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The Impact of Ultra-Processed Food Consumption on Health in Low- and Middle-Income Countries

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Editorial: The Impact of Ultra-Processed Food Consumption on Health in Low- and Middle-Income Countries

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Keywords: epidemiology, food processing, health, low-and middle-income countries (LMICs), ultra-processed food (UPF)

Editorial on the Special Issue

The Impact of Ultra-Processed Food Consumption on Health in Low- and Middle-Income Countries

INTRODUCTION

In recent decades food processing has drastically changed to address consumer preferences and has led to higher demand for food items with longer shelf-life and improved palatability ultimately achieving this by adding natural or artificial ingredients which may impact on the nutritional quality of these foods, which are often characterized by high fat, sugar and salt contents [1]. Ultra-processed foods (UPFs) are defined as formulations made largely or entirely with cheap industrial sources of substances extracted from food, often chemically modified with additives and with a small amount of whole food using a series of processes [2]. Most importantly, UPFs are deliberately designed to be highly palatable and appealing, with extended shelf lives, and can be eaten conveniently in any setting, and their formulation, presentation and marketing often promote overconsumption [3]. Robust evidence from rigorously conducted cohort studies shows a clear link between UPF intake and adverse health outcomes, including reduced survival and increased risk of major chronic diseases [5], often independent of overall nutritional quality [6].

UPFs have progressively displaced traditional diets globally, and now constitute a major part of dietary intake, accounting for up to 50% of the energy intake in high-income countries [4]. Between 2007 and 2022, annual sales of UPFs (initially under 150 kg per person) increased across low-, lower-middle-, and upper-middle-income countries, as well as in all lower-income regions [5].

However, evidence on the impact of UPFs on populations within the low- and middle-income countries (LMICs) is limited and inconclusive, making it paramount to explore the implications of the rising UPF consumption within these countries.

This is particularly important given that LMICs account for the majority of the world's population and are therefore at risk of a substantial public health burden. Importantly, exploration of UPFs in LMICs may bring to light the impact of common contributing factors including ethnicity, ingredients, tropical food consumption, occupational stress, and genetic or environmental factors.

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KEY HIGHLIGHTS OF THE SPECIAL ISSUE

This Special Issue features seven papers that explore diverse topics in the field of UPF consumption and health outcomes within the LMICs settings, making the findings and insights all the more valuable to public health knowledge. The seven papers in this Special Issue explored the impact of UPF consumption in diverse conditions including, across different life stages, and various health outcomes making the findings widely interesting. They highlight that in Senegal, amongst adults, higher UPF consumption was linked to critical nutrients associated with risk of non-communicable diseases including higher total fat, free sugars and lower protein intakes (Kébé et al.); they compare and state that adults with type 2 diabetes mellitus had an overall lower UPF consumption than those without diabetes emphasizing the importance of promoting healthy eating habits to limit comorbidities such as diabetes mellitus (Mahajan et al.); they urged to examine the impact of higher UPF intake on adiposity and metabolic disturbances amongst adolescents (Ghosh and Muley); they find that most children and adolescents consumed unhealthy UPFs daily and had an overall unhealthier lifestyle in the Mediterranean region (Rosi et al.); they investigate that in slum settings in Kenya, adolescents with higher energy intakes from UPF had highest total energy, total fat, and saturated fat and lowest protein, fibre, and minerals such as iron, calcium and zinc intakes (Wanjohi et al.); they urge additional studies to examine the impact of UPF consumption on cognitive performance needs in adolescents within low-income settings (dos Santos et al.); and demonstrate that at a community level in South Brazil there was an increased consumption of traditional food appreciating local culture and lower UPF intake as a result of effective nutritional counselling intervention (Pacheco et al.).

Future research should prioritize comprehensive, longitudinal studies in LMICs to better understand the health impacts of UPF consumption across the life course. Particular attention should be given to the interplay of context-specific factors such as ethnicity, local ingredients, tropical diets, occupational stress, and genetic or environmental influences. Further investigations are also needed to evaluate effective interventions for reducing UPF intake and promoting traditional, nutrient-rich diets, particularly among children, adolescents, and vulnerable populations. Such evidence could inform culturally appropriate public health policies and nutrition strategies to mitigate the growing burden of diet-related chronic diseases in LMICs.

AUTHOR CONTRIBUTIONS

MB, SS and LI wrote the initial draft of the editorial, and critically reviewed and appraised the contents written in this editorial. All authors contributed to the article and approved the submitted version.

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Association Between Ultra-Processed Food Consumption and Cognitive Performance Among Adolescent Students From Underdeveloped Cities in Brazil: A Cross-Sectional Study

João Victor Laurindo dos Santos[1,2], *Ingrid Sofia Vieira de Melo*[2], *Clara Andrezza Crisóstomo Bezerra Costa*[2,3], *Layanne Cabral de Almeida*[2], *Dafiny Rodrigues Silva*[4], *Débora Cavalcante Ferro*[1], *Déborah Tenório Costa Paula*[1], *Mateus de Lima Macena*[4] and *Nassib Bezerra Bueno*[1,4]*

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Objectives: The association between ultra-processed foods (UPF) consumption and cognitive performance needs to be better characterized in adolescents, especially in low-income settings, where the cost of human capital is high. This study investigated the association between cognitive performance and UPF in adolescents from the countryside of the Brazilian Northeast.

Methods: Adolescents (15–18 years old) from three public high schools were included. Food intake was assessed using three 24-hour dietary recalls. The classification of foods as UPF was determined according to the Nova classification. Cognitive performance was evaluated using the Non-Verbal General Intelligence Test.

Results: 116 adolescents were included, of which 50 (43.1%) showed low cognitive performance. The average energy intake was 1973.5 kcal, with 24.2% coming from UPF. Participants with low cognitive performance consumed 26.5% (95% CI: [22.2; 30.7]%) of daily energy intake from UPF compared to 22.5% ([18.8; 26.2]%) of those with medium-high cognitive performance (P = 0.17), without differences in energy and macronutrient intake.

Conclusion: Despite similar UPF consumption compared to the Brazilian average, no association was found between UPF consumption and cognitive performance in this low-income adolescent sample.

Keywords: adolescent, diet, food intake, ultra-processed foods, cognitive dysfunction

INTRODUCTION

Global dietary habits are undergoing a significant transformation, with a concerning increase in the consumption of ultra-processed foods (UPF). In developed countries, these products account for over 50% of total energy intake [1], while in many developing countries, such as those in Latin America, this proportion approaches 30% [2, 3]. Among adolescents in different regions of the world, such consumption varies from 25% to 65% of total daily energy intake [4–6]. According to dietary consumption analysis released in the Brazilian household budget survey of 2017–2018, in general approximately 20% of the Brazilian population's total daily calories are derived from UPF, and this share reaches 27% in Brazilian adolescents [7]. Factors such as hyper palatability, low cost, easy access, and intense marketing targeted toward the public may explain this trend [8].

The Dietary Guidelines for the Brazilian population, based on the Nova classification, recommends avoiding the consumption of UPF due to its low nutritional composition quality and the use of additives and other components in its fabrication [8, 9]. Excessive intake of UPF was found associated with the development of overweight, obesity, and chronic diseases such as diabetes, hypertension, metabolic syndrome, and dyslipidemia [10]. With the increase in UPF consumption among adolescents, these conditions, which were more prevalent among adult and elderly populations, have become increasingly present in this age group, as well [11]. Moreover, prior studies highlighted the association between UPF consumption and increased risk of cognitive impairment in older people [12, 13], but this association is not clear in adolescents.

It is noteworthy that adolescence represents an important phase of dietary habit formation as well as physical and neural development. Dietary intake during this phase is crucial to ensure the proper development of the prefrontal cortex, which is essential in the process of self-regulation [14]. Therefore, considering the nutritional characteristics of UPF, their consumption may lead to detriments in cognitive development. It is known that the adequate intake of macronutrients and micronutrients contributes to the integrity of the myelin barrier, neural cell membrane, neural proliferation, and synaptic formations [15], potentially impacting the proper cognitive development of individuals. Moreover, high sodium intake is related to cognitive impairment in adult and elderly individuals [16]. The fatty acid profile of the diet also exerts some influence, albeit marginal, with saturated fatty acid consumption being associated with cognitive impairment in adults [17]. In contrast, polyunsaturated fatty acid consumption appears to improve cognitive performance in children [18]. Furthermore, it is not known whether other factors besides the nutritional composition of these foods, such as the processing level and use of non-nutritive additives, may also play a role in the cognitive performance of the individuals [19].

To properly evaluate the impact of diet on cognition, it is essential to clarify the various terms used in this field. Cognitive performance refers to an individual's ability to perform cognitive tasks that involve mental processes such as memory, attention, executive functions, language, and perception [20, 21]. It is often assessed in clinical and research contexts to understand how different cognitive domains interact and how they can be affected by neurological or psychiatric conditions [20]. Cognitive domains refer to mental processes that involve the acquisition, processing, retention, and use of information [20, 22]. These domains reflect specific areas of mental functioning and include memory, attention, executive functions, language, and perception, among others [20]. Finally, cognitive impairment is defined as a disruption or decline in cognitive functions, indicating that some cognitive abilities are below what is expected for an individual's age, education, and cultural context [21, 22]. This impairment can be present at any time in a person's life. It can result from a variety of conditions, such as malnutrition, exposure to heavy metals, metabolic disorders, head trauma, and side effects of drug treatments for conditions such as cancer or Parkinson's disease [21, 22]. In addition, age-related conditions such as traumatic brain injury, neurodegenerative disorders (such as Alzheimer's disease), stroke, brain tumors, and brain infections can also cause cognitive impairment [21, 22].

Current studies on the relationship between UPF consumption and cognition are scarce and more common in older adults. A systematic review with meta-analysis of observational studies found associations between higher UPF consumption and cognitive impairment in adults [23]. Others evaluated the association between the consumption of these foods and cognitive performance in adults and elderly individuals in a cross-sectional study, observing a negative relationship between the two [24]. Additional studies corroborated these findings, indicating an association between UPF consumption and cognitive impairment in adults and elderly individuals with type 2 diabetes [13, 25, 26]. Nevertheless, few studies have investigated UPF consumption and cognitive performance in younger populations. Liu et al. conducted a cohort study with 325 Chinese children aged 4–7 years, in which they assessed dietary intake using the Food Frequency Questionnaire and cognitive function using the Verbal Comprehension Index [27]. It was found that children who consumed more than two groups of UPF showed a significant decrease in test scores. However, the consumption was measured by the weekly frequency of consumption of each group of UPF, without mentioning data on daily energy intake from UPF [27].

Thus, studies conducted in populations of different age groups indicate that high consumption of UPF may be associated with inferior cognitive performance. However, this relationship in adolescents, a population in the neural development phase that deserves attention, needs to be better elucidated in the scientific literature. The literature is even scarcer regarding populations in low- and middle-income countries, where the cost of human capital due to inadequate development conditions is even higher. Therefore, this study aimed to evaluate the association between cognitive performance and UPF consumption in adolescents residing in cities in the countryside of the Brazilian Northeast.

METHODS

Study Design and Ethical Aspects

This study is a secondary cross-sectional analysis of baseline data from a randomized clinical trial called "Internet-Based Nutritional Education versus Conventional Nutritional Education: A Randomized Clinical Trial," registered in the Brazilian Clinical Trials Registry (ReBEC) under the number RBR-9crqgt. This clinical trial received approval from the Research Ethics Committee of the Universidade Federal de

Alagoas, with protocol number 80728017.0.0000.5013, and was conducted in accordance with the principles of the Declaration of Helsinki. All parents or legal guardians of the adolescents provided written consent, and all adolescents consented to participate voluntarily. This article follows the guidelines for Strengthening the Reporting of Observational Studies in Epidemiology-Nutritional Epidemiology [28].

Population and Sample

Sampling was non-probabilistic, based on convenience. Participants were recruited through invitations made during presentations in the classrooms at three high schools in the state of Alagoas: Escola Estadual Monsenhor Clóvis Duarte de Barros in União dos Palmares municipality; Instituto Federal de Alagoas, in both Murici campus and Satuba Campus, in Murici municipality, and Satuba municipality, respectively. During these presentations, the researchers informed the students about the research and invited them to participate. The state of Alagoas is one of the poorest in the Brazilian Federation, with an average Human Development Index (HDI) of 0.687. It also has the highest illiteracy rate among people aged 15 and older (17.7%), an unemployment rate of 12.0% for individuals aged 14 and older, a GINI index of 0.498, and a significant percentage of households receiving income transfer program benefits: 34.9% from the Bolsa Família Program, 7.1% from the Continuous Cash Benefit program, and 7.3% from other social programs. Additionally, only 34.08% of households are connected to the sewage network, and the general water network supplies 68.14%. At the same time, the studied municipalities have even lower HDIs, with União dos Palmares at 0.593, Murici at 0.527, and Satuba at 0.660 [29, 30].

Adolescents attending these schools, aged between 15 and 18, were included according to the criteria of the World Health Organization (WHO) [31]. Adolescents who presented any condition that prevented anthropometric measurements, those who were HIV-positive, had type 1 diabetes, were pregnant, or were breastfeeding were excluded.

Variables

Exposure

Dietary Intake

Dietary intake assessment was conducted through 24-hour dietary recalls administered by trained interviewers. Three 24-hour recalls were collected over three different days, covering two weekdays and one weekend day. During the interviews, participants provided information on foods and beverages consumed from the time they woke up until bedtime. To aid in estimating the quantities consumed, interviewers used two photographic food quantification manuals [32, 33].

The collected data were processed using Avanutri® software, version 4.1 (Avanutri Equipamentos de Saúde Ltda, Rio de Janeiro, Brazil), which converted consumed foods and beverages into energy (kilocalories), carbohydrates, proteins, and fats (g). Information from the following databases was used: Brazilian Food Composition Table [34], Food Composition Table [35], and information provided by food product manufacturers, following this order of preference. Then, foods and beverages were categorized into three subgroups according to the Nova classification: unprocessed and minimally processed foods, processed foods, and UPF [36]. According to the Nova classification, unprocessed foods are obtained directly from plants or animals and undergo no alteration after leaving nature. Minimally processed foods are natural foods subjected to minimal processes such as removal of inedible parts, drying, grinding, filtering, roasting, boiling, pasteurization, refrigeration, freezing, or vacuum packaging, among others. These processes do not add substances to the original food and do not significantly alter its nutritional value. Processed foods are those manufactured by the industry by adding salt, sugar, or other culinary substances to natural or minimally processed foods, aiming to increase durability or improve sensory qualities. UPF are industrial formulations made entirely or largely from substances derived from foods, such as sugars, oils, fats, or salt, and additives like preservatives, antioxidants, and stabilizers. Ultra-processed foods generally contain little or no natural or minimally processed food [36].

Outcome

Non-Verbal General Intelligence Test (NV-GIT)

The NV-GIT assesses non-verbal intelligence and identifies incorrect processes in various types of reasoning. The test consists of 30 multiple-choice questions, each with six response options, only one of which is correct [37]. The reliability and internal consistency of the NV-GIT were verified, and satisfactory results were obtained. The Cronbach's Alpha coefficient was 0.89, the Spearman-Brown correction was 0.85, and the Test-Retest method showed a coefficient of 0.93. The validity of the NV-GIT was determined through the correlation between NV-GIT scores and four tests: Ravens Progressive Matrices (0.56), R1 (0.42), D70 (0.73), and G36 (0.65) [37].

Developed with the Brazilian population, the NV-GIT is widely used in Brazil. The NV-GIT was chosen for its ease of administration and simple interpretation of results. Unlike other nonverbal intelligence tests, it allows intelligence measures to be expressed on intelligence quotient (IQ) and percentile scales. Additionally, the NV-GIT can assess the mental state of people from 10 to 79 years old, covering three levels of education: Elementary, Secondary, and higher education [37].

The research team, who was previously trained by a psychologist, administered the test to the students. Prior to the test day, the principals from each school were contacted to allow the research team to visit classes, which were paused for 50 min in order for the questionnaires to be administered. All instructions provided in the test manual were strictly followed. There was no time limit, but the test protocols could only be returned after 20 min, as instructed in the test manual, to avoid characterizing withdrawal. Scoring was done using an answer analysis grid and according to the participants' educational level. Each adolescent was classified into one of the following intelligence level categories [37]: Extremely Low (up to 3 points, IQ below 69), Low (4–7 points, IQ between 70 and 79), Below Average (8–14 points, IQ between 80 and 89), Average (15–22 points, IQ between 90 and 109), Above Average (23–25 points, IQ between 110 and 119), High (26–27 points, IQ between 120 and 129), and Very High (28–30 points, IQ above 130).

For the present analysis, NV-GIT scores were grouped into three main categories to simplify statistical analysis. The scores were categorized as follows: Low cognitive performance, which includes the "Extremely Low," "Low," and "Below Average" score ranges; medium cognitive performance, which consists of the "Average" range; and high cognitive performance, which includes the "Above Average," "High," and "Very High" ranges.

Assessment of Covariates

Anthropometric Data

For anthropometric assessment, data on weight, height, and Body Mass Index (BMI) were collected. Body weight was recorded using a digital scale (Filizola®, São Paulo) with a capacity of 150 kg and a precision of 100g. Height was measured using a portable stadiometer. We used the AnthroPlus software developed by the WHO to assess child growth and calculate z-scores. This software is specifically designed to analyze growth data for children and adolescents aged 5–19 years, allowing comparison with the WHO reference curves. Z-scores were calculated for the following anthropometric indicators: Body Mass Index (BMI) by age and height by age. Participants were categorized according to the WHO reference curves [38]. Waist circumference was measured with a flexible, non-elastic tape positioned at the midpoint between the lower edge of the last rib and the iliac crest [39].

Physical Activity Level

Physical activity level was assessed using the short version of the International Physical Activity Questionnaire (IPAQ), validated for the Brazilian population and appropriate for adolescents [40, 41]. This version consists of eight open-ended questions addressing the time spent on activities such as walking, vigorous and moderate physical efforts, as well as periods of physical inactivity (time in a sitting position) during the last week. Based on this information, participants were classified into four levels of physical activity: sedentary, irregularly active, active, and very active.

Socioeconomic Level

The socioeconomic level was assessed using the Brazilian Economic Classification Criteria (BECC), developed by the Associação Brasileira de Empresas de Pesquisa (ABEP). Based on the BECC score, participants were classified into six economic classes, ranging from "A", the highest, to "D-E", the lowest, taking into account possession of household assets, educational level of the head of the household, and access to services such as piped water and street paving [42].

Bias

To avoid bias, three dietary recalls from three different days, comprising two weekdays and one weekend day, were collected. This approach was adopted because the use of three recalls results in more accurate estimates of energy and nutrient intake compared to a lower number of recalls [43, 44].

Statistical Analyses

Continuous variables were reported using the mean and the standard deviation measures, and categorical variables were exhibited as relative and absolute frequencies. Comparisons between groups for continuous variables were made using a one-way analysis of variance (ANOVA), whereas the chi-square test was utilized for categorical variables. To explore the relationship between low cognitive performance and ultra-processed food consumption, an analysis of covariance (ANCOVA) was used, adjusted for sex, age, body mass index, socioeconomic status, and physical activity level. The estimated marginal means (EMM) for energy intake according to food processing level, in percent, were calculated. An alpha value of 5% was adopted for all analyses. JAMOVI software version 4.2.0 (Sydney, Australia) was employed for all analyses.

RESULTS

Within the age range of interest for our study, there were a total of 851 potentially eligible students from the three schools. From these, 186 were interested in participating and were able to provide their parents' consent, and hence, they were recruited. After excluding 25 participants due to eligibility criteria and 45 participants who did not complete three dietary recalls, the final sample consisted of 116 adolescents, as shown in **Figure 1**. The participants had a mean age of 16.7 (0.9) years and a mean BMI-for-age of 0.02 (1.07) Z-score. Among the included adolescents, the classification based on raw NV-GIT scores was as follows: Extremely Low (n = 4; 3.4%), Low (n = 17; 14.7%), Below Average (n = 29; 25.0%), Average (n = 45; 38.8%), Above Average (n = 15; 12.9%), High (n = 4; 3.4%), and Very High (n = 2; 1.7%). Specifically, as categorized for the present analysis, 50 (43.1%) had a low, 45 (38.8%) had a medium, and 21 (18.1%) had a high non-verbal intelligence level. The socioeconomic and anthropometric characteristics of the participants are presented in **Table 1**. No statistically significant differences were observed for variables such as age, weight, height, or waist circumference across the cognitive performance categories. However, the BMI-for-age Z-score showed a statistically significant difference ($p = 0.01$), although this difference was not clinically relevant, as the values remained within normal growth ranges for adolescents. Additionally, no significant differences were found in the level of physical activity (assessed by the IPAQ) or in socioeconomic classification (BECC) across the cognitive performance categories.

Table 2 presents the dietary intake analysis. The mean energy intake of the sample from the three dietary recalls of each individual was 1973.5 (711.6) kcal, with a mean UPF intake of 503.6 (14.9) kcal, for a mean dietary UPF share of 24.2 (14.9) %. It is noteworthy that there were no differences in dietary energy intake and macronutrient content across levels of NV-GIT.

