally processed foods were associated with a higher chance of poor sleep quality. Furthermore, replacing a home-cooked meal prepared mostly of fresh/minimally processed foods with ultra-processed foods frequently was associated with poor sleep quality. The results of this study can contribute to the development of other studies that seek to define the effects of food consumption, according to the degree of processing and human health, as well as helping to understand how sleep quality is multifactorial and is influenced by various aspects of human behavior.

UPF consumption represents an important and growing part of the world food supply. Recent studies have reported that these foods represent a significant percentage of about 50–60% of the energy content in the usual diet of the average consumer in the United States, Canada, or the United Kingdom [13,39]. Over the past 30 years, Brazilian society has experienced major social transformations that have resulted in changes in its pattern of food consumption, nutrition, and health [40]. In this sense, we have observed increased access to ultra-processed foods and the

beginning of substitution of fresh/minimally processed foods by ready-to-eat foods. In Brazil, the National Food Purchasing Survey shows that the contribution of UPF in total calories increased by 58.7% between the years 2002–2020 [41]. The increase of UPF in the global food supply has coincided with an increase in the prevalence of obesity and non-communicable diseases in many countries [20,21]. The relationship between high UPF consumption and obesity is well described in literature [21]. However, there are no studies in the literature evaluating food consumption by NOVA classification with sleep quality in adults.

We found relevant and alarming results, in which individuals with the highest consumption of ultra-processed foods and the lowest consumption of fresh foods, according to the food consumption score, may be more than twice as likely to have poor sleep quality.

The relationship between food consumption and sleep is still recent in the scientific literature, but some experimental studies have demonstrated the role of some nutrients in the improvement or worsening of sleep [27,42]. The high consumption of saturated fats has been considered the most harmful to sleep, and some

nutrients such as zinc, vitamin B, polyphenols, and tryptophan have been associated with better sleep quality [27], but the studies are highly heterogeneous and still incipient.

The role of some specific UPFs was evaluated, such as processed meats and dairy products, showing negative associations with sleep quality [42]. Consistent with our findings, previous studies have reported an inverse association between diet quality and sleep [26,27,42,44,45]. A recent study of diabetic women assessed the association of sleep quality with two indicators of healthy eating, the Healthy Eating Index (HEI) and Diet Quality Index-International (DQI-I) emphasize increased consumption of fruits, vegetables, and whole grains, concomitant with reduced intake of refined grains, empty calories, added sugar, sodium, and saturated fatty acids. They found that the risk of sleeping poorly decreased by 88% and 92% of participants in the upper tertile of DQI-I and HEI, respectively [46].

Furthermore, the largest investigation of diet, sleep, and mental health by utilizing the UK Biobank with 502,494 middle-aged adults, observed a significant main effect of healthy diet score on healthy sleep score in the unadjusted and adjusted analyses. To examine the specific contributions of food groups and items, healthy sleep scores are associated with increased intake of vegetables, fruit, and fish, but a lower intake of processed meat [43]. A similar result is reported in the review by St-Onge et al. (2016) in which dairy products, fish, fruit, and vegetables, are described with sleep-promoting effects [27].

The mechanism by which sleep quality is determined by food consumption is multifactorial. First, UPFs are high in fat, calories, sugars, and low in micronutrients and fiber [47]. As shown in a systematic review of 19 studies with 86,961 individuals, where the highest caloric contribution of carbohydrates and fats in the diet, had the worst night's sleep [48]. A review study suggested that hyperglycemia-induced after a high sugar diet and the resulting compensatory hyperinsulinemia could induce the release of autonomic counterregulatory hormones, including adrenaline, cortisol, glucagon, and growth hormone [26], leading to shorter time in deep sleep, and therefore non-restorative sleep [49]. Furthermore, high sugar consumption may also contribute to a higher inflammatory profile [50], which may negatively impact sleep [51].

Another hypothesis is that the consumption of these foods is higher during the nighttime period, which may further worsen sleep quality [52–54]. Although we did not assess at what point in time UPF consumption was highest, we observed that individuals who reported replacing a home-cooked meal prepared primarily from fresh/minimally processed foods with ultra-processed foods were frequently associated with poor sleep quality. Since the circadian system is signaled in part by dietary intake, eating at consistent times is important for robust circadian rhythms. Thus, consuming UPF in the evening, because it contains high levels of sugars and saturated fats, can compromise sleep physiology, similar to what happens with disrupted sleep patterns after an abrupt change in time zone, called jet lag [53]. In addition, a high-carbohydrate meal in the evening can interfere with the circadian rhythm, altering body temperature and consequently reducing nocturnal melatonin secretion, determining factors for good sleep induction and quality [55].