Table 3 presents estimated marginal means for energy intake, in percent, according to the food processing level in the different classes of nonverbal intelligence level. No significant associations were identified between these variables. To further explore our

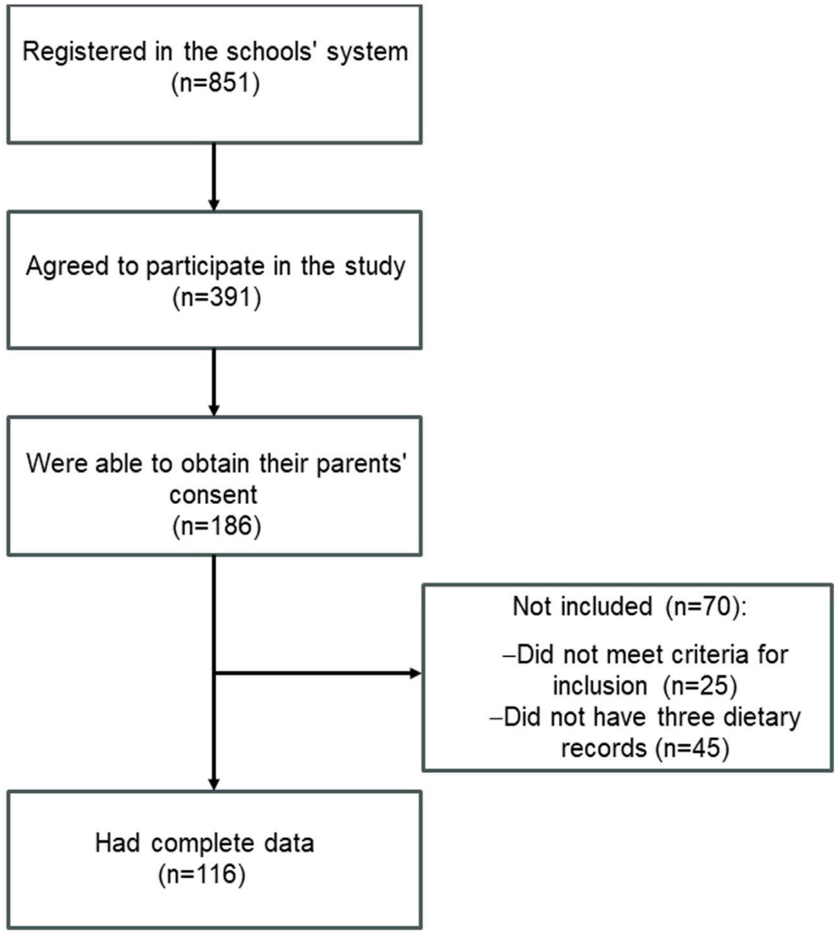

FIGURE 1 | Flowchart of participant selection (Brazil, 2018–2019).

TABLE 1 | Sociodemographic characteristics of the sample (n = 116) (Brazil, 2018–2019).

Variables	Total sample (n = 116)	(NV-GIT)			
		Mean (SD) Low (n = 50; 43.1%)	Medium (n = 45; 38.8%)	High (n = 21; 18.1%)	*p*-value[a]
Age (years)	16.65 (0.86)	16.86 (0.78)	16.47 (0.87)	16.52 (0.98)	0.06
Weight (kg)	60.69 (12.12)	59.26 (10.30)	62.56 (14.60)	60.10 (10.14)	0.40
Height (m)	1.66 (0.09)	1.67 (0.10)	1.65 (0.09)	1.71 (0.10)	0.09
WC (cm)	72.08 (8.22)	70.68 (7.63)	73.41 (9.06)	72.60 (7.53)	0.26
BMI-for-Age (Z-score)	0.02 (1.07)	0.13 (1.03)	0.37 (1.06)	−0.35 (1.05)	0.01
	n (%)	n (%)	n (%)	n (%)	*p*-value[b]
BECC					0.07
A, B1 and B2	23 (19.8)	8 (16.0)	7 (15.6)	8 (38.1)	
C1, C2 and D-E	93 (80.2)	42 (84.0)	38 (84.4)	13 (61.9)	
IPAQ					0.09
Very active and active	78 (67.2)	33 (66.0)	30 (66.7)	15 (71.4)	
Irregularly active and sedentary	38 (32.8)	17 (34.0)	15 (33.3)	6 (28.6)	

BECC, Brazilian economic classification criteria; WC, waist circumference; W-A, Weight-for-age; BMI-A, Body mass index-for-age; IPAQ, international physical activity questionnaire; NV-GIT, Non-verbal general intelligence test.
[a]*p-value for ANOVA one-way.*
[b]*p-value for chi-square tests.*

TABLE 2 | Dietary characteristics of the sample (n = 116) (Brazil, 2018–2019).

Variables	Total sample (n = 116)	(NV-GIT)			
		Low (n = 50; 43.1%)	Medium (n = 45; 38.8%)	High (n = 21; 18.1%)	*p*-value[a]
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	
Total energy (kcal)	1,973.56 (711.67)	2,016.97 (804.00)	1,881.05 (659.96)	2,068.47 (580.48)	0.61
Carbohydrate (%)	52.68 (7.96)	53.00 (9.21)	51.74 (6.83)	53.84 (6.68)	0.49
Protein (%)	20.12 (7.33)	20.84 (9.52)	20.03 (4.93)	18.42 (4.21)	0.74
Lipids (%)	27.69 (5.29)	27.33 (5.01)	28.22 (6.03)	27.58 (4.55)	0.74
Fiber (g)	21.77 (10.59)	20.92 (10.44)	22.41 (11.93)	22.74 (8.07)	0.52
Unprocessed or Minimally Processed (kcal)	976.95 (396.19)	957.15 (373.28)	986.74 (433.36)	1,003.13 (382.29)	0.88
Unprocessed or Minimally Processed (%)	50.90 (16.33)	50.40 (17.34)	52.20 (15.50)	49.35 (16.17)	0.23
Processed (kcal)	492.92 (302.10)	467.23 (309.13)	474.17 (300.22)	594.30 (281.33)	0.11
Processed (%)	24.82 (12.47)	23.03 (12.41)	25.12 (12.26)	28.48 (12.87)	0.77
Ultra-processed (kcal)	503.68 (407.59)	592.59 (492.03)	420.15 (282.25)	471.04 (387.67)	0.24
Ultra-processed (%)	24.26 (14.89)	26.57 (16.12)	22.67 (13.59)	22.17 (14.48)	0.34

[a]*p-value for ANOVA one-way.*

TABLE 3 | Estimated marginal means of multivariable analysis between Non-Verbal General Intelligence Test (NV-GIT) classifications and percentage of foods according to Nova (n = 116) (Brazil, 2018–2019).

Food intake	(NV-GIT)			
	Low	Medium	High	*p*-value[a]
	EMM [CI 95%]	EMM [CI 95%]	EMM [CI 95%]	
Unprocessed or Minimally Processed (%)	49.84 [45.17; 54.51]	52.52 [47.60; 57.44]	49.97 [42.67; 57.27]	0.71
Processed (%)	23.42 [19.86; 26.98]	25.05 [21.31; 28.80]	27.67 [22.12; 33.23]	0.44
Ultra-processed (%)	26.73 [22.47; 30.98]	22.41 [17.93; 26.89]	22.35 [15.70; 28.99]	0.32

[a]*Analysis of covariance adjusted for sex (female and male), age (years), body mass index-for-age (Z-score), Brazil Economic Classification Criterion (A, B1 and B2, and C1, C2, D-E), and International Physical Activity Questionnaire (Very active and active, and irregularly active and sedentary).*

data, we have merged the groups with medium and high cognitive performance and tested their percent of UPF intake against those of the low cognitive performance group. Although the statistical power increased, there were no significant differences between groups (EMM of %UPF intake for low cognitive performance: 26.5 [22.2; 30.7]%; medium-high performance: 22.5 [18.8; 26.2]%; $P = 0.17$).

As an exploratory analysis, we tested which exposures were associated with the higher intake of UPF in our sample. Nevertheless, neither sex, excess weight, BBEC, nor IPAQ showed significant associations with the dietary share of UPF intake (data not shown).

DISCUSSION

In the present study, the NV-GIT tool revealed a high prevalence of low cognitive performance (43.1%) among adolescents enrolled in three public schools in the interior of the state of Alagoas, Brazil. On average, 24.2% of their energy intake was derived from UPF, and this consumption was not associated with cognitive performance, according to the NV-GIT tool. The individuals with low cognitive performance also showed the same level of macronutrient intake, unprocessed and minimally processed foods as the individuals with medium and high cognitive performance, indicating that, in the present sample, no measures of dietary intake were associated with the degree of cognitive performance.

The lack of a significant association between UPF consumption and performance on the NV-GIT in the present study may be explained by the specifics of the cognitive aspects assessed by this test. The NV-GIT focuses on non-verbal cognitive skills such as problem-solving, visual-spatial perception, and abstract reasoning. These aspects may be less sensitive to the potential influences of UPF consumption compared to other cognitive skills. Previous studies with adults and children have identified an association between UPF consumption and cognitive function [13, 24, 27]. In these studies, cognitive function was assessed through tests that measured both verbal and non-verbal skills, whereas the NV-GIT focuses only on non-verbal skills. Additionally, there may be a significant difference between verbal and non-verbal skills in low-income participants, with a higher overall average in the non-verbal skills test [45], like those included in this research. This disparity can influence the results of cognitive tests differently. When we decided to use a non-verbal intelligence test, we assumed that it would be possible to identify students with low cognitive performance more accurately since the overall average of these tests is high in this age range. Those with lower averages could represent individuals with more significant cognitive difficulties. This approach is particularly relevant for low-income students, who may show a big gap between their verbal and non-verbal scores [45].

The heterogeneity found in the published studies hampers our ability to compare our prevalence of low cognitive performance with the literature. Few of the published studies report such prevalence rates, and they usually use different tools to assess cognitive performance. In many of these studies, only the mean scores obtained in the various cognitive domains are reported [13, 24, 26]. Furthermore, such limitation also extends to the comparison of the findings regarding the specific association between UPF consumption and cognitive performance in adolescents, with only studies relating dietary patterns to cognitive performance in this age range [46–50]. Future studies should investigate a wider number of cognitive domains in order to assess the potential association of UPF intake with this complex outcome, especially in adolescents.

Our hypothesis that UPF intake could negatively impact cognition in adolescents was supported by the unique nutritional characteristics of UPF. These foods tend to be rich in added sugars and saturated fats, factors that have been associated with effects that may contribute to cognitive deficits [17, 19, 26, 51–53]. Increasing evidence also indicates that the consumption of UPF is associated with a higher intake of pro-inflammatory ingredients and oxidative stress, both recognized as contributing factors to cognitive impairment [54–57]. Furthermore, UPF consumption may disrupt the gut microbiota, leading to an imbalance known as gut dysbiosis, which is associated with a higher risk of cognitive impairment [58–61]. Additionally, obesity-induced adiposity, often related to excessive UPF consumption, is marked by the presence of pro-inflammatory cytokines, which have been associated as contributing factors to cognitive impairment [62–65]. In contrast, unprocessed and minimally processed foods are rich in beneficial nutrients, such as essential fatty acids, polyphenols, and vitamins, with well-established antioxidant effects [66, 67]. Studies have shown that adopting healthy dietary patterns, which include a variety of these foods, can contribute to better cognitive functioning, even promoting structural changes in the brain, such as a larger left hippocampal volume, white matter, and gray matter [68–70]. These brain structures are associated with better cognitive functioning [71–73].

It is noteworthy that the share of dietary UPF consumption among the adolescents in our research was similar to the Brazilian adolescents' mean of 27.0%, as reported by the Brazilian household budget survey of 2017–2018 [7]. Also, other studies conducted with Brazilian adolescents show similar results. Rocha et al. found that UPF contributed an average of 28% of the total energy intake among adolescents in Brazilian public and private schools [74], and Martins et al. investigating adolescents from the same Brazilian region also found a share of 26% of energy arising from UPF [75]. It is noteworthy that this share of dietary energy arising from UPF is way lower compared to studies conducted in developed countries, such as the United States and Australia, where adolescents had a share of dietary energy arising from UPF of 67.0% and 54.3%, respectively [76, 77].

This study has some limitations. First, it is a cross-sectional study, which prevents the determination of causality between the investigated variables. Another limitation of the study was the use of a questionnaire to assess participants' physical activity level, which may also be subject to memory bias, overestimation or underestimation of physical activity, and difficulty in determining the intensity of the activity. Additionally, the sample size was modest, which may affect the generalizability of the findings and the low statistical power of the study. It is worth noting that our study has some significant strengths. The analysis was conducted on an age group that is less studied, and most studies on the topic are conducted in developed countries, which helps fill knowledge gaps in this specific population. Another strength was the use of three 24-hour recalls, which provided a more accurate estimate of the participants' dietary intake [43, 44]. Additionally, the study made adjustments for relevant confounding factors, thereby improving the understanding of the analytical framework.

In conclusion, UPF consumption was not associated with cognitive performance in the NV-GIT in adolescents residing in underdeveloped cities in Brazil. Although the nature of our study does not establish direct causal relationships and the current sample was not specifically recruited to test such hypotheses, the results can be viewed as exploratory and suggest that the potential role of consuming these foods on the cognitive performance of adolescents deserves further investigation, especially for different cognitive domains.

ETHICS STATEMENT

The studies involving humans were approved by Research Ethics Committee of the Universidade Federal de Alagoas. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

AUTHOR CONTRIBUTIONS

JdS: writing–original draft preparation, Writing-reviewing and editing, Formal analysis. DS: project administration, visualization, writing–reviewing and editing. CC, LdA, DF, DP, and MM: Investigation, Methodology, data curation, Writing–reviewing and editing. IdM: Resources, Writing–reviewing and editing. NB: Supervision, Conceptualization, Methodology, Writing–reviewing and editing, validation, Formal analysis. All authors contributed to the article and approved the submitted version.

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CONFLICT OF INTEREST

The authors declare that they do not have any conflicts of interest.

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Effectiveness of a Nutrition Counseling Intervention on Food Consumption, According to the Degree of Processing: A Community-Based Non-Randomized Trial of Quilombola Communities in South Brazil

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Objectives: To evaluate the effectiveness of a nutrition counseling intervention on food consumption according to the Nova classification that reflects levels of food processing.

Methods: Controlled community trial was conducted in quilombola communities in the South of Brazil. Four communities were allocated to the control group (CG) and the intervention group (IG), two communities comprised each group. A total of 158 individuals (CG = 87; IG = 68) were included in the study. The intervention consisted of six theoretical and practical workshops on food and nutrition education, conducted over a 4-month period. We used a 24-hour recall at baseline and another post-intervention.

Results: There was an increase in the consumption of traditional quilombola food as an effect of the intervention (from 14.5% to 20.7% in the IG, and from 12.7% to 16.0% in the CG, $p = 0.05$). There was no significant variation in the other Nova food groups according to time and intervention.

Conclusion: An increase in traditional quilombola food indicates a resumption of traditional food intake and appreciation of local culture as an effect of this intervention at the community level.

Clinical Trial Registration: www.clinicaltrials.gov, identifier NCT02489149.

Keywords: quilombola communities, nutritional counseling, dietary intake, food processing, NOVA classification

INTRODUCTION

The Nova system proposes the classification of foods based on the extent and purpose of the industrial processing [1]. Since its first publication, more than a decade ago [2], the Nova system has contributed to nutritional epidemiology and public health, by including other food dimensions into the dominant nutrient-based approach, such as ingredients and processing characteristics [3, 4]. At the level of foods, has been considered ingredients, processing characteristics, and impact on dietary patterns [4]. Although the Nova system classifies the foods into four food groups, the ultra-processed (Nova group 4) has received the main focus in the literature. These foods are industrial formulations with ingredients that might not be available for domestic use, ready for consumption, elaborated - entirely or mostly - from substances extracted from food or synthesized in the laboratory, with little or no intact food [5]. These products are normally nutritionally unbalanced and offer advantages for their convenience, durability, and hyper palatability. In addition, they have great sales profit, due to the low cost of ingredients, made in conjunction with attractive packaging and aggressive advertising [1, 5].

The trend toward increasing ultra-processed foods consumption is accompanied by the replacement of the traditional diet [1, 6]. In other words, the Nova group 1 (unprocessed and minimally processed foods) and Nova group 3 (processed foods) have been replaced by ultra-processed foods [4]. According to population-based data, the Nova group 1 still represents the base of the Brazilian diet [7]. However, the participation of ultra-processed foods in the total calories determined by household food purchases increased from 14.3 in 2002/03 to 17.3% and 19.4% between 2008/09 and 2017/18, respectively [7]. Furthermore, a growing body of evidence links ultra-processed foods to an increased risk of obesity, chronic disease, and mortality [8–10]. It has been recently estimated that more than a fourth of the increase in the prevalence of obesity in Brazil between 2002 and 2009 was attributable to ultra-processed foods [11].

In this context, the Dietary Guideline for the Brazilian Population, the main instrument to promote healthy eating practices in the country and updated in 2014, incorporated the Nova system as the guide for food choices, bringing as the golden rule always prefer natural or minimally processed foods and freshly made dishes and meals to ultra-processed food [12]. Also, the document points out the existence of population groups more vulnerable to nutritional issues, such as the quilombolas, and emphasizes the dialogue with sociocultural, economic, and environmentally sustainable dimensions [12].

The quilombola communities are racial/ethnic groups of black ancestry, originating during the period of slavery and after abolition. They usually, but not exclusively, live in isolated territories as a form of resistance to racial/ethnic oppression [13]. In the quilombola communities of the State of Rio Grande do Sul in the South of Brazil, homemade foods play a key role, including bakery products and traditional meals based on rice and beans [14]. However, the replacement of traditional foods by ultra-processed in quilombola communities has been observed [15].

Concerning food consumption based on the Nova system, there is a gap in national population-based data from quilombola communities. A study conducted in 14 Brazilian States showed that sweets (including candies, gelatin, and ice cream), packaged snacks, canned or inlaid meat, chocolate milk, ready-made cookies and cakes, and soft drinks or powdered soft drinks were purchased in the previous week by almost all families, including those in extreme poverty [16]. In the state of Rio Grande do Sul, the same locality where this study was conducted, ultra-processed represented the main options for snacks, including cookies (31.4%), packaged salty snacks (10.2%), and candies (9.3%) [17]. Thus, these data suggest a nutritional transition framework for quilombolas' diet [15].

A nutrition counseling nutrition interventions in quilombola communities should focus on the promotion of traditional food habits, since cooking activities is a mechanism of cultural resistance, and actions to mitigate ultra-processed foods consumption [15]. As historically, quilombola communities are a vulnerable group to food and nutrition insecurity, the growing share of ultra-processed foods in the diet of these communities, particularly due to the above-mentioned characteristics of the ultra-processed foods, can lead to the double burden of malnutrition [4]. Therefore, the current study aimed to evaluate the effectiveness of a nutritional counseling intervention on food consumption, according to the Nova system food classification in quilombola communities in the South of Brazil.

METHODS

Design and Sampling

The current study is a non-randomized, controlled, parallel, cluster-type intervention conducted in four quilombola communities in the South of Brazil. Thus, it is in accordance with the TREND statement's recommendations for behavioral and public health interventions involving non-randomized research [18].

The studied sample originated from the main research project entitled "Food and Nutrition Education in quilombola communities with food insecurity: rescue of food culture, promotion of healthy eating and the demand for the Human Right to Food." It was carried out from 2014 to 2016. The four quilombola communities of the Rio Grande do Sul that had the highest prevalence of overweight and food insecurity, according to a population-based study [19] and, considering the logistic and financial capacity of the study, were eligible to participate in his project. Two communities were assigned to the intervention group (IG) and control group (CG), respectively. **Supplementary Figure S1** shows the location of these quilombola communities in the same region of the State of Rio Grande do Sul (Canguçu, Pelotas, Cristal, and Nova Palma).

These cities are located in the extreme south of Brazil, with an agricultural economic tradition, and formed from large farms that used the labor of individuals enslaved in the 18th and 19th

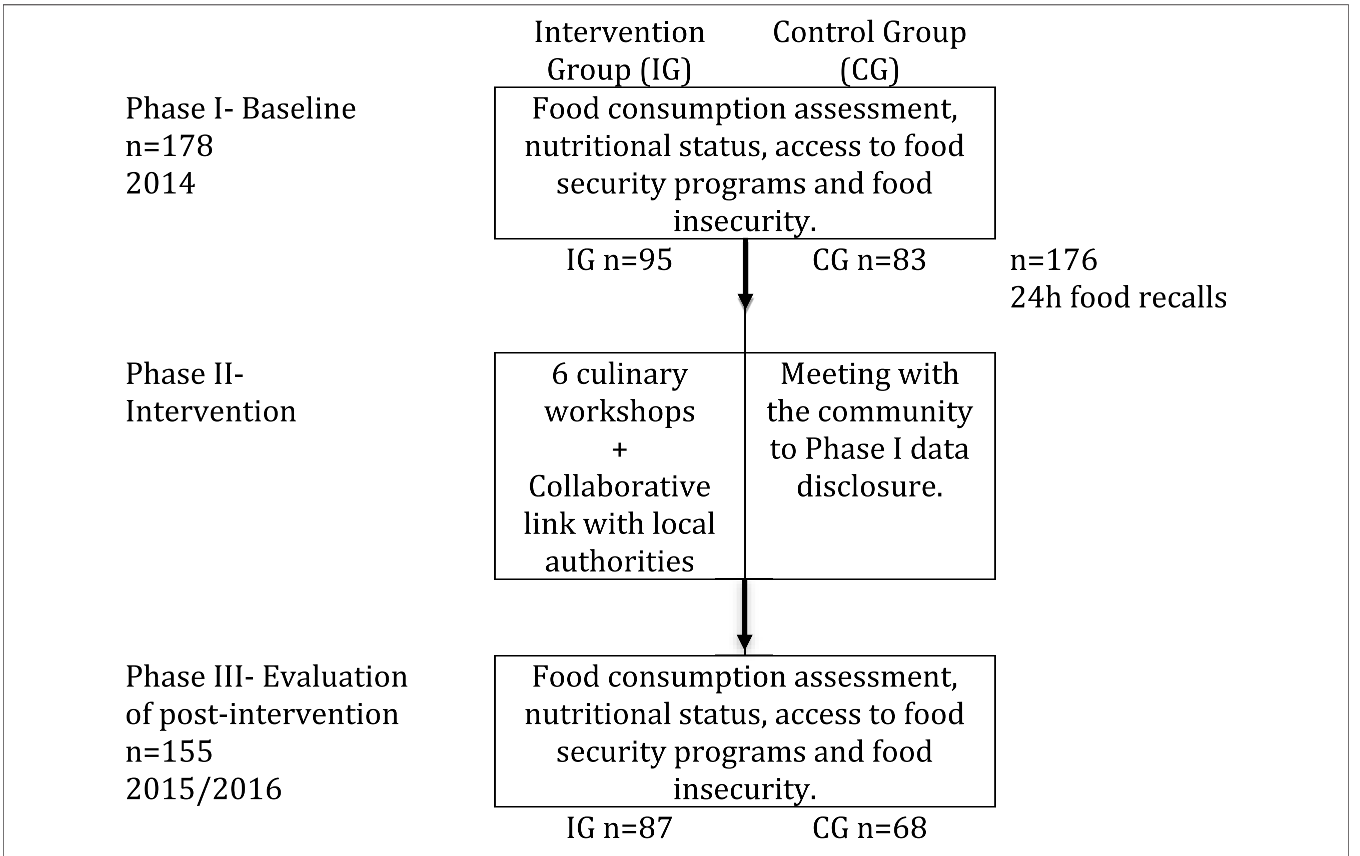

FIGURE 1 | Flowchart of the study design conducted in four quilombola communities in Rio Grande do Sul, Brazil, 2014–2016.

centuries. Besides, the communities included in this study are located in the rural areas of the cities mentioned above. They have low coverage of health services, low education levels [14], important illiteracy and unemployment rates, precarious housing conditions, and a high prevalence of chronic non-communicable diseases such as hypertension [20], diabetes, and overweight [14].

All self-declared heads of households in these four communities, located in the rural areas of the municipalities of Pelotas (n = 61), Canguçu (n = 35), Cristal (n = 42), and Nova Palma (n = 40), totaling 178 individuals, were included in the study. Of these, two communities received an educational nutritional intervention (Passo do Lourenço and Algodão communities, in the municipalities of Canguçu and Pelotas, respectively), and two did not, serving as control groups (Serrinha do Cristal and Rincão do Santo Inácio, in the municipalities of Cristal and Nova Palma, respectively).

Study Design

This study was registered at ClinicalTrials.gov under the identifier: NCT02489149. **Figure 1** presents the study phases. Phase I refers to the baseline, the intervention was performed in phase II, and phase III is the post-intervention evaluation.

In Phase I, quantitative and qualitative diagnosis was performed. The quantitative diagnosis consisted of a census-type survey involving all those responsible for families according to self-attribution criteria of the intervention communities and controls on their food consumption, nutritional status, access to programs to fight hunger, and the prevalence of food insecurity, measured by Ebia scale [21]. For qualitative data collection, focus groups were conducted to assess traditional habits and recipes.

Intervention strategies for Phase II were developed based on Phase I results and were conducted over a 4-month period. Workshops were carried out with the community members to form multipliers (**Supplementary Table S1**). The workshops are detailed in their methodology and materials for their reproduction in a booklet that was produced and then distributed to all participating families [22]. Actions with the institutional public, including municipal managers - from the areas of health, education, culture and rural development, as well as health professionals from the Family Health Strategy teams in the region, were carried out to minimize food insecurity and promote healthy eating.

Instruments and Data Collection

For phases I and III, standard pre-coded and pre-tested questionnaires were employed. Questions about socioeconomic and demographic features including age, education, sex, skin color, income, physical activity, access to health services, social development, and benefit from social programs were answered by the person responsible for the self-assigned household at the time of the interview. Trained interviewers measured the nutritional status of household heads. The scale used was from the Marte® brand with a capacity of 200 kg and an accuracy of 50g, along with Exact Height® brand anthropometers with an accuracy of 1 mm. The BMI was calculated as the weight in kilograms divided by the height in squared meters (kg/m^2) [23]. The interviewers underwent extensive training to administer the questionnaire and perform anthropometric measurements. A manual was created and provided for quick reference, containing descriptions of all variables, alternative questions for instances where interviewees did not understand the initial question, and guidance on coding responses. Physical activity was evaluated by International Physical Activity Questionnaire (IPAQ) short form that asks about three specific types of activity undertaken in the three domains: walking, moderate-intensity activities and vigorous intensity activities; frequency (measured in days per week) and duration (time per day) are collected separately for each specific type of activity. A combined total physical activity metabolic equivalent-minute per week (MET-min/week) was computed as the sum of walking + moderate + vigorous MET-min/week scores [24].

To assess dietary intake, trained and standardized interviewers applied two 24-hour recalls: one at baseline and another post-intervention. In addition to the quantities (in homemade measures), the 24-hour recall included information on the food brands, the form of preparation, the place where the food was obtained (inside or outside the home), the time of consumption, whether the food was classified as diet or light (any food or beverage whose recipe is altered to reduce fat, carbohydrates, and sugar for example), and whether it was classified as homemade, ready for consumption or ready to heat, facilitating the subsequent classification according to food processing.

The Automated Multiple-Pass Method [25] was employed to obtain more accurate information concerning food consumption. This method comprises five steps designed to minimize memory bias in 24-hour recall reporting. Additional questions were asked using a conference list of commonly forgotten products and, finally, the recipes for the preparations were detailed. A photographic album of homemade measurements was used to estimate the quantities [26]. In addition, the interview was conducted preferably in the interviewee's home and kitchen, where the utensils, and the brand of food consumed could be observed. The questionnaires, after being reviewed and coded by the field supervisor, were entered with double check of the data.

The data obtained in the study were double-entered in the Epidata software version 3.1 and the 24-hour dietary recalls in ADS Nutri [27]. The Brazilian Table of Food Composition – TACO was used as a reference for energy and nutrient calculations.

Outcome

The outcome measured was the percentage of energy contribution from the different Nova system groups. This system classifies food into four categories based on the extent and purpose of the industrial processing: unprocessed or minimally processed foods (Group 1), processed culinary ingredients (Group 2), processed foods (Group 3), and ultra-processed foods (Group 4) [1]. Our analysis adheres to the original four groups outlined by the Nova classification. However, due to the cultural traditions of the quilombola population, the results also distinguish "traditional quilombola food," which is separated from the processed foods group.

Traditional quilombola food (included in Nova Group 3) refers to preparations made at home using unprocessed or minimally processed foods (Group 1) and culinary ingredients (Group 2). Examples include homemade bread, cakes, bread rolls, and recipes incorporating vegetables such as carrots, pumpkin, and corn, as well as dishes like beans with canjica, cornmeal with meat, guacamole, and oven-baked sweet potatoes, among others [12].

Data Analysis

Descriptive data analysis was performed to characterize and compare the CG and IG at baseline through frequency distribution, means and standard deviation (SD). Pearson's chi-square and Student's T-test were used to test differences between the categorical and continuous variables, respectively. The outcome was used as a continuous variable. For comparison of the energy contribution from the Nova food groups between groups, before and after intervention, the Generalized Estimation Equations model was used. We estimated the effect of belonging to a group (intervention or control), the time in between the first and third phases, and the interaction of these two factors.

The robust estimator was employed with an unstructured work matrix and normal distribution with identity binding function. The *post hoc* test adopted was the Bonferroni test. The absence of data in the third phase of the study was treated as loss (missing) without data imputation. In all comparisons, a p-value <0.05 was considered significant. Data analysis was performed using the IBM SPSS statistical software, version 18.0.

Ethical Aspects

The study was approved by the Human Research Ethics Committee of the Federal University of Rio Grande do Sul (UFRGS) and all participants signed the Informed Consent Form. In addition to the measures mentioned, as this is a study in traditional communities, previous contacts were also made with the leaders of the communities, to expose the research goals and obtain their consent.

RESULTS

All those responsible for the families of four communities, two communities that participated in the intervention actions and two control communities were evaluated, totaling 178 adults interviewed and 176 24-hour food recalls collected. In the final evaluation (phase III), 21 individuals (11.8%) were lost to follow-up. Thus, the final sample comprised 158 individuals (CG = 87, IG = 68).

TABLE 1 | Demographic, socioeconomic, anthropometric characteristics, food and nutritional security of those responsible for the families of quilombola communities in Rio Grande do Sul at the baseline, Rio Grande do Sul, Brazil, 2014 (n = 178).

Variables	Intervention group (n = 95)	Control group (n = 83)	*P*-value
Sex (female)	66.3%	73.5%	0.30
Age (years)	45.4 ± 15.6	44.1 ± 16.5	0.60
Race/color (black or brown)	91.6%	85.5%	0.20
Schooling (years)	4.2 ± 5.4	4.6 ± 4.1	0.64
Family monthly income (reais)	819.0 ± 954.8	903.2 ± 638.8	0.50
Per capita monthly income (reais)	280.3 ± 2,990	317.7 ± 269.7	0.38
Has a signed work card	2.7%	1.7%	0.71
Inhabitants per house hold	3.73 ± 2.26	3.61 ± 1.75	0.72
BMI (kg/m^2)	28.65 ± 5.97	28.07 ± 5.65	0.53
Physical activity (MET-min/week)	7,620 (3,066–15,360)	7,332 (2,739–15,090)	0.76
Food and nutritional security			<0.01
Security/Low insecurity	41.1%	74.7%	
Moderate insecurity/Severe	58.9%	25.3%	
Access to cash transfer program	57.9%	47.0%	0.15
Consumption of food produced by the family	55.8%	68.7%	0.09

**Results expressed by mean ± SD, frequency (%), and median (P25 - P75). Student T-test; chi-square or Mann-Whitney U Test; p < 0.05.*
Abbreviations: BMI, body mass index.
Physical activity: combined total physical activity MET-min/week computed as the sum of Walking + Moderate + Vigorous MET-min/week scores.

TABLE 2 | Contribution in grams and percentage of total calories per day from Nova food groups, traditional quilombola food, and nutrient consumption by those responsible for the quilombola communities in Rio Grande do Sul on the baseline study, Rio Grande do Sul, Brazil, 2014 (n = 176).

	Intervention group (n = 95) Mean ± SD		Control group (n = 83) Mean ± SD		*P*-value
	Kcal/d or g/day	%TEV/day	Kcal/d or g/day	%TEV/day	
Unprocessed or minimally processed foods[a]	1383.7 ± 953.7	52.3 ± 20.7	1289.0 ± 775.3	52.0 ± 21.4	0.92[a]
Processed culinary ingredients[a]	184.9 ± 175.9	16.1 ± 13.4	160.6 ± 157.4	19.8 ± 14.3	0.07[a]
Processed foods[a,b]	141.6 ± 153.6	16.8 ± 13.6	113.4 ± 117.8	14.4 ± 11.8	0.64[a]
Traditional quilombola food[a]	102.6 ± 103.4	14.5 ± 12.4	85.8 ± 85.4	12.7 ± 11.3	0.32[a]
Ultra-processed foods[a]	106.2 ± 164.7	13.9 ± 15.4	147.3 ± 219.1	15.0 ± 19.2	0.68[a]
Energy (Kcal/d)	1821.7 ± 955.8	—	1825.1 ± 824.9	—	0.98
Protein (g/d)	71.5 ± 44.3	15.8 ± 6.4	72.5 ± 48.9	16.0 ± 7.3	0.89
Carbohydrate (g/d)	213.7 ± 110.5	49.8 ± 15.9	221.2 ± 111.3	49.7 ± 15.8	0.91
Fat (g/d)	71.9 ± 61.3	33.0 ± 13.5	70.6 ± 47.6	33.0 ± 13.5	0.65
Fiber (g/d)	22.2 ± 13.7	—	21.2 ± 13.8	—	0.63
Sodium (mg/d)	3634.3 ± 4838.4	—	3336.8 ± 2883.7	—	0.63

%TEV: percentage of the total energy value.
[a]*P value for the difference of the means of the percentage of the total energy consumption.*
[b]*Including culinary preparations according to original Nova classification.*

Table 1 shows the sociodemographic, anthropometric and food and nutritional security characteristics of those responsible for the families at the baseline, as well as, the differences between the IG and CG. A difference was found in the food and nutritional security variable. In the IG communities the moderate and severe food insecurity was greater than in CG communities of the IG (58.9% vs. 25.3%).

Table 2 shows the baseline dietary intake according to allocation group. There was no significant difference in the mean daily total energy (1,821.7 ± 955.8 kcal/d in the IG, 1,825.1 ± 824.9 kcal/d in the CG) and proteins, fibers, and sodium. The percentage of contribution to the total calories from unprocessed or minimally processed foods was approximately 52% for both groups, processed culinary ingredients (16.1% in the IG, 19.8% in the CG), processed foods (16.8% in the IG, 14.4% in the CG), and ultra-processed foods (13.9% in the IG, 15.0% in the CG).

Table 3 shows the percentage values of energy contribution of the Nova food groups before and after the intervention, according to allocation group. Any food group presented statistically significant variation as a function of the effect of the intervention, except traditional quilombola food that presented an increase in consumption from 14.5% to 20.7% in the IG, and from 12.7% to 16.0% in the CG (p = 0.05) as an effect of the intervention. There was a variation in the percentage of the energy contribution from the several food groups, in the CG and IG, attributed to a variation in time regardless of the intervention. The group of unprocessed or minimally processed foods (from 52.3% to 45.6% in the IG, and from 52.0% to 49.0% in the CG, p = 0.01) and culinary ingredients

TABLE 3 | Changes in the percentage of the total energy value of consumption of unprocessed or minimally processed foods, culinary ingredients, processed foods, ultra-processed foods and traditional quilombola food between the pre and post intervention periods of those responsible for the family of Quilombola communities in Rio Grande do Sul, Rio Grande do Sul, Brazil, 2014 and 2016 (n = 155).

	Phase 1		Phase 3		*P*-value for intervention	*P*-value for time	*P*-value for interaction (intervention*time)
	Intervention (n = 93)	Controls (n = 83)	Intervention (n = 87)	Controls (n = 68)			
	%TEV		%TEV				
Unprocessed or minimally processed foods	52.3 ± 20.7	52.0 ± 21.4	45.6 ± 16.5	49.0 ± 21.7	0.54	0.01	0.35
Culinary ingredients	17.8 ± 14.7	18.1 ± 13.0	13.2 ± 8.8	13.8 ± 10.2	0.73	<0.01	0.87
Processed foods[a]	16.8 ± 13.6	14.4 ± 11.8	22.3 ± 18.2	19.7 ± 16.5	0.24	<0.01	0.74
Traditional quilombola food	14.5 ± 12.4	12.7 ± 11.3	20.7 ± 18.6	16.0 ± 15.7	0.05	<0.01	0.34
Ultra-processed foods	13.9 ± 15.4	15.0 ± 19.2	18.6 ± 15.5	17.7 ± 20.1	0.97	0.02	0.55

%TEV: Percentage of the total energy value.
Generalized Estimation Equation Model; Bonferroni.
Values expressed by means ±SD.
P *values expressed for the effects of the intervention, time and interaction between intervention and time.*
[a]*Including culinary preparations according to original Nova classification.*

(from 17.8% to 13.2% in the IG, and from 18.1% to 13.8% in the CG, $p < 0.01$) had a reduction in the percentage of contribution as an effect of time. In contrast, processed foods, traditional quilombola food, and ultra-processed foods increased (significance values for the effect of time related to the data in **Table 3**).

Table 4 shows total energy among the groups and subgroups of the Nova classification. We found a reduction in the contribution of total calories per day, as well as calories consumed through meat and fruit. In the evaluation of subgroups, a significant difference was found between the means of consumption from phase I to phase III for meat, rice, beans, roots and tubers, oil and sweetened beverages that include soft drinks. The percentage contribution from meat, oil and roots and tubers was reduced. Meat varied due to time, as did rice presenting a reduction and beans presenting an increase. Roots and tubers, vegetable oils were reduced according to time and intervention. In contrast, the intake of traditional quilombola foods and soft drinks increased with both time and intervention.

DISCUSSION

This community-based non-randomized trial evaluated the effectiveness of a nutritional counseling intervention on food consumption, according to the degree of processing in quilombola communities. It was noted that the consumption of traditional quilombola food (part of the Nova group 3) potentially increased after intervention, suggesting that actions at the community level may promote healthy eating and rescue the traditional food culture.

In the workshops carried out during the intervention, traditional recipes identified during the research were prepared in the focus groups, encouraging the use of traditional ingredients such as sweet potatoes, canjica, beans, and pork. Previous studies found that community interventions focused on the development of culinary skills [28–30] obtained significant results in the increase in the frequency and daily amount of vegetable consumption [29, 30]. Also, the development or perpetuation of culinary skills – necessary for the preparation of traditional dishes – are positively associated with a better quality of diet and inversely related to the consumption of ultra-processed [31].

Other experiences with community interventions of quasi-experimental methodology are found [32, 33] aimed at traditional populations [32, 34–36] or with an approach to the cultural perspective of the communities [37]. Browne et al. [32] explored eleven systematic reviews on nutritional education interventions in Australian Aboriginal communities. The findings suggest the success of the interventions occurred mainly when there was community involvement in the development and implementation of programs, including programs with complex approaches that integrate knowledge, skills, and access to healthy foods, nutritional education with a community approach, and workshops on culinary skills [32].

Similarly, interventions aimed at black communities [37], native populations of North America [34], Alaska [35], and Ecuadorian indigenous people [36] argue in favor of incorporating cultural aspects of the community, with actions developed in collaboration with the target sample, as a relevant aspect for the success of the initiatives, as well as for the sustainability of the results of promoting healthy eating over time. Collectively oriented interventions, with the potential to stimulate a healthier environment and circumvent voluntary behavior changes, are capable of causing changes in food consumption in order to reduce inequities [38]. On the other hand, nutritional interventions focused on individual orientations can be exclusionary and especially affect those with greater socioeconomic disadvantages [38, 39].

We did not find significant changes in the other Nova food groups. In the present study, the consumption of ultra-processed foods was lower than that reported for the general Brazilian population. According to data from the National Food Survey

TABLE 4 | Distribution of total energy among the groups and subgroups of the Nova classification by those responsible for the family of quilombola communities in Rio Grande do Sul of the Intervention group, Rio Grande do Sul, Brazil, 2014 (n = 155).

Food subgroup	Phase 1		Phase 3	
	kcal/d Mean ± SD	% of TEV Mean ± SD	kcal/d Mean ± SD	% of TEV Mean ± SD
Total energy value	1821.7 ± 955.8	—	1538.8 ± 758.4	—
Group1: fresh or minimally processed foods	952.7 ± 197.8	52.3 ± 20.7	800.2 ± 162.3	52.0 ± 21.4
Beef, poultry, fish and seafood, eggs	385.2 ± 399.8	19.6 ± 16.8	229.8 ± 238.2[i]	14.1 ± 11.6
Rice and other cereals (including pasta and other pasta)	216.8 ± 189.2	12.7 ± 9.0	212.6 ± 183.2[i]	14.2 ± 10.7
Beans and other legumes	94.8 ± 73.9	6.7 ± 6.5	105.2 ± 91.0[i]	7.7 ± 7.2
Roots and Tubers	50.8 ± 95.4	3.2 ± 6.6	20.0 ± 54.8[j]	1.3 ± 3.6
Milk and natural yogurt	32.9 ± 69.0	1.9 ± 4.3	29.4 ± 57.7	1.9 ± 4.0
Fruits and fruit juices	117.7 ± 200.8	6.5 ± 10.2	75.1 ± 129.4	5.3 ± 8.3
Legumes	17.3 ± 27.1	1.2 ± 2.4	15.5 ± 23.6	1.0 ± 1.4
Others[a]	9.1 ± 34.6	0.6 ± 2.0	3.6 ± 4.9	0.3 ± 0.5
Group 2: processed culinary ingredients	293.3 ± 128.1	16.1 ± 13.4	304.7 ± 108.4	19.8 ± 14.3
Table sugar[b]	90.8 ± 135.0	4.9 ± 7.4	86.7 ± 130.8	5.4 ± 6.8
Vegetable oils	162.4 ± 317.9	7.7 ± 9.8	74.1 ± 64.8[j]	5.7 ± 5.2
Other culinary ingredients[c]	52.1 ± 82.3	3.5 ± 6.6	43.3 ± 62.0	2.7 ± 3.8
Group 3: processed foods	306.0 ± 129.9	16.8 ± 13.6	221.6 ± 89.5	14.4 ± 11.8
Traditional quilombola food	264.0 ± 304.1	14.5 ± 12.4	314.3 ± 309.2[j]	20.5 ± 18.7
Fresh bread	1.7 ± 16.1	0.2 ± 1.6	0	0
Ham and other salty meats, smoked or canned	0	0	0	0
Cheese	0	0	1.3 ± 8.7	0.1 ± 0.5
Canned vegetables	0.7 ± 4.1	0.02 ± 0.1	0.7 ± 5.0	0.1 ± 1.0
Others[d]	42.9 ± 112.8	2.1 ± 4.9	18.0 ± 63.8	1.0 ± 2.9
Group 4: ultra-processed foods	253.2 ± 147.2	13.9 ± 15.4	238.5 ± 145.6	15.0 ± 19.2
Candies[e]	36.2 ± 83.0	1.9 ± 4.2	64.0 ± 175.9	3.2 ± 7.5
Pizzas, hamburgers and sandwiches	17.0 ± 110.5	0.7 ± 4.4	6.4 ± 30.4	0.6 ± 3.3
Sweetened drinks	20.7 ± 50.4	1.1 ± 2.6	35.5 ± 67.3[j]	2.1 ± 4.5
Salty snacks[f]	27.5 ± 103.5	1.3 ± 4.2	26.6 ± 110.1	1.7 ± 6.7
Frozen dishes, “instant” and long-lasting[g]	0.7 ± 6.7	0.1 ± 0.8	8.1 ± 46.6	1.0 ± 5.3
Reconstituted meat and fish products	54.6 ± 170.1	3.1 ± 9.9	57.8 ± 131.6	3.6 ± 7.1
Ultra-processed breads and breakfast cereals	30.0 ± 94.9	2.3 ± 8.3	29.0 ± 87.6	2.1 ± 6.4
Others[h]	67.4 ± 127.7	3.5 ± 6.7	81.5 ± 141.3	4.5 ± 6.2

%TEV: percentage of the total energy value.
[a]Oil seeds, coffee, tea and ferment.
[b]Including honey.
[c]Including animal fats like butter, lard, sour cream, and vinegar.
[d]Salted or caramelized oilseeds, beer, and wine.
[e]Cookies, cakes, sweet bakery products, candies, lollipops, chocolate, gelatin, ice cream and other industrialized desserts.
[f]Including crackers and processed snacks.
[g]Including instant or canned soups, or ready-made pasta dishes.
[h]Margarine, ready-made sauces, soy-based products and distilled alcoholic beverages.
[i]Analysis of the Generalized Estimation Equation Model showed a statistically significant difference attributed to time.
[j]Analysis of the Generalized Estimation Equation Model showed a statistically significant difference attributed to time and the intervention.