The consumption of some nutrients from fresh or minimally processed foods can alleviate the symptoms of poor sleep quality. Some of these nutrients are calcium, magnesium, vitamins A, C, D, E, and K, tryptophan, and isoflavones [42]. Among the potential mechanisms for the impact of these nutrients on sleep, it is highlighted that they may be related to the synthesis of serotonin and melatonin. These neurotransmitters are known to be involved in the sleep and wake cycle [27].

In addition to poor sleep quality, high UPF consumption can worsen health status as they contribute to overweight and obesity, as well as cause hormonal, metabolic, and physiological changes [56]. Since psychological dysfunctions are linked to poor sleep quality, it is of utmost importance to study these relationships. However, as this is a cross-sectional study, it is not possible to assess whether the consumption of UPF causes bad sleep. Therefore, a clear understanding of what matters and how various aspects contribute to the effects is highly necessary.

Our study has some strengths. To our knowledge, this is the first study to assess the consumption of UPF in association with sleep quality. We use the NOVA classification, which classifies groups of foods according to their nature, purpose, and extent of industrial processing and not merely by nutrients and type of food. Furthermore, the sample design brings robustness to the study: i) representative random sample of the resident population from different socioeconomic strata; ii) assessment by household survey iii) face-to-face study during the pandemic of covid-19. Also, DAG was used to make explicit assumptions about the relationship between food consumption and sleep; used to guide analysis plans and decisions about possible confounders.

The main limitations of this study are the variables obtained by self-report, which can lead to underestimation of risk behaviors or overestimation of protective behaviors. However, the assessment of sleep quality needs to be performed subjectively, since it considers intrinsic factors to the individuals' perception of their sleep. However, potential confounding may still be possible. Furthermore, the assessment of ultraprocessed food consumption was performed with the use of an FFQ that was not specifically designed to collect data regarding this new classification of foods. Therefore, there is the potential for some degree of misclassification of ultraprocessed food consumption inherent in our methodology. However, the FFQ was created using the foods most consumed by the Brazilian population and according to the most important national surveys [57,58]. Although we adjusted for poor sleep quality factors and other potential confounders to account for the fact that those participants who reported higher consumption of UPF also had an unhealthier lifestyle in general and the sleep quality can be worse in immobilization due to lockdown, anxiety about becoming ill, loss of relatives due to covid-19 and depressed mood, residual confounding cannot be ruled out in our study. Not performing an interrater reliability analysis of the interview participants may also be a potential limitation. To reduce any biases related to the application of the questionnaire, the interview was conducted face-to-face, the interviewers were extensively trained before the data collection, and also, instruments validated in previous studies.

There are significant public health implications of our study. To date, prevention and control of non-communicable diseases are becoming a growing concern. UPFs are beginning to be recognized as an emerging health risk as they are related to a worse nutritional pattern, characterized by high energy density, added sugars, sodium, saturated and trans fats, and refined carbohydrates. The positive association between UPFs consumption and poor sleep quality may increase the chances of understanding adverse health events. Encouraging reduced consumption of UPFs and increasing the proportion of unprocessed or minimally processed foods is a direct way to address the problem [12]. Macro interventions and state regulations play a vital role, such as taxation of food and enforcement of food marketing.

5. Conclusion

Most of the individuals studied had poor sleep quality, and the higher frequency of ultra-processed foods consumption

concomitant with lower consumption of fresh and minimally processed foods during the pandemic is a factor associated with a higher chance of poor sleep quality. Furthermore, replacing a home-cooked meal prepared mostly of fresh/minimally processed foods with ultra-processed foods frequently was associated with poor sleep quality. The results of this study can contribute to the development of other studies that assess causality between food consumption, according to the degree of processing and sleep quality.

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Authors' contributions

ACSA, RDM, MCM GLLMC, and ALM contributed to the conception and design of the work, to the acquisition, analysis, and interpretation of data, and to the draft of the manuscript. LAAMJ, ACSA, and HNC contributed to the analysis, interpretation of data, and the draft of the manuscript. All authors revised it critically for important intellectual content and approved the submitted version.

Declaration of competing interest

The authors declare that they have no conflicts of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.clnesp.2022.03.023>.

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