(INA), based on the personal food consumption module applied to a subsample of households from the 2017–2018 Household Budget Survey (POF), the average daily *per capita* energy contribution from ultra-processed foods was 19.7% [40]. Additionally, between 2008–2009 and 2017–2018, this percentage increased by 2.04 percentage points among Black individuals, but not among White individuals [41]. At baseline in the present study, ultra-processed food consumption contributed 15% or less to the total energy intake in both the intervention and control groups. Although the POF results are not representative of traditional communities, such as quilombolas, the trends observed in the Black population highlight an increasing consumption of ultra-processed products, driven by a complex food system. This growing trend presents challenges for interventions aimed at reducing the consumption of ultra-processed foods in vulnerable populations, particularly when considering the low daily fiber intake and sodium levels exceeding recommended guidelines for adults in these groups [42, 43].

Furthermore, there was a reduced total energy daily from baseline to post-intervention period, which may affect the distribution of the percentual of energy from the Nova food groups. The reduction in the average consumption of total energy from unprocessed and minimally processed foods may be caused by a significant reduction in the energy obtained from meat and eggs. Among the Nova group 1, the mentioned foods may provide the greatest energy density, as well as, they have a high monetary cost [44]. In contrast, ultra-processed foods usually present high energy density [5] contributing to the growing participation of these products in the total daily energy in consequence of reducing foods of Nova group 1.

In this sense, an important barrier to established changes in food consumption among quilombola communities might be the economic dimension. Traditional communities, such as the quilombolas, have become a target of the big food industry since they represent the social stratus with the lowest participation of these products in the diet. It may indicate an emergent framework of inequalities in food consumption. Since the traditional communities have been exposed to food with low nutritional quality which may lead to diseases related to nutritional deficiencies, as well as, overweight/obesity and other chronic diseases [4]. Also, predictions of the food prices in Brazil suggest that ultra-processed foods can be cheaper than unprocessed and minimally processed in the next years [45]. Among the Nova group 1, the “staple foods” as rice, been, and cassava are the main representants of this group in the traditional diet of the quilombolas [15–17], the reason could be because they are more economically available than other fresh foods (i.e., fruits and vegetables).

Another construct that could be a barrier to healthy changes in the quilombola diet is the food environment [46], as the low availability of healthy foods. We observed in these communities that there is low availability of vegetables for purchase, while variety and quantity are abundant of ultra-processed, such as soft drinks and snacks. As the quilombola communities included in this study are located in areas far from urban centers, they comprise a typical food desert, usually found in low-income urban or rural areas where the closest source of nutritious food is far away or difficult to access due to a lack of transportation, where residents have limited access to affordable, nutritious food, particularly fresh fruits, vegetables, and other whole foods necessary for a healthy diet, [46, 47]. Thus, even if individuals have the resources to buy fruits and vegetables, they do not find quality products, and at the same time, they are exposed to several advertising stimuli to ultra-processed.

Strengths of this study relate to its design, the sample of a traditional community with scarce data in the literature, and the intervention was developed in collaboration with several actors (people from the communities, health professionals, local government represents, and researchers), considering the food context of the participant communities. Despite the data collection, the 24 h recall is an instrument highly recommended to collect data on food processing in consumption surveys, and it was built to collect detailed information on food processing [48]. However, caution is necessary in interpreting 24 h recall data as representative of usual intake, because they were applied once at baseline and another post-intervention.

The study has several limitations. The high prevalence of food insecurity across all communities, which was even more pronounced in those who participated in the intervention. However, sensitivity analyses, adjusting for this variable in the models, revealed no significant changes in the estimates for any of the outcomes. Additionally, there were follow-up losses within an already small sample. The intervention duration, the number of workshops, and the decision to limit workshop participation to a smaller group of individuals with potential for wider dissemination were logistical necessities but may have restricted the intervention’s reach across the entire community. Since quilombola communities present some heterogeneity, our results should be interpreted with caution. Finally, the short-term nutritional counseling intervention may be insufficient to produce changes in the eating habits of individuals inserted in a complex scenario of the food system, socioeconomic vulnerability, and high prevalence of food and nutritional insecurity, which has as a background structural racism [15]. Structural racism is a barrier to healthcare and a risk factor for illness of the Black population. A systematic review [49] found that perceived racial discrimination is associated with an unhealthy dietary pattern, characterized by higher consumption of sweets and fats and lower consumption of fruits and vegetables. The conceptual framework proposed by the authors of that systematic review to explain the relationship between racial discrimination and eating habits highlighted the interactions between social and biological mechanisms [49].

In conclusion, we found that a nutrition counseling intervention is likely to promote healthy food habits by rescuing traditional culinary preparations in quilombola communities in the South of Brazil. However, changes in the consumption of minimally processed foods were not found. Furthermore, the intervention did not mitigate the increasing trend of ultra-processed foods in quilombolas’ diet. In this sense, our findings raise the hypothesis that to obtain substantial changes in the food consumption of subgroups with high social vulnerability, intervention studies, and public policies need to act on distinct variables of the food system.

ETHICS STATEMENT

The studies involving humans were approved by Comitê de Ética da Universidade Federal do Rio Grande do Sul. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants’ legal guardians/next of kin.

AUTHOR CONTRIBUTIONS

PP contributed to conception or design, contributed to acquisition, analysis, or interpretation, drafted the manuscript, and gave final approval. FdSB, MN, DK, LN, FdS, and MD contributed to conception or design, contributed to analysis, or interpretation, critically revised the manuscript, and gave final approval. All authors contributed to the article and approved the submitted version.

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CONFLICT OF INTEREST

The authors declare that they do not have any conflicts of interest.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.ssph-journal.org/articles/10.3389/ijph.2024.1607549/full#supplementary-material

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A Comparative Study on the Consumption Patterns of Processed Food Among Individuals With and Without Type 2 Diabetes

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Objective: The study aims to analyse the eating patterns and consumption of ultra-processed food (UPFs) among individuals with and without diabetes.

Methods: A comparative cross-sectional study was conducted across Pune, India, with 100 individuals with type 2 diabetes (T2D) and 208 without diabetes. A detailed FFQ (Food Frequency Questionnaire) developed by NOVA-UPF Screener with 33 ultra-processed food items was used to evaluate the consumption patterns of UPF.

Results: Most of the participants with diabetes have a habit of eating breakfast daily (68%), prefer lunch from home (72%), and about 20% avoid eating at a restaurant. While only 45.7% of the participants without diabetes have breakfast daily, and 88.4% prefer to eat lunch outside rather than homemade food. Comparative analysis shows that all 33 UPFs were consumed significantly less by individuals with diabetes than those without diabetes ($p < 0.001$).

Conclusion: The reduced intake of UPFs highlights greater dietary caution among individuals with T2D. Therefore, these findings emphasize the importance of promoting healthy eating habits and limiting UPF consumption among the general population to prevent the onset of metabolic conditions like diabetes.

Keywords: ultra-processed food, consumption, dietary pattern, diabetes, non-communicable diseases

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INTRODUCTION

The rising prevalence of non-communicable diseases (NCDs) has become a significant public health concern globally. The sharp surge is seen because of the changing lifestyle and dietary habits. The advent of technology has significantly enhanced our comfort, leading to a decrease in physical activity [1]. Not only activity but technology has also changed our eating patterns, switching us from eating whole grains and freshly produced to consuming ultra-processed food (UPFs) due to convenience, widespread availability, and enhanced palatability [2, 3]. Due to their easy availability, these UPFs have become an integral part of our daily routines, representing a significant portion of the total energy intake. For instance, sugary cereals consumed in breakfast, packaged snacks like chips and cookies consumed during the day, and ready-to-eat frozen dinners or foods ordered from outside have become everyday staples in many households. Some studies have shown that daily intake of UPFs has reached 42% in Australia and more than 56% in the UK as part of their total energy intake [4].

These foods are often high in sugars, unhealthy trans-fat, preservatives, colors, and artificial flavors, which contribute to major health issues, including obesity, cardiovascular disease, inflammatory diseases, and metabolic disorders like Diabetes [5]. The excess added sugar, unhealthy fat, and salt in UPFs gives excess empty calorie intake, which leads to insulin resistance, the root cause of most metabolic disorders [6]. It has been seen that high consumption of UPFs is associated with an elevated risk of developing Type 2 Diabetes (T2D). A meta-analysis involving a large cohort revealed that a moderate (10%) increase in UPFs leads to a 12% higher risk of developing T2D [7] and high consumption increases the risk by 31% [4]. Studies have also shown that populations consuming excess UPFs gain weight and experience metabolic syndrome, both of which are significant risk factors for diabetes [8, 9].

The rapid growth of UPFs consumption in India has increased at a compound annual growth rate (CAGR) of 13.37% from 2011–2021 and is projected to account for 39% of food retail sales by 2032 [10]. This correlates significantly with the alarming rise in diabetes and prediabetes rates, currently at 11.4% and 15.3% of the population respectively [11]. The rising prominence of these foods, particularly among urban populations, can be attributed to the evolving food environment. This landscape is increasingly dominated by food deserts and swamps, limiting access to fresh and nutritious meals. Additionally, the convenience and affordability of these foods further drive their consumption. These factors collectively promote unhealthy dietary patterns, thereby contributing to the growing prevalence of non-communicable diseases (NCDs). The high consumption and detrimental effects are also compounded by the attractive packaging and marketing technique, which often targets vulnerable populations, including children and those with lower socioeconomic status [12]. Given the rising prevalence, understanding the dietary patterns and their impact on the health is more critical than ever. This observational study compares UPFs consumption patterns among individuals with and without T2D. By analyzing these consumption patterns, we aim to identify key differences that may contribute to the increased prevalence of Type 2 Diabetes in certain groups. The findings will possibly provide valuable insights into the dietary behaviors associated of the population, thus aiming to promote healthier eating habits.

METHODS

Study Design

This research employs a comparative cross-sectional study design to analyze the dietary patterns of individuals with and without T2D. This design allows for understanding the amount of ultra-processed food consumption at a specific time between two groups. The study was conducted in Pune, India, between April and June 2023. It was approved by the Institutional Ethics Committee (No. SIU/IEC/556). The present study follows the institute's requirement and Helsinki's rule. Written informed consent was obtained from all participants before data collection, ensuring they understood the study's purpose, procedures, and any potential risks involved. Participants with T2D were recruited from five different Diabetic clinics across Pune. Individuals without diabetes were recruited from the general population and accompanied by their relatives or friends at the primary care clinic. A combination of purposive and snowball sampling methods was utilized. Purposive sampling was employed to select participants with T2D based on specific criteria, while snowball sampling helped recruit participants without T2D through referrals from initial participants.

Inclusion and Exclusion Criteria

The study includes participants from only Pune City, India, of either sex and age group 20–60 years. Confirmed T2D subjects were recruited as per their medical records or physician diagnosis with a minimum of 1 year of disease. Individuals with Type 1 Diabetes, Gestational Diabetes, pregnant women, and breastfeeding mothers were excluded from the study. Individuals with severe cognitive impairments or those unable to provide informed consent were also excluded. Nondiabetics were selected based on the absence of any known medical condition. Any major illness like cancer, HIV, or hospitalized patients were excluded from the study. The entire process of screening and enrolling is shown in **Figure 1**.

Data Collection

A validated questionnaire collected demographic data, including age, gender, and health history. Anthropometric variables, like height, weight, and Body mass index (BMI), and their dietary behaviors were recorded. We carried our weighing scale and stadiometer to collect the anthropometric data, ensuring accuracy and consistency in the measurements. We validated the anthropometric variables by calibrating the equipment from time to time. We also ensured that measurements were taken by trained professionals and that standard protocols were followed. All the responses to questions were collected by conducting face-to-face interviews to ensure clarity and accuracy. This helps to understand their nutritional status, dietary preferences, and choices of eating outside food. A Food Frequency Questionnaire (FFQ) based on the NOVA-UPF Screener was utilized to evaluate ultra-processed food consumption over the last 7 days. The tool was developed by Brazil scientists and is a validated tool to quickly and easily evaluate and track the consumption of these foods [13]. The Nova classification screener was also used in a study conducted in India. The study employed the Nova classification to analyze UPF consumption patterns and their impact on nutrition in the Indian population [5] This demonstrates the utility and relevance of the Nova screener in assessing dietary patterns specific to India. Given its successful application in previous research within the Indian context, we have chosen to utilize the Nova screener in our study to ensure consistency with established methodologies and enhance the validity of our findings. Under Nova classification, foods are categorized into four groups based on extent and purpose of processing: Group 1- Unprocessed or Minimally processed; Group 2- processed Culinary Ingredients; Group 3- Processed Food; and Group 4- Ultra-processed food [3]. Ultra-processed products are mainly ready to consume and have a long shelf life, high energy, and low nutritional value [14]. The questionnaire listed 33 food items that belong to Group 4 of the NOVA classification. The food items were taken from seven

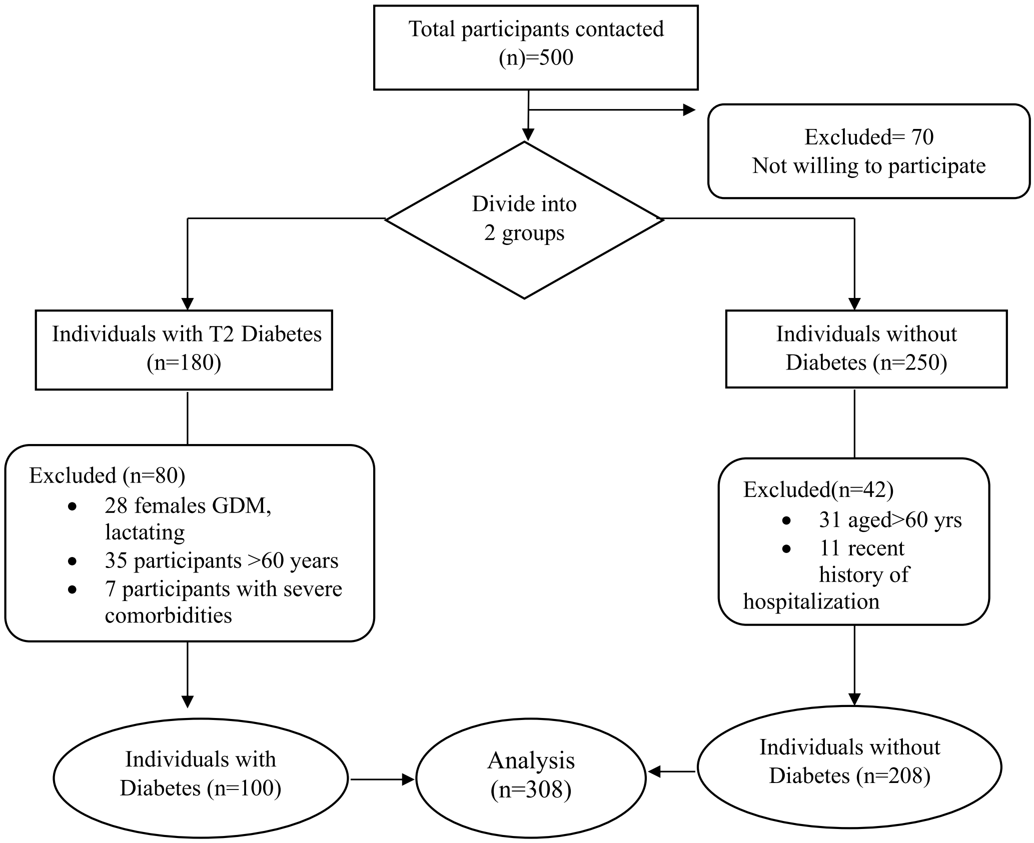

FIGURE 1 | Flowchart showing recruitment, screening, and selection of participants (Pune, India, 2024).

categories: Bakery items, breakfast items, snacks, sauces/spreads, chocolate/candies, drinks, and sugar/sweeteners. The participants were asked to choose consumption for the last 7 days as Not consumed, Consumed Daily, or Consumed 2–3 times/week.

Statistical Analysis

The collected data was cleaned and checked for completeness. Then was entered in MS Excel, and analyzed using SPSS v23. Descriptive statistics were used to express the demographic data in terms of mean, standard deviation, frequency (n), and percentage (%). The chi-square test was used to find the statistical significance between the groups (individuals with and without T2D). A p-value of <0.05 was considered to be significant. MANOVA (Multivariate Analysis of Variance) was performed to examine the effect of multiple items of ultra-processed food between the two groups. Wilk's lambda, significance, and partial Eta Square Values were used to compare the effect between the groups.

RESULTS

Demographics

A total of 308 participants were recruited for the study, comprising 100 individuals with T2 diabetes and 208 without T2D. The group of individuals without diabetes is double the size of those with diabetes to enhance comparative analysis. There were 60% males and 40% females with diabetes, with almost similar gender distribution among individuals without diabetes as well (62%) males and (38%) females. The mean age of the diabetic population was 46.05 ± 11.07 years. However, the nondiabetic mean age was 31.30 ± 6.26 years. The mean BMI of diabetic populations was 27.53 ± 3.67 $kg/m^{2,}$ while of the non-diabetic population, it was 24.41 ± 3.87 kg/m^2. Most of the diabetic population (96%) were married, whereas the individuals without T2D had fewer married people (41.9%). Both groups with 68% of the individuals with diabetes and 59.6% without T2D having completed graduation. There were 29% postgraduates in the diabetic population and 39.9% in without T2D group. Only 3% of the diabetes group and 0.5% of the without T2D group held a PhD degree. **Table 1** shows the demographic characteristics of the participants.

Eating Behaviors

Table 2 shows the eating behaviors of individuals with and without diabetes There was no significant difference in the dietary choices of both groups. When asked about the breakfast schedule, 68% of the diabetic participants preferred breakfast daily, while only 47.1% of the participants without T2D had it daily ($p < 0.001$). It was found that participants without

TABLE 1 | Demographic characteristics of the individuals with and without Type 2 Diabetes (Pune, India, 2024).

S.N.	Variables	Individuals with T2D n (%)	Individuals without T2D n (%)
1	Total Participants	100	208
2	Gender		
	Male	60 (60.0)	129 (62.0)
	Female	40 (40.0)	79 (38.0)
3	Age, years (Mean ± SD)	46.05 ± 11.0	31.3 ± 6.2
4	BMI, kg/m^2 (Mean ± SD)	27.53 ± 3.6	24.4 ± 3.8
5	Marital Status		
	Married	96 (96.0)	87 (41.9)
	Unmarried	4 (4.0)	121 (58.1)
6	Education Status		
	Graduation	68 (68.0)	123 (59.6)
	Post Graduation	29 (29.0)	84 (39.9)
	PhD degree	3 (3.0)	1 (0.5)

TABLE 2 | Eating behaviors among individuals with and without Type 2 Diabetes (Pune, India, 2024).

S. N	Variables	Individuals with T2D n (%)	Individuals without T2D n (%)	Chi-square (p-value)
1	Food Preferences			0.547
	Vegetarian	47 (47.0)	108 (51.9)	
	Non-Vegetarian	53 (53.0)	100 (48.1)	
2	Breakfast Schedule			
	Don't prefer having breakfast	21 (21.0)	17 (8.17)	0.000*
	Skip breakfast once a week	5 (5.0)	30 (14.4)	
	Skip breakfast more than once a week	6 (6.0)	63 (30.2)	
	Prefer having breakfast daily	68 (68.0)	98 (47.11)	
3	Lunch Practices			
	Preferred getting lunch from home	72 (72.0)	91 (43.7)	0.000*
	Preferred eating or ordering from outside	2 (2.0)	39 (18.75)	
	Follow either	26 (26.0)	78 (37.5)	
4	Eating out at a restaurant			
	Daily	4 (4.0)	22 (10.5)	0.000*
	Once a week	63 (63.0)	154 (74.0)	
	More than once a week	13 (13.0)	77 (37.0)	
	Never	20 (20.0)	18 (8.6)	
5	UPFs consumption			
	Daily	26 (26.0)	33 (15.8)	0.000*
	Once a week	51 (51.0)	81 (38.9)	
	More than once a week	13 (13.0)	74 (35.5)	
	Never	10 (10.0)	20 (9.6)	

**p is significant at a level of <0.05.*

T2D were not regular with their breakfast routine, and almost 30.2% of participants skipped their breakfast more than once a week. A statistical significance ($p < 0.000$) was also observed when comparing their lunch practices. Most individuals with diabetes (72%) preferred to get their lunch from home, 2% preferred eating or ordering lunch from outside, and 26% followed both practices, either getting lunch from home or eating outside food. Similarly, the comparison of UPF consumption between the individuals with and without diabetes also showed a statistical significance ($p < 0.001$). About 51% individuals with diabetes ate packaged food only once a week, 13% more than once a week, 26% daily, and 10% never consumed packaged food, whereas, in the case of individuals without diabetes, 15.8% ate daily, 38.9% once a week, 35.6% more than once a week and only 9.6% do not eat UPF.

Ultra-Processed Food Consumption

According to the NOVA Group 4 classification, the UPF studied here was divided into seven categories: Bakery, Breakfast, Snacks, Sauces/spread, Chocolate/candies, Drinks, and Sweeteners, and the most common items used were studied in each category. **Table 3** shows the complete description of UPF consumption between the two groups. Except for bread from the category of bakery items, consumption of other foods was statistically different ($p < 0.0001$) between the two groups. For Bread, (25%) of the subjects with diabetes and (21.2%) without diabetes did not consume bread in the last 7 days. Biscuits have emerged as popular choice among participants with diabetes as 39% consumed them daily, 33% consumed them 2–3 times per week, and only 28% did not consume them. Nearly 42.3% of subjects without diabetes did not consume biscuits, 50.9% consumed 2–3 times per week, and only 6.7% consumed daily. There was statistical significance for ready-to-eat breakfast items ($p < 0.05$) except for the instant oats, whose consumption was almost similar in both groups. The subjects with diabetes were seen to avoid ready-to-eat breakfast items, as 69% do not consume cornflakes, 86% avoid muesli, 96% granola, 67% instant noodles, 88% pasta, 70% instant idli- dosa mix, 91% ready-to-eat frozen meal. On the other hand, two to three times per week consumption of breakfast items was more in participants without diabetes when compared with subjects with diabetes as 38.4% ate cornflakes, 41.8% muesli, 34.1% instant oats, 41.8% granola, 72.6% instant noodles, 50% instant pasta, 49.1% instant idli dosa mix, and 44.2% frozen ready-to-eat meals.

There was also statistical significance ($p < 0.001$) when snack consumption was compared. The consumption was seen to be less among diabetic subjects as 71% do not consume chips, 54% namkeen/farsaan, 93% tortilla/nachos, and 69% pizza/burger/wraps. A similar statistical significance ($p < 0.001$) was observed when sauces/spreads and chocolates/candies were compared among the two groups. Participants with diabetes were seen to avoid sauces/spreads as 69% do not eat tomato ketchup, 96% mayonnaise, 63% processed plain salted butter, and 96% avoid flavored butter. They also avoid chocolate/candies, as 95% do not consume milk chocolates, 97% dark chocolates, and 91% candies. However, participants without diabetes seemed to consume more, as 50% ate milk chocolates, 51.4% dark chocolate, and 39.4% candies two to three times per week.

TABLE 3 | Ultra-processed food consumption between individuals with and without Type 2 Diabetes (Pune, India, 2024).

Food item	Individuals with T2D (n = 100)			Individuals without T2D (n = 208)			P value
	No Consumption (%)	Daily Consumption (%)	Consuming 2–3 times/ week (%)	No Consumption (%)	Daily Consumption (%)	Consuming 2–3 times/ week (%)	
Bakery Items							
Biscuit	28	39	33	42.3	6.7	50.9	0.000*
Bread	25	5	70	21.2	7.6	71.2	0.555
Pav/bun	65	2	33	32.7	0	66.8	0.000*
Cupcake/muffin	94	1	5	58.1	0	41.9	0.000*
Toast	54	25	21	45.1	3.4	51.5	0.000*
Khari	85	3	12	62	2.9	73.1	0.000*
Breakfast Items							
Cornflakes	69	2	29	53.4	7.7	38.4	0.033*
Muesli	86	0	14	46.2	12.0	41.8	0.000*
Instant Oats	58	2	40	61.5	4.3	34.1	0.521
Granola	96	0	4	57.7	0.5	41.8	0.000*
Instant noodles	67	1	32	27.4	0	72.6	0.000*
Instant pasta	88	0	12	49.5	0.5	50	0.000*
Instant idli/dosa mix	70	3	27	50	0.9	49.1	0.001*
Frozen, ready-to-eat meal	91	0	9	55.3	0.5	44.2	0.000*
Snacks							
Chips	71	0	29	31.7	4.32	63.9	0.000*
Namkeen/Farsaan	54	6	40	27.4	8.2	64.4	0.000*
Tortillas/Nachos	93	2	5	62.9	0.5	36.5	0.000*
Pizza/burger/wraps	69	0	31	38.9	0	61.1	0.000*
Sauces/Spreads							
Tomato Ketchup	69	0	31	44.7	1.9	53.4	0.000*
Mayonnaise	96	0	4	57.7	0	42.3	0.000*
Processed plain salted butter	63	1	36	32.2	4.8	63	0.000*
Flavored butter	96	0	4	63.9	0	36.1	0.000*
Chocolates/Candies							
Milk Chocolate	95	1	4	47.6	2.40	50	0.000*
Dark chocolates	97	1	2	47.6	0.9	51.4	0.000*
Candies	91	1	8	59.6	0.9	39.4	0.000*
Drinks							
Packaged juice	87	1	12	56.3	3.4	40.4	0.000*
Aerated Drinks	72	0	28	43.3	0.5	56.3	0.000*
Energy Drinks	94	1	5	58.7	0	41.3	0.000*
Flavored milk	96	1	3	68.7	0	41.3	0.000*
Sugar/Sweeteners							
Sugar in Tea, coffee or milk	75	16	9	16.3	33.6	50	0.000*
Sweetener in Tea, coffee or milk	91	3	6	70.2	4.3	25.5	0.000*
Flavored Yoghurt	94	0	6	54.3	1.4	44.3	0.000*
Package Kheer, Payasam	95	0	5	68.3	0	31.7	0.000*

**p is significant at a level of <0.05.*

A statistical significance ($p < 0.001$) was also observed when various drinks and sugar/sweeteners were compared. A similar trend of individuals with T2D was seen avoiding these two categories as 87% do not consume packaged juice, 72% aerated drinks, 94% energy drinks, and 96% flavored milk. They consume these drinks less often, as only 12% consume packaged juice, 28% aerated drinks, 5% energy drinks, and 3% flavored milk two to three times per week. However, the consumption was seen more in subjects without T2D, as 40.4% consume packaged juice, 56.3% aerated drinks, 41.3% energy drinks, and 41.3% flavored milk two to three times per week. Participants with T2D were also seen to avoid sugar and sweeteners, as 75% avoid sugar, and 91% avoid sweeteners in tea, coffee, or milk. They also avoided flavored yogurt, package kheer, and payasam, as 94% and 95% did not consume it over the last 7 days. However, in comparison, the consumption was more in without T2D group as 50% use sugar, 25.5% sweetener, 44.3% flavored yogurt, 31.7% package kheer, and payasam two to three times per week.

The UPF food consumption between two groups (with and without diabetes) was analyzed through multivariate tests as shown in **Table 4**. The multivariate test shows a statistical

TABLE 4 | Multivariate Analysis[a] for consumption of ultra-processed among subjects with and without Type 2 Diabetes (Pune, India, 2024).

Effect		Value	F	Significance (p)	Partial eta square (η^2)
Intercept	Pillai's Trace	0.967	246.721[b]	0.000	0.967
	Wilks' Lambda	0.033	246.721[b]	0.000	0.967
	Hotelling's Trace	29.715	246.721[b]	0.000	0.967
	Roy's Largest Root	29.715	246.721[b]	0.000	0.967
Individuals with diabetes vs. without diabetes	Pillai's Trace	0.540	9.763[b]	0.000	0.540
	Wilks' Lambda	0.460	9.763[b]	0.000	0.540
	Hotelling's Trace	1.176	9.763[b]	0.000	0.540
	Roy's Largest Root	1.176	9.763[b]	0.000	0.540

[a]*Design: Intercept + Diabetic Status.*
[b]*Exact statistic.*

significance between the consumption of ultra-processed food, F (33,274) = 9.763, p = 0.000 (p < 0.05), Wilk's Λ = 0.460, partial η^2 = 0.540. A partial η^2 value greater than 0.14 represents a significant effect, indicating the large proportion of the variance explained by the impact. Here, partial η2 is 0.540, indicating a large effect size. This means that 54% of the variance in ultra-processed food consumption can be attributed to the difference between individuals with and without diabetes. The large effect size implying the difference in consumption is not only statistically significant but also practically significant.

Test-of-between subjects show the significant consumption of different ultra-processed food among the both groups and a statistical significance was observed among consumption of pav/bun, cupcake/muffin, toast, khari, muesli, granola, instant noodle, instant pasta, instant idli dosa mix, frozen ready product, chips, tortilla/nachos, fried namkeen, pizza/burger/wraps, Milk chocolate, Dark chocolate, Candies, tomato ketchup, mayonnaise, butter (plain or flavored), package juice, cold drinks, energy drinks, flavored milk, sugar, sweetener, Flavored yogurt, package kheer or payasam. A significant large effect is seen in certain food items as partial η^2 value is found to be greater than 0.14, like Granola (0.153), Instant noodles (0.140), milk chocolate (0.212), dark chocolate (0.235), Mayonnaise (0.154), sugar in tea, coffee, milk (0.302) and flavored fruit yogurt (0.154) as shown in **Table 5**.

DISCUSSION

The present study examined the consumption patterns of UPFs among individuals with and without T2D. There was a significant difference in eating habits, food preferences, and consumption of UPFs between the two groups. It was seen that individuals with T2Dare more aware of their health conditions and have breakfast daily, prefer to have lunch from home, avoid eating outside, and package food to maintain their blood sugar levels. However, existing literature says that prior studies on T2D participants suggested showcase that they do not have healthy eating habits [15, 16]. Diabetes is a metabolic disorder and can be managed by proper awareness of eating habits. A study was done to educate people about the benefits of the Mediterranean diet, which has helped control sugar levels and improve lipid profile and weight loss in 3 months [17]. Our study observed that most participants reported having breakfast daily; however, we did not assess how this behavior impacts diabetes risk. Future research could explore this potential relationship. In our study, participants seemed aware of their eating habits, as many of them had breakfast daily. There are associations between breakfast consumption and a lower risk of Diabetes Conversely, the population without T2D tends to eat more packaged food and prefers to eat more at restaurants or outside food. A recent study also shows similar trends among the urban Indian middle-class populations, highlighting that consumers in India are opting for more processed food due to various factors such as globalization, urbanization, and changing socio-cultural dynamics. The food choices are driven by convenience, availability, and marketing of processed food [18].

The observed healthier eating patterns among individuals with diabetes may be attributed to prior dietary counseling received at diagnosis. Dietary and lifestyle interventions are often recommended as first-line management strategies for diabetes, emphasizing the reduction of ultra-processed food intake and promoting whole, nutrient-dense food [19]. Several studies have shown that structured nutritional education programs can significantly improve dietary behaviors, leading to better glycemic control and weight management [7, 8]. In our study, individuals with diabetes seemed aware of their eating habits and consuming homemade meals. However, we did not collect information on whether participants with T2D had received dietary counseling at the time of diagnosis. Since nutritional education plays an important role in diabetes management by influencing food choices and dietary habits, the absence of this data may introduce an unaccounted variable, potentially affecting the study behavior. Further research should include this variable to understand its impact on dietary behavior better.

The present study analyzed the different UPFs based on Nova classification. We observed an increasing trend of bakery items like bread and biscuits, which have become integral to every household. Here, marketing influences consumer choices and dietary habits [20]. Brands often position their products as "Diabetic-friendly" by highlighting specific health benefits like sugar-free, whole grain, and high fiber. We did not directly evaluate the influence of marketing or advertisement on dietary choices. However, previous research studies suggest that marketing may play a role in promoting ultra-processed foods as convenient or healthful options, warranting further investigation. Attractive packaging can also enhance the

TABLE 5 | Tests of Between-Subjects Effects of ultra processed food consumption among individuals with and without Type 2 Diabetes (Pune, India, 2024).

Category	Dependent variable	Mean square	F	Significance	Partial Eta Sq
Individuals with T2D vs. without T2D	Biscuit	0.090	0.109	0.742	0.000
	Bread	0.169	0.241	0.624	0.001
	Pav/bun	28.685	31.817	0.000*	0.094
	Cupcake/muffin	35.648	49.084	0.000*	0.138
	Toast	10.404	12.045	0.001*	0.038
	Khari	14.338	19.023	0.000*	0.059
	Cornflakes	10.292	2.827	0.094	0.009
	Muesli	30.927	41.010	0.000*	0.118
	Instant oats	0.660	0.720	0.397	0.002
	Granola	39.145	55.168	0.000*	0.153
	Instant noodle	42.394	49.883	0.000*	0.140
	Instant pasta	39.502	48.499	0.000*	0.137
	Chips/Fries	37.193	43.810	0.000*	0.125
	Nachos/Tortillas	25.590	36.761	0.000*	0.107
	Fried Namkeen/Farsan	17.578	21.133	0.000*	0.065
	Pizza/Burger/Wraps	24.405	26.353	0.000*	0.079
	Milk Chocolates	58.917	82.296	0.000*	0.212
	Dark Chocolates	65.983	94.155	0.000*	0.235
	Candies	26.640	35.812	0.000*	0.105
	Tomato Ketchup/Sauce	14.699	15.618	0.000*	0.049
	Mayonnaise	39.641	55.532	0.000*	0.154
	Salted Processed Butter	22.538	25.541	0.000*	0.077
	Packaged Flavored Butter	27.761	41.001	0.000*	0.118
	Packed Juice	23.615	30.297	0.000*	0.090
	Aerated cold soft drinks	21.926	23.614	0.000*	0.072
	Energy Drinks	34.710	47.939	0.000*	0.135
	Flavored Milk	17.026	30.392	0.000*	0.090
	Sugar in Tea, Coffee, Milk	67.066	132.501	0.000*	0.302
	Sweetener in Tea Coffee Milk	10.962	18.413	0.000*	0.057
	Flavoured Fruit Yogurt	40.986	55.632	0.000*	0.154
	Packaged Kheer Payasam	19.302	29.646	0.000*	0.088
	Instant Mix Idli Dosa	11.935	12.837	0.000*	0.040
	Packaged Branded Ready to Eat Frozen	33.988	43.843	0.000*	0.125

**p is significant at a level of <0.05.*

perceived value of processed food. It has been found that consumers rely on visual cues and branding rather than nutritional information when making food choices, leading to increased consumption of processed food [21]. A study sought to explore the main stakeholders, frameworks, motivations, and interactions within the global UPF system that have contributed to the widespread prevalence of UPFs in population diets. According to this study, the systems thinking approach underscores that diminishing UPF consumption necessitates tackling interrelated factors like as food cost, cultural changes, and marketing strategies [22]. By acknowledging these linkages, our work introduces a population-specific viewpoint, so underscoring the necessity for comprehensive solutions.

Ultra-processed snacks are engineered to be highly palatable, exploiting human cravings for sweetness and saltiness. The manipulation of flavors makes them more appealing, leading to increased consumption [23]. This can be seen in the case of the consumption of snacks in the study, where both groups show consumption of chips, namkeen, and nachos, pizza, burgers due to their taste, convenience, and affordability. The combination of sugar, salt, and fat in ultra-processed food can create addictive eating behaviors. Various studies show that these foods trigger reward pathways in the brain, a similar behavior to addictive substances, and can lead to overconsumption and increase the risk of disease [24, 25]. The consumption of sugar-sweetened beverages was also higher in nondiabetic participants than in the diabetic group. Regular intake of these beverages is linked to insulin resistance and fatty liver [26]. A systematic review highlighted that a higher intake of sugar-sweetened beverages correlates to a 13% increased risk of T2D and an 8% increased risk of cardiovascular diseases per additional consumed daily serving [27].

The higher consumption of ultra-processed food among individuals without T2D raises significant public health concerns. Regular intake of these foods is associated with an increased risk of developing non-communicable diseases, including T2D, obesity, and cardiovascular diseases. The increased consumption of ultra-processed food may add fuel to this fire. Not only NCDs, high intake of such food can even lead to mental disorders like a 48%–53% increased risk of anxiety and a 22% increased risk of depression [28]. The potential reasons why individuals with T2D may consume less ultra-processed food is that they are more likely to engage in health-conscious behavior because of the dietary recommendations given by dietitians, like avoiding foods high in sugar, unhealthy fats, and additives that are prominent in ultra-processed food. The second reason can be influenced by behavioral factors like increased health literacy and motivation to manage the disease. Overall, this research emphasizes the critical role of targeted nutritional education and supportive policymaking in reducing the public health burden associated with UPF consumption.

Limitations

The current study has certain limitations that have to be acknowledged. The present study uses the Nova classification system, which has notable limitations. While the Nova framework effectively categorizes foods based on the extent of processing, it does not assess their nutritional content. This means that nutritionally balanced foods may be included in Nova Group 4 if they have undergone extensive industrial processing. For instance, dark chocolate, classified as ultra-processed (Nova group 4), contains flavonoids with positive health outcomes, such as improved cardiometabolic markers and reduced inflammation, However, plain yogurt, which is rich in protein, calcium, and probiotics, is minimally processed (Nova Group 1) does not fall under the ultra-processed category. Misinterpretations of the Nova classification may lead to overestimations of unhealthy food intake in the study population. Additionally, reverse bias presents a significant limitation. Participants with T2D may underreport their consumption of UPFs due to social desirability or perceived stigma, potentially leading to skewed data. This could result in an underestimation of actual UPF consumption within this group. A relatively small sample size, participants were from one city and may not represent the entire nation's population. The study relied on self-reported data for dietary and anthropometry information, subject to recall bias. Participants may underreport or overreport the consumption of particular food, particularly unhealthy or socially undesirable items. The present study is a cross-sectional study and cannot establish causality between the consumption of processed food and the development of NCDs. A longitudinal study design would be more appropriate for examining the long-term effects of dietary habits on increased risk.

Conclusion

The study compared the consumption of UPFs among two distinct populations. The results highlighted that the T2D population is more aware and consumes less processed food than those without T2D. One of the reasons would be restrictions due to medical conditions, and information physicians share about healthy eating. This also suggests a potential lack of awareness among the healthy group regarding the health risks of consuming UPFs regularly. The finding highlights the need for nutritional education among the non-diabetic population to promote healthier eating habits and reduce reliance on ultra-processed food. As the prevalence of undiagnosed diabetes and pre-diabetics is on the rise, especially among the Indian population, there is an urgent need for awareness sessions. Further research can explore the specific factors contributing to differences in consumption patterns between the two groups and provide insights that inform public health strategies and help promote healthier eating habits across the broader population.

ETHICS STATEMENT

The studies involving humans were approved by Institutional ethical committee, Symbiosis International University. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

AUTHOR CONTRIBUTIONS

AM planned study design, data collection, statistical analysis, writing manuscript. AD planned study design, writing manuscript. AM supervision of study, design, conceptualization, editing and revised manuscript.

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CONFLICT OF INTEREST

The authors declare that they do not have any conflicts of interest.

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Ultra-Processed Food Consumption Is Associated With Poor Diet Quality and Nutrient Intake Among Adolescents in Urban Slums, Kenya

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Objectives: To assess the caloric contribution of ultra-processed foods (UPFs), factors associated with UPFs energy intake and investigate the relationship between UPFs energy intake, diet quality and nutrient intake among adolescents in urban slums, Kenya.

Methods: A cross-sectional household study amongst adolescents (10–19 years, N = 621) collected socio-demographic and dietary intake data. Global Diet Quality Score (GDQS); mean and percentage total energy intake (%TEI) from UPFs; and nutrient intakes were computed. Regression analysis assessed the factors associated with UPFs energy intake, and the association between %TEI from UPFs and diet quality.

Results: Mean daily energy intake was 1,604 kcal (±550), 25.2% from UPFs. Higher leisure screen time (≥2 h/day) [OR = 1.9 (1.2–3.1)] was associated with UPFs energy intake. Household wealth index (quintile five vs. one) [OR = 2.6 (1.3–6.0)] was associated with non-UPFs energy intake. UPFs (%TEI) was inversely associated with GDQS score (quartile four vs. one) [β = −2.9 (−3.4 to −2.1)]. Adolescents with higher %TEI from UPFs (quartile four) had highest total energy, total fat and saturated fat; and lowest protein, fibre, iron, calcium and zinc intake.

Conclusion: UPFs contribute substantially to adolescents' energy intake and are linked to poor diet quality and nutrient intake.

Keywords: ultra-processed, overweight, obesity, double burden of malnutrition, urban, slum, diet-quality, Kenya

INTRODUCTION

The double burden of malnutrition (DBM) among adolescents, characterised by increasing overweight and obesity and a slow decline in undernutrition (stunting and wasting), is a major concern in low-income countries [1]. Unhealthy diets, including ultra-processed foods (UPFs) and foods that are high in fat, salt and sugar are a key driver of DBM [2, 3]. Rapid urbanisation is associated with changes in the food systems, characterised by increased availability of cheap and convenient unhealthy foods for the needs of the burgeoning urban population [4].

The NOVA classification system is the most widely used method for classifying the healthiness of food, based on the level of processing [5] and generally categorises foods into four groups: 1) unprocessed or minimally processed foods, 2) processed culinary ingredients, 3) processed foods and 4) UPFs [6]. UPFs comprise the least healthy food group in the NOVA classification, and their consumption is associated with the double burden of malnutrition (DBM) [3]; poor diet quality including high levels of salt, sugar and saturated fats [7–9], and low levels of protein, iron, vitamins and fibre [10–12] in adolescents. UPFs are also associated with excessive weight gain and increased risk of overweight, obesity, non-communicable diseases (NCDs) [13], metabolic [14] and cardio-metabolic syndromes [15]. Furthermore, a review of food systems in low and middle income countries including Africa, documents the existence of locally produced food/snacks resembling UPFs, although they are mainly not pre-packaged and often supplied through informal food vendors as ready to eat street fast foods, especially in urban areas [4, 16]. Similar to UPFs, such local snacks contain high levels of unhealthy saturated and trans fats, sugar, salt, highly refined carbohydrates [4, 17] and their frequent consumption is associated with poor diet quality and non-communicable diseases [18, 19].

Global and national healthy diet guidelines and key messages encourage consumption of minimally processed foods, and discourage consumption of foods that are high in fat, salt and sugar [20, 21] for optimal health and prevention of overweight/obesity and diet related diseases. The Kenyan guidelines for healthy diets further encourage consumption of foods rich in iron, zinc and calcium by adolescents [20]. Despite this, the burden of overweight and obesity is rising alongside that of chronic undernutrition and micronutrient deficiencies among adolescents in the sub-Saharan region [22, 23]. In Kenya, 43% of adolescent boys are underweight [24]. In addition, overweight/obesity prevalence among girls has increased from 8% in 2003 to 13% in 2022 [24]. In the Kenya National Micronutrient Survey, about 80% of adolescents (10–14 years) were zinc deficient while 27% of pregnant adolescents were anaemic or iron deficient [25].

Evidence on the dietary practices including UPFs consumption by adolescents in Kenya and sub-Saharan Africa is limited [26, 27], available literature mainly focus on food group (e.g., fruit and vegetable) consumption, and dietary diversity [28]. This study aims to address this evidence gap by 1) assessing the caloric contribution of UPFs to adolescents' daily energy intake, 2) identifying factors associated with UPFs energy intake and 3) investigating the relationship between UPFs energy intake, diet quality and nutrient intake, among adolescents in urban slums in Kenya.

METHODS

Study Design and Setting

A cross-sectional household survey of adolescents aged 10–19 years living in three major urban slums in Nairobi (*Mathare*, *Korogocho*, and *Viwandani*) was conducted from August to December 2021. *Mathare* slum is the second largest and one of the oldest slums in Kenya, with an estimated population density of 68,941 persons/km^2 [29]. *Korogocho* slum is the fourth largest in Nairobi. It has an estimated population density of 100,000 persons/km^2, with a longer mean slum residency (14 years) and a higher prevalence of chronic poverty and non-migrants (born in the slum) compared to Viwandani [30]. *Viwandani* slum is the smallest of the three with an estimated population density of about 12,825 persons/km^2. It is located in the main industrial area, has a shorter mean slum residency (8 years) and has a relatively higher social economic status (SES), the lowest unemployment rate and lowest prevalence of chronic poverty compared to *Mathare* and *Korogocho* [31]. The three slums are generally characterised by poor housing and congestion; inadequate infrastructure including health, education, water and sanitation; high levels of violence, crime and insecurity; high unemployment and poverty rates and food insecurity [30, 32]. The African Population and Health Research Center operates the Nairobi Urban Health and Demographic Surveillance System (NUHDSS) in *Korogocho* and *Viwandani* slums, through which health and demographic data are collected routinely from about 79,000 individuals (aged 0–105 years) living in 25,000 households [30]. This study was nested within the NUHDSS and a larger *Healthy Food Africa* (HFA) project [33]. To obtain the sampling frame for this study, the NUHDSS census was used in Korogocho and Viwandani, while a separate household listing was conducted in Mathare.

Sample Size Estimation and Sampling

Sample size was calculated using Cochrane's formula for estimating sample size for proportions, using the documented prevalence of overweight/obesity among school going adolescents in Nairobi as 17.6% [34], and taking into account a level of precision of 5%, with 95% confidence level. Adjusting for a 20% non-response rate yielded a sample size of n = 327 (~330) adolescents. Two age strata of younger (10–14 years) and older adolescents (15–19 years) were powered independently. A total sample size of 660 for both age groups was therefore estimated. A list of all households with eligible adolescents was obtained from the NUHDSS data for Korogocho and Viwandani and a household listing from Mathare. In the household listing, community health promoters visited all households in the slum, listing down all eligible adolescents in each household. Simple random sampling was then used to select a sample of 660 adolescents, proportionate to the number of eligible adolescents in each slum.

Data Collection

Socio-Demographic Characteristics

A structured interviewer-administered questionnaire was used to collect adolescents' socio-demographic information, including individual level [*age, sex, cultural background (ethnicity), self-reported leisure screen time* (e.g., *TV, and phone, computer, social media, and video games*)], household (*wealth index*) and neighbourhood (*slum of residence, duration in the slum*) characteristics. Household asset ownership was obtained from the adolescents' primary caregiver, from which a household wealth index was computed using principal component analysis and categorised into household wealth index quintiles [35].

Anthropometric Measurements (Nutritional Status)

Anthropometric measurements (height and weight) were taken using standardised procedures, barefoot with minimum clothing [36]. Two measurements were taken for both height and weight and the average obtained. Height-for-age (HAZ), and BMI-for-age Z-scores (BMIAZ) were computed using the WHO anthros Stata macros (2007) [37]. The Z-scores were then classified as thin (BMIAZ < −2), overweight (BMIAZ >+1 and <+2), obese (BMIAZ > +2 BMI) and stunted (HAZ < −2), based on the WHO 2007 growth reference [37]. Overweight/obesity were combined as one group due to a small sample in the obesity group.

Dietary Data Collection

Dietary data were obtained through multiple 24-hour (24-h) open recall interviews, using the multiple pass method [38]. To capture intra-individual variability in dietary intake, repeat 24-h recalls were conducted on two non-consecutive days, representing one weekday and one weekend, within 2 weeks. Information on each of the food items consumed including the eating time and details of the food items (food type, ingredients of mixed dishes and brand names of commercially produced foods, and cooking method) and the amount consumed were collected. The food portion sizes and amounts consumed were estimated with the aid of the Kenya adolescent photographic food atlas [39], which contains photographic estimates of household measures, quantities and weights of foods that are commonly consumed by adolescents in urban settings in Kenya. The average (mean) amount and energy intake for both days was computed for subsequent analysis.

NOVA Food Classification

The NOVA food classification system [6] was used to classify the foods consumed by the adolescents according to the level of processing as: 1) *Nova group 1 - minimally processed foods* which include natural foods that have undergone minimal processing such as milling, grinding, drying, crushing, roasting, without addition of salt, sugar or oil, 2) *Nova group 2 - foods of culinary use* which are extracted directly from group 1 foods or nature and mainly used in the cooking, preparation or seasoning of group 1 foods, e.g., oil, sugar and salt, 3) *Nova group 3 - processed foods* which include foods that have undergone processing through addition of group 2 foods (e.g., salt and sugar) mainly for preservation, improving the shelf life or sensory qualities, e.g., canned vegetables, meat, fruits, etc., and group 4) *Nova group 4 foods-UPFs* which are foods containing one or more ingredients that result from a series of industrial processes and mostly of exclusive industrial use, which are of no/rare domestic culinary use and are rarely/never used in home cooking, such as artificial flavours, sweeteners, thickeners, emulsifiers, etc. [6]. In addition to UPFs within the NOVA classification, local deep fried, savoury and sweet snacks including pastries (e.g., *doughnuts*, *mandazi*, and *samosa*) and deep fried potato snacks (e.g., French fries, *bhajia*, and crisps) purchased mainly from informal and street food vendors were identified and included in the UPFs group. This method of categorising UPFs has been used previously by Reardon et al (2021) in describing processed food typologies in sub-Saharan Africa [4]. In subsequent analysis, the UPFs group represented the less healthy food category, while the *NOVA group 1*, *2* and *3* were combined into one non-UPFs food group representing the healthier food category (**Supplementary Table S1**). Mean daily energy and nutrient intake from each of the two food groups; UPFs and non-UPFs, were computed by summing up the energy and nutrient intake from all the food items in each group. The caloric contribution of UPFs in daily energy intake was computed as the percentage of total energy intake (% TEI) from UPFs sources. Both mean daily energy intake (*kcal*) and % TEI from UPFs and non-UPFs were categorised into quartiles with quartile one (Q1) representing the lowest and quartile four (Q4) representing the highest intake, for subsequent analysis.

Nutrient Intake

The Kenya food composition tables [40] were used to establish the energy and nutrient content of the foods consumed. The nutrients assessed included total fat, saturated fat, protein, fibre, zinc, calcium and iron. Total fat and saturated fat represented nutrients associated with overweight/obesity and NCD risks while iron, calcium and zinc represented positive nutrients of concern for adolescents in Kenya [20] and the most common micronutrient deficiencies (iron and zinc) among school going children and adolescents in Kenya [25]. In cases where information on some foods or nutrients was not found in the Kenya food composition tables, other food composition tables such as Tanzania [41], Western African [42], South African [43] were consulted. Energy and nutrient information in the food composition tables is provided per 100g of each item, therefore, conversion was made to reflect the content in the actual amount consumed. The nutrient content in the diet was adjusted for energy using the energy density method; macronutrients (protein, carbohydrate, fat, saturated fat) were expressed as percentage of energy intake (% TEI) while fibre, zinc, iron and calcium were expressed per 1,000 kcal (g/mg per 1,000 kcal) [44]. Participants with energy intakes >4,000 and <500 kcal per day, indicating implausible energy intake and potential misreporting, were excluded from the analysis [45].

Diet Quality

The global dietary quality score (GDQS) was computed according to the standardised method by the *Intake Center for Dietary Assessment* (2022), which is validated for adolescents and women of reproductive age [46]. Food items consumed were classified into 24 food groups according to their positive or negative contribution to overall diet quality and health outcomes [46]. The 24 food groups comprised of 15 "healthy" food groups that contribute positively to overall diet quality (*citrus fruit, deep orange fruits, other fruits, dark green leafy vegetables, cruciferous vegetables, deep-orange vegetables, other vegetables, legumes, deep orange tubers, nuts/seeds, whole grains, fish and shell* *fish, poultry and game meat, low fat dairy, eggs*); seven "unhealthy" food groups that negatively contribute to overall diet quality (*white roots and tubers, processed meat, refined grains and baked goods, sugar-sweetened beverages, juice, sweets and ice-cream, purchased deep fried foods*); and two "*unhealthy in excessive amounts*" food groups whose optimal intake increases diet quality but excess intake decreases diet quality (*red meat, high fat dairy*). The *liquid oil* group was excluded due to difficulties in estimating the amounts and type of oil consumed by the adolescents. Mixed dishes were decomposed into the major individual ingredients while purchased deep fried snacks were double coded both in the original food group and the *purchased deep fried foods* category as described by the *Intake Centre for Dietary Assessment* (2022). Each of the food groups were assigned a score ranging from 0.25 to 4, based on the amount consumed and their contribution to diet quality [46]. The total GDQS was then calculated by summing up the scores from all the food groups consumed, with a higher GDQS indicating higher diet quality and the opposite for lower GDQS.

Statistical Analysis

Data analysis was conducted using Stata version 17 (StataCorp, College Station, Texas United States). Descriptive statistics including mean (±sd) and percentages were used to summarise the adolescents' socio-demographic characteristics, total energy intake, mean energy from UPFs and non-UPFs, and caloric contribution (% TEI) of UPFs to daily energy intake. Multinomial logistic regression was used to assess the factors associated with quartiles of mean energy intake from UPFs and non-UPFs (kcal/day), with quartile one (lowest intake) as the reference category for quartiles two to four (Q2, Q3, Q4) and adjusting for factors that potentially influence dietary behaviour from literature, including individual (sex, age, cultural background, leisure screen time), household (wealth index) and neighbourhood (slum of residence, duration of slum residency) characteristics.

Linear regression was used to assess the association between quartiles of %TEI from UPFs and diet quality (GDQS score), adjusting for age, sex, wealth index, slum of residence, duration of slum residency, leisure screen time, and ethnicity which showed a significant association with UPFs or non-UPFs daily energy intake. Nutrient intake data were highly skewed; therefore, Kruskal-Wallis tests were used to test the differences in median nutrient intake across the quartiles of % TEI from UPFs.

RESULTS

Adolescent Characteristics by UPFs and Non-UPFs Energy Intake

A total 621 out of 660 sampled adolescents were available for the two rounds of 24-h recall interviews. Thirty-nine were unavailable for at least one round of dietary data collection due to relocation out of the study area or to boarding school. Of the n = 621, n = 14 were excluded due to implausible energy intake, whereby n = 12 reported a very low energy intake (<500 kcal per day) while n = 2 reported a very high energy intake (>4,000 kcal/day), resulting in an overall sample of n = 607 participants included in the analysis.

Social Demographic Characteristics

The mean (SD) age was 14 (13.7) with a slightly higher proportion of younger adolescents (63.9%) and girls (60.1%). The mean duration of stay in the slum was 12 (4.2) years, majority (72.3%) of the adolescents had lived in the slum for more than 10 years and those residing in Mathare slum (41.0%). Slightly more than half had more than 2 h of leisure screen time per day (55.2%) (**Table 1**).

Nutrition Status

A higher proportion of adolescents were overweight/obese (13.3%) compared to those who were thin (6.3%), while 13.3% were stunted (**Table 1**).

Energy Intake From UPFs and Non-UPFs

The mean (SD) daily energy intake was 1,604 (550) kcal. Mean energy from UPFs was 428 kcal contributing 25.2% of total daily energy intake. Of the UPFs energy intake, 9.1% (146 kcal) was from conventional UPFs (NOVA classification), while 17.6% (282 kcal) was from local UPFs (**Table 1**).

Factors Associated With UPFs and Non-UPFs Energy Intake

UPFs Intake

Individual level (cultural background, screen-time) and neighbourhood characteristics (slum of residence, duration of slum residency) were associated with UPFs energy intake. Adolescents who reported a higher leisure screen time (≥2 h/day) [OR = 1.9 (95% CI 1.2–3.1)] and those living in Mathare (largest slum of the three) [OR = 2.4 (95% CI 1.3–4.3)] were more likely to have a higher UPFs energy intake (Q4) compared to those with less screen time (<2 h/day) and living in Korogocho slum, respectively. Conversely, adolescents from the Luhya cultural background [OR = 0.5 (95% CI 0.2–0.9)] and those with a longer slum residence duration (>10 years) [OR = 0.5 (95% CI 0.3–0.8)] were less likely to have higher (Q4) UPF energy intake compared to those from the Kikuyu cultural background and those with a shorter duration of stay in the slum (≤10 years), respectively (**Table 2**).

Non-UPFs Intake

Individual (age), household (wealth index) and neighbourhood (slum of residence) characteristics were associated with non-UPFs energy intake. Adolescents from households in the fourth [OR = 2.6 (95% CI 1.2–5.8)] and fifth [OR = 2.6 (95% CI 1.3–6.0)] wealth index quintiles were more likely to have a higher (Q4) non-UPFs energy intake compared to those in the first wealth index quintile. Adolescents living in Mathare [OR = 3.2 (95% CI 1.7–6.0)] and Viwandani [OR = 4.4 (95% CI 2.2–8.7)] were more likely to have higher non-UPFs energy intake compared to those from Korogocho (lowest SES of the three). On the other hand, older adolescents (>15 years) [OR = 0.5 (0.3–0.8)] were less likely

TABLE 1 | Adolescent characteristics and comparison of ultra-processed foods and non-ultra-processed foods energy intake by adolescent characteristics; Ultra-processed food consumption is associated with poor diet quality and nutrient intake among adolescents in urban slums, Kenya, 2021.

Individual level characteristics		Adolescents [N (%)]	Mean (SD) UPFs* energy intake (kcal/day)	Mean (SD) non-UPFs* energy intake (kcal/Day)
Sex	Male	243 (39.9)	424.0 (347.3)	1,208.8 (444.1)
	Female	364 (60.1)	429.4 (362.2)	1,150.0 (444.1)
Age (years)	10 to 14	388 (63.9)	420.7 (352.0)	1,206.2 (445.4)
	15 to 19	219 (36.1)	438.9 (363.7)	1,115.2 (438.3)
Cultural background	Kikuyu	185 (30.5)	425.3 (347.7)	1,151.8 (435.5)
	Luo	124 (20.4)	471.3 (353.3)	1,150.2 (415.4)
	Luhya	97 (16.0)	384.8 (371.5)	1,154.6 (475.3)
	Kamba	118 (19.4)	419.6 (362.0)	1,204.4 (435.9)
	Other	83 (13.7)	425.8 (353.2)	1,234.3 (483.4)
Leisure screen time	≤2 h	271 (44.8)	394.4 (347.1)	1,163.2 (453.6)
	>2 h	336 (55.2)	453.9 (361.5)	1,181.8 (437.8)
Energy intake (kcal)		607 (100)	428.1 (357)	1,175.6 (445)
Household and community level characteristics				
Wealth index quintiles	1	119 (19.7)	396.8 (310.7)	1,069.3 (435.6)
	2	123 (20.3)	398.9 (333.8)	1,134.5 (398.8)
	3	124 (20.5)	473.2 (389.1)	1,194.2 (462.5)
	4	115 (19.0)	409.7 (369.3)	1,205.7 (381.6)
	5	124 (20.5)	459.2 (370.0)	1,261.7 (513.6)
Residence	Korogocho	179 (29.5)	366.9 (283.2)	1,032.4 (359.1)
	Viwandani	179 (29.5)	397.1 (316.0)	1,297.1 (506.0)
	Mathare	249 (41.0)	492.1 (415.8)	1,185.4 (425.5)
Duration in the slum	≤10 years	168 (27.7)	483.5 (385.2)	1,186.0 (427.7)
	>10 years	439 (72.3)	405.8 (342.3)	1,168.7 (451.4)
BMI for age	Thin	38 (6.3)	465.2 (339.4)	1,090.8 (449.7)
	Overweight/obese	81 (13.3)	464.9 (367.7)	1,159.0 (484.0)
Height for age	Stunted	81 (13.3)	422.9 (389.9)	1,259.8 (435.0)

UPFs, Ultra-processed foods.

to have a higher (Q4) non-UPF energy intake compared to younger adolescents (10–14 years) (**Table 2**).

Association Between UPFs Intake, Diet Quality (GDQS) and Nutrient Intake

There was an inverse association between diet quality (GDQS) and the quartiles of % TEI from UPFs. Adolescent with the highest % TEI from UPFs (Q4) had about three points lower GDQS compared to those with the lowest % TEI from UPFs (Q1) [β −2.9 (95% CI −3.7 to −2.1)] (**Table 3**).

Median energy, total fat and saturated fat increased while protein, fibre, calcium and zinc decreased across the quartiles of % TEI from UPFs. Adolescents with the highest % TEI from UPFs (Q4) had the highest median total energy, total fat and saturated fat intake; and lowest median proteins, fibre, iron, zinc and calcium intake (**Table 4**).

DISCUSSION

This study assessed the caloric contribution of UPFs to daily energy intake, the factors associated with UPFs and non-UPFs energy intake and the relationship between UPFs energy intake, diet quality and nutrient intake among adolescents in urban slums in Nairobi, Kenya. The findings indicate that about a quarter of adolescents' daily energy is from unhealthy (UPFs) food sources. Individual (age, ethnicity and screen time), household (wealth index), and community/neighbourhood factors (slum of residence and duration of stay) are associated with UPF/non-UPFs energy intake. Adolescents with high UPFs energy intake are likely to have a poor overall diet quality, high intake of nutrients promoting obesity/NCDs (total fat and saturated fats) and lower intake of health promoting nutrients (protein, fibre, calcium, iron, zinc). Overweight/obesity was more prevalent than thinness. About 13% of the adolescents were overweight/obese, aligning with the national prevalence of overweight/obesity (14%) among adolescents, while the prevalence of thinness (6%) was slightly lower than the national average (13%) [24].

Most of adolescents' daily energy intake comes from non-UPFs sources which aligns with the Kenyan healthy eating guidelines/key messages encouraging the consumption of unprocessed or minimally processed foods and limiting the consumption of processed foods and those high in fat, salt and sugar [20]. This also agrees with global literature indicating high consumption of non-processed or minimally processed foods, such as grains, fruit, and vegetables and lower consumption of UPFs in SSA compared to other parts of the world, especially in HICs [4, 47, 48]. UPFs (NOVA classification) contribution to daily energy intake (9%) by adolescents in this study aligned with findings from previous studies in Kenya (8%) [49] and Ethiopia (9%) [50], although both studies did not include locally prepared UPFs. The UPFs consumption was

TABLE 2 | Association between socio-demographic characteristics and ultra-processed foods and non-ultra-processed foods energy intake (kcal/day); Ultra-processed food consumption is associated with poor diet quality and nutrient intake among adolescents in urban slums, Kenya, 2021.

Ref (Q1)	UPFs energy intake (kcal/day)						Non-UPFs energy intake (kcal/day)					
	Q2		Q3		Q4		Q2		Q3		Q4	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Individual characteristics												
Sex Male (ref)	1		1		1		1		1		1	
Female	1.1	(0.7–1.8)	0.9	(0.6–1.5)	1.1	(0.7–1.8)	0.7	(0.4–1.1)	0.5	(0.3–0.8)	0.7	(0.5–1.2)
Age 10–14 years	1		1		1		1		1		1	
15–19 years	0.9	(0.6–1.5)	1.2	(0.7–2.0)	1.3	(0.8–2.1)	0.8	(0.5–1.2)	1.0	(0.6–1.7)	0.5	(0.3–0.8)*
Cultural background Kikuyu (ref)	1		1		1		1		1		1	
Luo	1.1	(0.6–2.3)	1.9	(0.9–3.8)	1.3	(0.7–2.6)	0.6	(0.3–1.2)	0.7	(0.4–1.4)	1.9	(1.0–3.9)
Luhya	0.5	(0.2–1.0)	0.8	(0.4–1.6)	0.5	(0.2–0.9)*	0.8	(0.4–1.7)	0.8	(0.4–1.7)	1.3	(0.6–2.7)
Kamba	1.1	(0.6–2.1)	0.8	(0.4–1.7)	0.6	(0.3–1.1)	0.8	(0.4–1.6)	1.2	(0.6–2.3)	1.0	(0.5–2.1)
Other (Specify)	0.8	(0.4–1.8)	1.0	(0.5–2.1)	0.7	(0.3–1.4)	1.0	(0.4–2.0)	0.9	(0.4–2.1)	1.6	(0.7–3.4)
Screen time <2 h	1		1		1		1		1		1	
≥2 h	1.0	(0.6–1.6)	1.2	(0.7–1.9)	1.9	(1.2–3.1)*	1.2	(0.7–1.9)	1.6	(1–2.50)	1.2	(0.7–1.9)
Household and community characteristics												
Wealth index Poor (ref)	1		1		1		1		1		1	
Poorer	0.9	(0.4–2.0)	1.0	(0.5–2.0)	0.9	(0.4–1.9)	1.1	(0.6–2.3)	1.2	(0.6–2.5)	1.4	(0.6–3.0)
Middle	2.0	(0.9–4.3)	1.4	(0.6–2.9)	1.6	(0.8–3.5)	0.9	(0.4–1.8)	1.6	(0.8–3.2)	1.6	(0.7–3.4)
Richer	1.2	(0.6–2.6)	0.7	(0.3–1.5)	1.6	(0.4–1.8)	1.5	(0.7–3.3)	2.0	(0.9–4.3)	2.6	(1.2–5.8)*
Richest	1.2	(0.6–2.6)	1.0	(0.5–2.1)	1.6	(0.7–3.0)	1.6	(0.8–3.3)	1.0	(0.5–2.2)	2.6	(1.3–6.0)*
Slum of residence Korogocho (ref)	1		1		1		1		1		1	
Viwandani	1.0	(0.5–1.9)	1.6	(0.9–3.0)	1.5	(0.8–2.9)	0.9	(0.5–1.8)	1.8	(1–3.5)	4.4	(2.2–8.7)*
Mathare	1.0	(0.6–1.8)	1.2	(0.7–2.2)	2.4	(1.3–4.3)*	1.1	(0.6–1.8)	1.8	(1.1–3.3)	3.2	(1.7–6.0)*
Duration in the slum <10 years	1		1		1		1		1		1	
>10 years	0.7	(0.4–1.2)	0.7	(0.4–1.2)	0.5	(0.3–0.8)*	0.7	(0.4–1.2)	0.8	(0.5–1.4)	0.9	(0.5–1.5)

*UPF, Ultra processed foods; OR, odds ratio. * P < 0.05*

TABLE 3 | Association between percentage energy intake from ultra-processed foods and Global Diet Quality Score; Ultra-processed food consumption is associated with poor diet quality and nutrient intake among adolescents in urban slums, Kenya, 2021.

Diet quality*	Mean	Quartiles of % TEI from UPFs			
		Q1	Q2	Q3	Q4
		ref	β(95% CI)	β(95% CI)	β(95% CI)
GDQS	20.5 (18.5–23.0)	1	−1.3 (−2.1–−0.5)	−1.9 (−2.7–−1.1)	−2.9 (−3.7–−2.1)

**Regression analysis of association between GDQS, score and quartiles of % TEI from UPFs adjusting for age, sex, wealth, slum, ethnicity, duration in slum, leisure screen time. GDQS, global diet quality score; UPFs, Ultra processed foods.*

TABLE 4 | Median nutrient intake across quartiles of percentage energy intake from ultra-processed foods; Ultra-processed food consumption is associated with poor diet quality and nutrient intake among adolescents in urban slums, Kenya, 2021.

Nutrient intake*	Quartiles of % TEI from UPFs					*P*-value
	Median	Q1	Q2	Q3	Q4	
Energy (kcal)	1,543.4 (1,207.7–1,912.2)	1,345.7	1,501.9	1,551.9	1,771.1	0.001
Fat (%TEI)	26.2 (22.0–30.5)	24.3	24.7	26.1	28.4	0.001
Saturated fat (% TEI)	8.8 (6.1–12.6)	7.7	8.0	9.1	10.4	0.001
Carbohydrate (% TEI)	59.9 (55.4–64.0)	60.2	60.9	60.0	58.9	0.011
Protein (% TEI)	10.8 (9.8–12.3)	11.9	11.1	10.8	9.8	0.001
Fibre (mg/1000 kcal)	19.0 (15.3–22.9)	22.6	20.2	18.6	15.5	0.001
Iron (mg/1,000 kcal)	9.4 (8.2–11.2)	9.6	9.3	9.5	9.2	0.153
Zinc (mg/1,000 kcal)	4.1 (3.6–4.8)	4.8	4.4	4.0	3.4	0.001
Calcium (mg/1,000 kcal)	352.1 (238.7–408.8)	344.7	334.0	335.7	282.2	0.001

**Kruskal-Wallis test of the difference in the median nutrient intake across the quartiles of UPFs energy.*

**UPFs, Ultra-processed foods.*

much lower than from middle and high income countries such as Brazil, Belgium and the UK where UPFs contribution to adolescents daily energy intake is about 30% and 60% [9, 51, 52]. However, with the on-going nutrition transition observed in LMICs including SSA, UPFs consumption is projected to soon equal that in HICs, if no mitigation plans are undertaken [4, 53]. This is of concern given adverse health outcomes, such as overweight, obesity, cardiometabolic, mental and neurological conditions that have been linked to high UPF consumption in adolescents in HICs [7, 54–56]. It is also important to note that in addition to industrially produced UPFs as described in the NOVA classification, locally prepared UPFs contribute substantially to unhealthy food consumption among adolescents in the study context. Turner et al. pointed out the existence of informal food systems in LMICs such as street vendors who provide local ready to eat, cheap street fast foods, that have minimum or no food packaging and labelling, as a key difference between food environments in HICs and LMICs [16]. Implementation of food environment policies to mitigate unhealthy food consumption in LMICs should therefore address the wide range of unhealthy food types supplied through both formal (pre-packaged UPFs) and informal food (local prepared UPFs) systems.

We found that adolescents' individual, household and community/neighbourhood characteristics were associated with UPFs consumption. At an individual level, screen time was associated with higher UPFs consumption. Similarly, a high screen time was associated with higher UPFs consumption in other studies [57, 58], some concluding that prolonged television and computer viewing hours favoured the passive consumption of junk foods and sugar sweetened beverages [59]. In a qualitative study among adolescents in the study area watching TV and spending time on social media were highlighted as among the competing activities that hindered the preparation and consumption of healthy homemade meals, leading adolescents to opt for more convenient UPFs that were ready to eat or needed minimal preparation [60]. As such, interventions to promote healthier dietary behaviour for adolescents should incorporate strategies to limit leisure screen time in favour of health promoting activities, such as play and physical activity.

At household level, higher wealth index quintile was associated with non-UPFs consumption. Similarly, at neighbourhood level, adolescents living in the (relatively) higher SES slum (Viwandani) were more likely to consume non-UPFs compared to those in the poorest slum (Korogocho). Our finding aligns with those from other studies that have found associations between UPFs consumption and socio-economic status, with a higher caloric cost of non-UPFs foods compared to UPFs [61] and higher likelihood of UPFs consumption among individuals and neighbourhoods with low socio-economic situation [62, 63]. A study of food insecurity in urban slums Nairobi indicated consumption of cheap, ready-to-eat and street foods as a strategy to save food related costs, compared to preparation of home-made meals requiring extra expenses for preparation and cleaning such as water and fuel [64]. This was also reflected in a qualitative study with adolescents in the study area which revealed economic access as one of the drivers of UPFs consumption, with a general perception that UPFs were cheap and easily affordable in the slum neighbourhood while non-UPFs were less affordable [60]. This may explain the higher likelihood of consumption of non-UPFs by wealthier households and higher SES neighbourhoods than poorer households/neighbourhoods. Strategies to create a healthier food environment in urban contexts should therefore consider improving the affordability and accessibility of healthier non-UPFs in economically deprived neighbourhoods and households.

Our study demonstrates that high-energy intake from UPFs sources is linked to poor diet quality (lower GDQS). This concurs with studies in Ethiopia and Brazil where UPFs energy intake was inversely correlated with diet quality (GDQS) [50, 65], and a multi-country European study where UPFs consumption was associated with poor diet quality, lower fruits and vegetables consumption and high consumption of "junk" foods [11].

Furthermore, higher UPFs caloric intake was related to higher consumption of nutrients related to obesity and NCDs (total fat, saturated fat) and decreased intake of health promoting nutrients (protein, fibre, iron, calcium, zinc) by the adolescents. Similarly in Brazil, high energy contribution from UPFs was associated with lower protein, fibre, iron and zinc intake in young adolescents [10], while in Chile, UPFs consumption was associated with high fat and saturated fat intake and inversely associated with fibre intake [66]. UPFs consumption therefore is detrimental to achieving healthy diets and optimal diet quality and nutrient intake by adolescents, which potentially increases their susceptibility to overweight/obesity, micronutrient deficiencies and diet related NCDs in the long-term [46, 67]. As such, efforts to address the double burden of malnutrition and chronic micronutrient deficiencies among adolescents in SSA should include the reduction in UPFs consumption as one of the strategies.

Strengths and Limitations

This is the first study to provide evidence on the extent of consumption of UPFs, factors associated with UPFs consumption and the association between UPFs, diet quality and nutrient intake among adolescents in urban slum contexts in Kenya. The study combined both industrially produced UPF as described in the NOVA system and also local UPFs produced and supplied through informal and street food vendors, ensuring a comprehensive inclusion of the wide range of unhealthy foods consumed by adolescents in Kenyan urban slum contexts. The use of a 24-h recall limits the assessment of usual UPFs intake by the adolescents. Therefore, longitudinal studies are recommended to track the consumption of UPFs by adolescents and its association with health outcomes.

Conclusion

Unhealthy foods, including UPFs, substantially contribute to adolescents' daily energy intake, and are related to poor diet quality, lower intake of health promoting and higher intake of obesity and NCD related nutrients. This calls for interventions to address the consumption of unhealthy foods among adolescents in urban slums in Kenya and SSA. Such interventions should incorporate the wide range of unhealthy food types supplied through both formal and informal food environment in Kenyan urban slums and similar contexts.

ETHICS STATEMENT

This study was approved by AMREF ethics and scientific review committee (protocol number P919/2020). This study was conducted in accordance with the local legislation and institutional requirements. Written informed consent for participating in the study was provided by the participants' legal guardian/next of kin while a written assent was obtained from the adolescents.

AUTHOR CONTRIBUTIONS

MNW: led the study conceptualisation, data collection, data analysis, drafting, review and finalisation of manuscript; EWK-M, GA, and KK-G: guided the study conceptualisation, data analysis, manuscript drafting, reviewed all versions of the manuscript; MH, RP, CW, DA, NL, SK, and LP: contributed to the data analysis, reviewed all versions of the manuscript. All authors contributed to the article and approved the submitted version.

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CONFLICT OF INTEREST

The authors declare that they do not have any conflicts of interest.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.ssph-journal.org/articles/10.3389/ijph.2024.1607891/full#supplementary-material

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Ultra-Processed Food Consumption Among College Students and Their Association With Body Composition, Bowel Movements and Menstrual Cycle

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Objectives: The current research aimed to explore the association of ultra-processed food consumption among college students with body composition, bowel movements, and menstrual irregularities with a focus on females.

Methods: A cross-sectional study was conducted in Pune, India among 110 university students of both genders aged 18–25 years. A developed and validated Food Frequency Questionnaire (FFQ) based on the NOVA classification was used to evaluate UPF consumption, while the Constipation Scoring System (CSS) and the Premenstrual Symptoms Screening Tool assessed bowel habits and menstrual health, respectively. Anthropometric measurements, including BMI, body fat percentage,and visceral fat were recorded using an Omron Karada Analyzer.

Results: A higher percentage of participants were female (74.8%). Most participants (52.3%) consumed more than three meals daily, while 42.1% ate outside food 2–3 times per week. Higher UPF consumption showed a trend toward increased body fat ($p = 0.053$) and was significantly associated with greater visceral fat accumulation ($p < 0.05$). No significant associations were found between UPF intake and bowel movement, gastrointestinal symptoms, or menstrual cycle irregularities ($p > 0.05$).

Conclusion: Higher UPF consumption showed a trend toward increased body fat percentage, though not statistically significant. These findings highlight the need to reduce UPF intake to mitigate potential risks of increased adiposity and metabolic disturbances.

Keywords: ultra-processed food choices, body composition, body mass index, bowel movements, irregular menstrual cycle

Abbreviations: UPF, Ultra-Processed Food; PBF, Percentage of Body Fat; PMS, Pre-Menstrual Syndrome; MC, Menstrual Cycle; BM, Bowel Movement.

INTRODUCTION

The reports on food adulteration have increased, and the consumption of highly processed and ready-to-eat items has grown. The consumption of such food has contributed to rising obesity rates globally and in India [1]. Teenagers and young adults are often the most affected by changing food habits, social pressures, and socioeconomic factors [2].

A balanced diet is essential for energy and provides macronutrients, essential fats, amino acids, vitamins, and minerals [3]. Improper nutrient intake can harm health, leading to issues like hair loss, brittle nails, and weight loss [4]. Excessive intake of fast foods high in fats, sugars, and sodium contributes to weight gain and various health issues, including obesity [5].

An ultra-processed food (UPF) is created primarily for commercial gain, designed to be hyper-palatable. These foods often include organic or synthetic additives, preservatives, and colorings to enhance taste and appeal. Industrial processing methods like frying, freezing, and hydrogenation are typically used in their production. Avoiding UPF among teenagers and young adults is crucial for protecting future generations. Poor nutrition can lead to chronic health issues like Type 2 diabetes, obesity, and cardiovascular disease [6].

Understanding UPF consumption among college students is necessary for their health and wellbeing [7]. Poor dietary consumption among college students can impact their health and academic performance [8]. Reports indicate that university students experience a significant shift in lifestyle, greatly affecting their dietary habits [9]. Most college students usually eat in a mess and college canteen facilities availing limited or routine healthy eating options [10]. Other major factors influencing their dietary consumption are availability of time and financial conditions [11]. Limited time and a fixed budget make it hard to balance studies, extracurriculars, cooking, and cleaning, leading many to rely on mess services, street food, or convenience items for affordability and convenience [12]. Young adults and teenagers face higher disease risk due to increased consumption of processed foods high in fat, sugar, sodium, and preservatives, along with reduced intake of fresh, nutritious meals [13]. Moreover, the availability of UPF is higher and cheaper as compared to healthy homemade meals [14]. Enhanced taste also induces UPF consumption among students [15]. A repetitive menu with limited taste in the mess food also provokes students to have ultra-processed foods [7]. UPF consumption among students are influenced by social, psychological, and financial factors such as mood, cravings, quality, pricing, preferences, and eating behaviors [16].

India's diverse religious and cultural landscape influences ultra-processed food (UPF) consumption and dietary behaviours. Thus, a wide range of consumption patterns across the population is observed [15]. Students relocating for higher studies often have difficulty adjusting to new food tastes and ingredients, resulting in a reliance on ultra-processed foods to satisfy cravings [17]. Studies indicate that male students often skip breakfast and rely on outside foods, while female students are more likely to prepare meals and include some fruits and vegetables in their diets [18].

Irregular meal timings, high intake of fats and sugars, and lack of physical activity among students contribute significantly to global obesity and related health issues, including impaired bowel movements [19]. Early onset of chronic diseases related to obesity and overweight in adults also negatively affects students' academic performance [20]. Rising academic stress, lifestyle changes, and cheap fast food availability have led to unhealthy diets, increasing obesity, and nutritional disorders in teenagers and adults [21].

Diet influences the body composition of individuals, including weight-to-height ratios and the percentage of body fat index (PBF) [5]. Higher consumption of calorie-dense foods like French fries and candies is linked to increased PBF and BMI, while students who eat more fruits and vegetables have lower values for these metrics [22]. Many students snack on high-fat and sugary foods, a significant cause of weight gain, regardless of their health conditions [23]. Healthy eating habits reflect healthy and normal body composition indicators like adipose tissue, BMI, and body type [7].

An unhealthy diet may cause common health problems such as gastric issues including acidity, bloating, and constipation [24]. Students are experiencing constipation regularly due to low consumption of fruits, and vegetables, and high intake of sugar, fat, and refined products [25]. UPF consumption are associated with constipation as they have a high impact on the colon [26]. Also, unhygienic food habits and high consumption of sugary foods have been associated with diarrhoea [27]. Low-fibre diets can disrupt digestion, causing constipation, diarrhoea, and other gastric issues, and may increase the risk of inflammatory and irritable bowel disorders over time [28]. Irregular bowel movements can impact gut health and mood, leading to symptoms like headaches, coated tongue, foul breath, and depression. This can significantly reduce the productivity and wellbeing of students and individuals [2].

Rising cases of polycystic ovarian disease (PCOD) and female infertility were found associated with UPF consumption from childhood to infancy [20]. Pre-menstrual syndrome (PMS) symptoms are linked to unhealthy food consumption. In female students, high caffeine intake, fried foods, sweets, zero-calorie drinks, smoking, lack of physical activity, and higher BMI are associated with increased insulin resistance and worsened PMS symptoms [13, 29]. Obesity is a major risk factor for various diseases like type 2 diabetes mellitus and dyslipidaemia, and it has adverse effects on iron status [11]. Mindful eating and a balanced diet promote long-term health. Educating students about avoidance of UPF and implementing proper nutrition practices are essential [24].

The study evaluated how UPF consumption among college students affects body composition, bowel movement, and PMS symptoms.

METHODS

Study Design and Participants

This cross-sectional study targeted students aged between 18 and 25 years enrolled at a University in Pune, India. A non-random sampling technique was employed to recruit 110 diploma, undergraduate, and postgraduate students both genders over

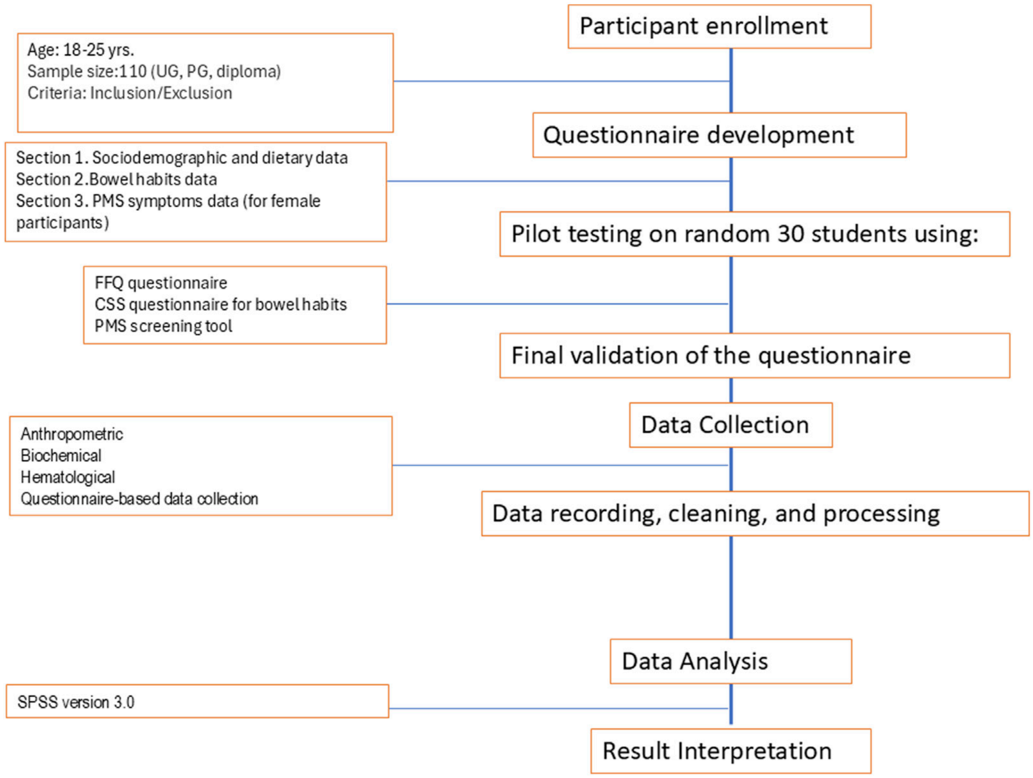

FIGURE 1 | Flow chart of the study (Ultra-Processed Food Consumption Among College Students and Their Association With Body Composition, Bowel Movements and Menstrual Cycle, Pune, India. 2024).

3 months. The study followed a two-phase approach with inclusion criteria specifying students aged 18–25 years without known health issues (**Figure 1**). Exclusion criteria included students with health conditions, bleeding disorders, refusal to consent, or those enrolled at other institutions. Ethical approval was obtained from Symbiosis Skills and Professional University (SSPU/R/2024/461) following the institutional guidelines. Written informed consent was obtained from all participants before their involvement in the study. This study was conducted between April 2024 and July 2024.

Each study participant had a face-to-face interview to answer the questionnaire, where each student took 20–30 min to complete the questionnaire and to perform the physical measurements privately in the presence of the researchers. A trained nurse performed the haemoglobin assessments as a part of the participant health screening, rather than as a study variable. BMI was classified based on the World Health Organization (WHO) guidelines: participants with a BMI below 25 kg/m^2 were categorized as normal body weight, those with a BMI ranging from 25 to 29 kg/m^2 were classified as overweight, and a BMI of 30 kg/m^2 or higher was defined as obesity.

Phase 1: Questionnaire Development

A structured questionnaire was developed and validated to collect data, covering socio-demographic details, dietary habits, UPF consumption, gastrointestinal health, and premenstrual syndrome (PMS) symptoms. The questionnaire consisted of three sections:

1. Sociodemographic and dietary assessment: Included questions on age, gender, weight, height, frequency of engagement in physical activity, and dietary consumption, assessed using a validated Food Frequency Questionnaire (FFQ) to measure the frequency of UPF consumption.
   Reference for UPF Classification: The validated Food Frequency Questionnaire (FFQ) with frequency categories ranging from daily to never was used for assessing UPF consumption. This questionnaire was developed and then validated based on the NOVA classification system [30], which categorizes food according to its level of processing. This classification method ensured a standardized evaluation of ultra-processed food intake.
2. Bowel movement assessment: Utilized the Constipation Scoring System (CSS) to evaluate bowel habits and stool frequency
3. Menstrual health assessment: The Premenstrual Symptoms Screening Tool applicable to female participants, was used to document the menstrual cycle irregularities and symptoms related to PMS.

The questionnaire was adapted from previously validated tools ensuring reliability in assessing dietary consumption and health indicators. A pilot testing was done with 30 participants to refine clarity and relevance, feedback was incorporated into the final version before full-scale data collection started.

Phase 2: Data Collection

Anthropometric data, dietary intake, physical activity, bowel habits, and PMS symptoms were collected. Height was measured with a stadiometer; weight, BMI, body fat, and visceral fat were estimated using an Omron Karada analyser.

Data Analysis

Statistical analysis were performed using SPSS Version 3.0. Descriptive statistics, including means and standard deviations, were calculated for anthropometric and dietary variables. Pearson's correlation test was used to examine the relationship between UPF consumption and body composition, bowel movements, and menstrual cycle. A p-value of <0.05 was considered statistically significant.

RESULT

Demographic Characteristics and Dietary Assessment

A comprehensive survey of 110 students was done and we assessed dietary habits, encompassing age, gender, living arrangements, meal patterns, water intake, dietary behaviours, and physical activity levels. Although the study was conducted in both genders; most participants were female (74.8%) and belonged to the 18–25 years age group. A majority (72%) were day scholars, while 28% lived in hostels. In meal preparation, 61.7% cooked their meals, while 38.3% used external food sources like mess services.

Meal Frequency and Dietary Patterns

We analyzed meal frequency, outside food consumption, water intake, and breakfast eating habits of the participants. Results indicated that 52.3% consumed more than three meals daily, while 25.2% had two or three meals. Regarding outside meals, 42.1% ate out 2–3 times weekly, and 38.3% did so once a week. Water intake showed that 44.9% consumed 2–3 L daily, with 20.6% exceeding 3 L, indicating good hydration. For breakfast, 35.5% never skipped it, while 19.6% always did.

Physical Activity

Physical activity levels varied among the participants, with 35.5% being inactive, 35.5% engaging in daily exercise, and 39.3% exercising 2–3 times weekly. These findings indicate a significant proportion of the participant students incorporated regular physical activity into their routines, although a significant percentage remained inactive.

Dietary Consumption Patterns

The dietary habits of respondents were further assessed in terms of food consumption frequency (**Supplementary File S1**). A significant proportion reported consuming fresh fruits (54.7%) and milk/milk products (50.5%) daily. The intake of cooked and raw vegetables was lower, with 37.9% consuming them daily. Interestingly, 34.7% of participants never consumed meat, while 36.8% never consumed eggs, highlighting notable dietary exclusions. Alcohol consumption was relatively low, with 77.9% of respondents abstaining completely.

Ultra Processed Food Consumption Patterns

To analyze ultra-processed food (UPF) consumption, participants rated various UPF items on a scale of 1–5, where 1 indicated the lowest consumption and 5 the highest (**Table 1**). The results showed that chocolates (23.2%) and ice cream (25.5%) were among the most frequently consumed UPFs.Conversely, mayo (38.3%) and soft drinks (33.7%) had lower reported consumption. These findings suggest variability in UPF intake, with some products being more commonly consumed than others.

Table 1 illustrates participants' ratings, revealing their tendencies toward different ultra-processed foods and offering insights into consumption trends and dietary inclinations.

Relationship Between UPF Consumption and Body Composition

The anthropometric analysis of participants revealed a mean height of 159 cm, weight of 58 kg, and BMI of 22.4, placing most individuals within normal and overweight categories. The mean percentage of body fat index (PBF) was 28%, indicating a tendency towards higher adiposity. **Table 2** presents the relationship between UPF consumption and body composition, analyzed using ANOVA. Food intake was categorized based on the NOVA classification system, which groups foods by processing level. Unprocessed or minimally processed foods, such as fresh fruits, vegetables, whole grains, plain dairy, and unseasoned lean meats were identified as healthy food categories. Ultra-processed foods (UPFs) were identified as foods, such as packaged snacks, sugary-sweetened beverages, instant noodles and processed meats that are industrially formulated food products containing additives [30]. The result showed that while healthy food consumption did not significantly affect body composition ($p = 0.479$), UPF consumption exhibited a trend towards significance ($p = 0.053$), suggesting a potential association between frequent UPF intake and increased body fat.

Although the observed association did not reach the full statistical significance, the F-value of 3.196 for UPF consumption indicates notable variability in body composition among different intake groups. These findings suggest that higher UPF consumption may contribute to increased fat accumulation, highlighting the need for further study to explore its long-term metabolic effects. Given the growing reliance on UPFs, understanding their role in adiposity and body composition changes over time remains critical for promoting healthy dietary habits.

Relationship Between UPF Consumption and Visceral Fat

Dietary patterns, particularly the consumption of UPFs play a crucial role in body fat distribution and metabolic health. In this study, a significant positive correlation was observed between UPF consumption and visceral fat levels ($p < 0.05$), indicating that individuals with high UPF intake tended to have greater visceral fat accumulation.

TABLE 1 | Consumption patterns of ultra-processed food items among the participants (Ultra-Processed Food Consumption Among College Students and Their Association With Body Composition, Bowel Movements and Menstrual Cycle, Pune, India. 2024).

Ultra processed food item	Lowest rating % [1]	Highest rating [5]
Burger	26.3	17.9
Pizza	22.1	22.1
Samosa	24.2	6.3
Vada Pav	18.9	13.7
Noodles	28.4	12.6
Packet/Ready to Eat Foods	30.5	9.5
Biscuits	24.2	5.3
Cakes/Pastries	16.1	17.2
Soft Drinks	33.7	8.4
Bread and Bakery Items	14.7	9.5
Mayo	38.3	7.4
Ketchup/Sugar-Based Sauces/Dips	31.9	7.4
Chocolates	14.7	23.2
Ice Cream	14.9	25.5
Chat	17.0	24.5

TABLE 2 | The relationship between ultra-processed food consumption and body composition (Ultra-Processed Food Consumption Among College Students and Their Association With Body Composition, Bowel Movements and Menstrual Cycle, Pune, India. 2024).

Food Consumption Type	Between and Within Groups	Sum of Squares	df (degrees of freedom)	Mean Square	F-value	Sig.(p-value)
Healthy Food	Between Groups	53.427	2	26.714	0.75	0.479
	Within Groups	1,281.496	36	35.597		
	Total	1,334.923	38			
UPF	Between Groups	1,178.355	2	589.177	3.196	0.053
	Within Groups	6,636.722	36	184.353		
	Total	7,815.077	38			

TABLE 3 | Correlation between ultra-processed food consumption and gastrointestinal symptoms and bowel movement (Ultra-Processed Food Consumption Among College Students and Their Association With Body Composition, Bowel Movements and Menstrual Cycle, Pune, India. 2024).

Gastrointestinal symptoms and bowel movement	Food consumption type	p-value
How often do you suffer from constipation	Healthy food	0.846
	UPF[a]	0.843
How often do you suffer from bloating and acidity	Healthy food	0.860
	UPF	0.307
How often do you experience incomplete evacuation	Healthy food	0.676
	UPF	0.475

[a]UPF: Ultra-Processed Foods, classified according to [30]
No correlations were found to be statistically significant at p *< 0.05.*

Relationship Between UPF Consumption and Gastrointestinal Symptoms and Bowel Movement

Ultra-processed food (UPF) consumption has been suggested to influence digestive health, particularly bowel movement patterns. This study examined the association between UPF intake and common digestive issues such as constipation, bloating, and incomplete evacuation. However, the findings indicated no significant correlation between UPF consumption and bowel movement irregularities ($p > 0.05$) as shown in **Table 3**.

Constipation frequency did not differ significantly between individuals consuming healthy foods and those consuming UPFs ($p = 0.843$). Similarly, bloating and acidity were not significantly associated with UPF intake ($p = 0.307$), nor was the sensation of incomplete evacuation ($p = 0.475$). These results suggest that UPF may not have an immediate or direct association with bowel movement patterns among the study participants.

Relationship Between UPF Consumption and Menstrual Cycle

The association between UPF consumption and menstrual patterns was analysed among female respondents to assess whether dietary habits influenced menstrual regularity and

TABLE 4 | Correlation between ultra-processed food Consumption and Menstrual Cycle (MC) Regularity and premenstrual symptoms (Ultra-Processed Food Consumption Among College Students and Their Association With Body Composition, Bowel Movements and Menstrual Cycle, Pune, India. 2024).

Menstrual cycle (MC) regularity & PMS symptoms	Food consumption type	p-value
MC regularity	Healthy food	0.443
	UPF[a]	0.698
Which symptoms do you experience in menstruation	Healthy food	0.617
	UPF	0.969
Do you experience food cravings before menstrual cycle	Healthy food	0.838
	UPF	0.232

[a]UPF: Ultra-Processed Foods, classified according to [30]
No correlations were found to be statistically significant at $p < 0.05$.

premenstrual symptoms (PMS). The findings indicated no significant relationship ($p > 0.05$) between UPF consumption and menstrual cycle regularity, suggesting that frequent intake of UPF does not directly associate with the timing or consistency of the menstrual cycles. Similarly, common menstrual symptoms such as back pain and fatigue were not significantly linked to dietary patterns, indicating the food choices-whether healthy or ultra-processed -did not influence these discomforts. Although many participants reported experiencing food cravings before menstruation, these cravings did not show a statistically significant correlation with either healthy food consumption ($p = 0.838$) or UPF consumption ($p = 0.232$). **Table 4** summarizes these findings, reinforcing that UPF intake had no notable association with menstrual cycle regularity, symptoms, or cravings.

DISCUSSION

The findings suggest that UPF consumption, while not significantly affecting BMI—most respondents were in the normal to overweight range—strongly influence PBF, with an average of 28%, exceeding healthy levels. This highlights BMI's limitations for not differentiating fat from lean mass, making it an inadequate measure for detailed nutritional or gender-specific body composition assessments [29]. PBF and visceral fat levels are key markers for linking UPF consumption to body composition. With a mean PBF of 28% ± 5.01%, many female participants approached or exceeded the recommended 15%–30% range, indicating excess fat likely influenced by UPF consumption, enhancing future obesity risk [21]. Visceral fat, a key health marker (4% ± 4%) was generally within healthy limits. However, dietary patterns revealed insufficient protein intake, with 36% never consuming eggs and 34% avoiding chicken, indicating potential protein deficiencies, especially among vegetarians. Only 37.9% reported daily fruit consumption, far below recommended levels, risking micronutrient deficiencies.

These findings highlight significant nutritional gaps with potential long-term health risks [7]. The FFQ questionnaire highlighted a preference for ultra-processed foods such as chocolates (25%), ice creams, and chaat (24% each), followed by pizzas (22%), burgers (17%), and noodles (12%). These preferences reflected a reliance on UPF over freshly prepared meals, driven by time constraints and stressful lifestyles. This dietary pattern correlates with elevated body fat percentages (PBF) due to the high fat and low food nutrient content. Additionally, 42% of participants ordered food 2–3 times weekly, while 35% reported no physical activity, contributing to visceral fat accumulation and metabolic health risks.

These findings suggest students rely heavily on outside food and exhibit low physical activity levels, resulting in higher PBF and visceral fat percentages. Such habits increase susceptibility to metabolic disorders, underscoring the need for targeted dietary and lifestyle interventions [31].

UPF Consumption and Its Association With Bowel Movements

The dietary patterns and their relation with bowel movements were studied (**Figure 2A**). Sugar items and high-lipid foods have been linked with constipation as compared to grains, fruits, and vegetables [6]. Most participants (76.6%) reported bowel movements (BM) 1–2 times daily, while 15% had BM twice weekly, 2.8% had BM once weekly, and 5.6% less than once weekly.

Those with infrequent BM were often linked to never consuming grains like cereals and pulses (8%). Although 37% of respondents consumed raw or cooked vegetables, fibre intake remained low overall.

Regarding constipation, 35.5% reported never experiencing it, 41.1% experienced it rarely, 18.7% experienced it sometimes, and 4.7% experienced it always. Constipation was more prevalent among those favouring low-fibre, high-sodium ultra-processed foods such as pizza, burgers, and noodles, which are associated with incomplete evacuation and unsatisfactory bowel movements. These findings highlight the role of dietary habits in gastrointestinal health and the potential risks of UPF consumption [7]. Low intake of soluble fibre has been associated with feelings of incomplete evacuation. Among respondents, 37.4% reported never experiencing incomplete evacuation, 39.3% mentioned rare incomplete evacuation, 19.6% mentioned it sometimes, and 3.7% mentioned it to experience always. These symptoms may correlate with high consumption of sugary items like cakes and pastries (17% preference) and ready-to-eat foods such as noodles (22% preference).

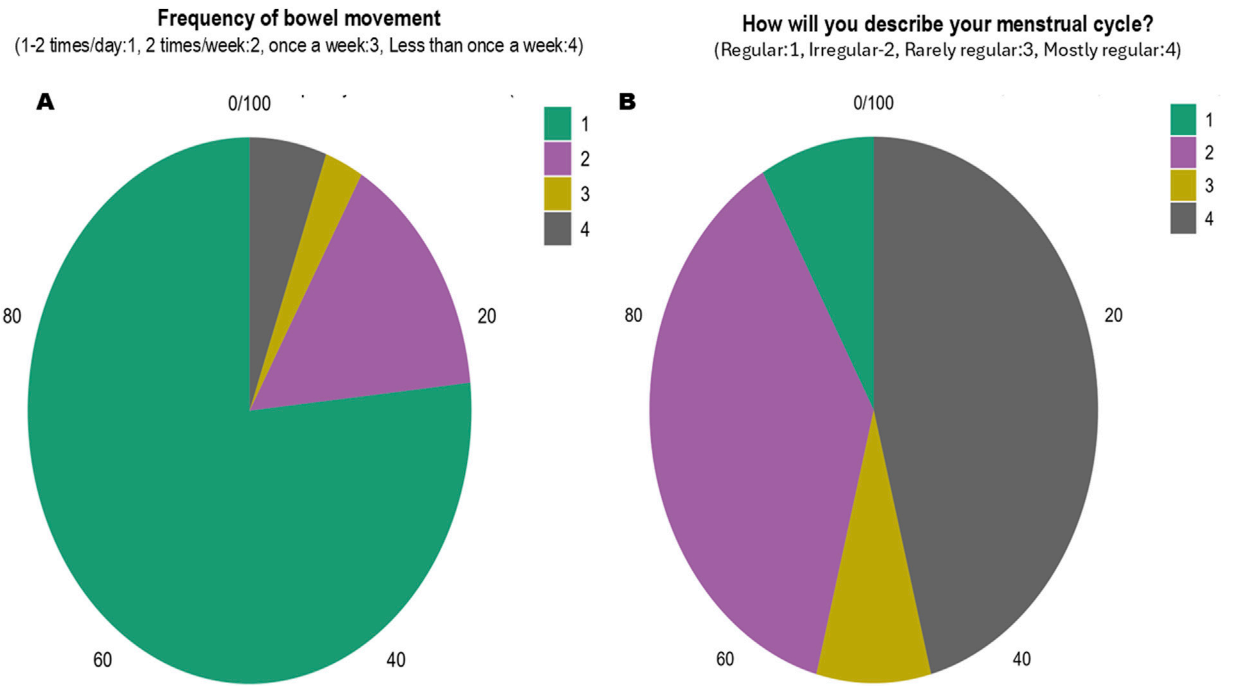

FIGURE 2 | Presentation of the questionnaire-based survey results on **(A)** the frequency of bowel movement, and **(B)** reported menstrual cycle conditions by the female participants (Ultra-Processed Food Consumption Among College Students and Their Association With Body Composition, Bowel Movements and Menstrual Cycle, Pune, India. 2024).

Adequate daily intake of soluble and insoluble fibres is crucial for reducing gastrointestinal issues while incorporating prebiotics and probiotics is known to support gut health and improve digestive function [26]. Around 24.3% of respondents reported never experiencing acidity or bloating, while 40.2% experienced it rarely, 30.8% experienced it sometimes, and 4.7% always experienced it. These issues were more common among participants with low soluble fibre intake and high consumption of sugary items like cakes and pastries. Longer meal gaps and sedentary lifestyles also exacerbated these problems. Notably, 25% of respondents consuming two or fewer meals per day and 19% skipping breakfast had higher occurrences of bloating and acidity.

Regarding supplements, 75.7% never used bran fibre or laxatives for constipation relief. Analysis revealed no significant differences in bowel movement frequency (F-ratio = 0.750, $p = 0.479$) or acidity/bloating issues related to ultra-processed food consumption (F-ratio = 0.252, $p = 0.860$). Despite this, further research focusing on daily food intake, meal size, and meal portion proportions is recommended to understand these relationships.

UPF Consumption and Its Association With PMS Symptoms

Our study found that 37.6% of respondents had regular menstrual cycles, while 45.9% reported irregular cycles (**Figure 2B**). The population with irregular cycles correlated with high consumption of fat- and sugar-rich foods, suggesting that UPF consumption may impact menstrual health and PMS symptoms. We noted that 27% of the participants regularly skipped breakfast, and 48% skipped it frequently.

Previous research links inconsistent breakfast consumption with a higher occurrence of menstrual disorders in teenage girls [32]. This highlights the potential influence of eating habits on menstrual cycle regularity [33]. Along with UPF consumption, irregularity in taking meals can also lead to a disrupted menstrual pattern. A family history of menstrual abnormalities can lead to irregular menstrual cycles due to genetic defects, 91.9% reported no family history of menstrual abnormalities, while only 8.1% reported having such a family history. This refers to the fact that most of the irregular menstrual cycles in the given study are associated with increased UPF consumption among the female population. Abbas et al. further concluded that dysmenorrhea, fatigue, irritability, and anxiety were the most common symptoms of PMS experienced by women [34].

In this study, the most commonly reported symptoms before the MC were cramps (16.9%) and mood swings (20.5%). Back pain (13.3%) and fatigue (2.4%) were also reported, and a significant percentage (47.0%) reported experiencing all of the above symptoms. These commonly occurring symptoms before the MC are usually seen in females lacking physical activity. We noted that 27% of the participants did not engage in any physical activity, and 42% engaged in physical activity twice or thrice a week. These elevated symptoms during PMS can be linked to lower physical activities among respondents. Connecting with lifestyle, 75.0% reported experiencing food cravings during or before their menstrual cycle, while 25.0% reported no food cravings. Among the respondents, 53.7% reported feeling changes in their premenstrual syndrome (PMS) due to the consumption of high-fat, high-sugar foods, which included severe to moderated acne breakdown, while 46.3% reported no such changes. Similarly, Bancroft et al. observed that 72% of the female participants reported premenstrual food cravings [32].

The study findings suggest no significant association between UPF consumption and menstrual irregularities or premenstrual symptoms (PMS). Analysis of menstrual abnormalities based on healthy or UPF consumption yielded F-ratios of 0.157 and 0.079 ($p > 0.05$), indicating no significant role of these dietary consumption in menstrual irregularities. Similarly, symptoms such as cramps, mood swings, fatigue, and back pain reported before menstruation showed no significant variation based on food consumption ($p > 0.05$). Food cravings during or before the MC were unaffected by dietary consumption, as reflected in F-ratios of 0.046 and 1.417. These findings suggest that UPF consumption has minimal association with menstrual health and related symptoms. However, potential biases and confounding factors, such as meal proportions, symptom severity, genetic predispositions, or medical conditions, warrant further investigation through more detailed studies.

Conclusion

UPF consumption may not significantly be associated with BMI but are associated with higher PBF. This highlights BMI's limitations as a standalone indicator of body composition, particularly for women with higher body fat levels. While the average visceral fat level was at a healthy level, many individuals relying heavily on ultra-processed meals and engaging in little physical activity showed potential for excessive fat accumulation. Among vegetarians, inadequate intake of fruits, vegetables, and protein was found associated with increased body fat and nutritional deficiencies.

Ultra-processed foods were also associated with digestive issues, such as bloating and constipation, although changes in bowel frequency were not statistically significant. Irregular menstruation was associated with high fat and sugar intake and skipping meals.

These findings underscore the multifaceted impacts of ultra-processed foods and the need to integrate body composition and physiological markers alongside BMI in nutritional assessments.

DATA AVAILABILITY STATEMENT

Data will be available from the authors on request.

AUTHOR CONTRIBUTIONS

AG, led the conceptualization, design, data collection, and analysis of this study and drafted the manuscript, ensuring that each section accurately reflected the research findings and objectives. AM supervised the research, offering her extensive expertise and critical oversight throughout the study. She guided the refinement of the research objectives and ensured methodological rigor.

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CONFLICT OF INTEREST

The authors declare that they do not have any conflicts of interest.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.ssph-journal.org/articles/10.3389/ijph.2025.1607712/full#supplementary-material

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Ultra-Processed Foods Consumption Is Associated With Intakes of Critical Nutrients Related to Non-Communicable Diseases Among Adults in Dakar, Senegal

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Objectives: Nutritional transition in Senegal favors the exposure to ultra-processed foods (UPF) which are linked to the development of non-communicable diseases (NCDs). This study aimed to assess UPF consumption and their contribution to dietary intakes of critical nutrients associated with NCDs.

Methods: Dietary intakes of 301 urban adults were assessed using a multi-step 24-hour dietary recall. Foods consumed were classified using the NOVA classification, and nutrient composition was determined using nutritional labels or food composition tables.

Results: UPF contributed to 17.4% of total energy, 43% of free sugars, 26.9% of total fat, 24.4% of sodium and 24% of potassium intakes. Higher UPF consumption was associated with higher intakes of energy, free sugars, fat, potassium and protein. Higher UPF consumption was also positively associated with a non-recommended intake level of total fat (OR = 2.56; $p = 0.002$) while a negative association was found with non-recommended intake levels of potassium (OR = 0.01; $p < 0.001$) and protein (OR = 0.43; $p = 0.009$).

Conclusion: UPF contribute significantly to the intakes of critical nutrients, are associated with *poor diet quality and* might be a major determinant of the inc*idence* and prevalence of *non-communicable diseases.*

Keywords: Ultra-processed foods consumption, critical nutrients, non-communicable diseases, adults, diet quality, Senegal

INTRODUCTION

Globalization, urbanization and significant demographic growth observed in most developing countries, such as Senegal, have resulted in a nutritional transition. This transition refers to the evolution and changes in dietary habits and the effects of these changes on nutrition and health [1, 2]. Dietary patterns characterized by high levels of fats, sugars, salt and energy-dense foods, but deficient in fiber and essential micronutrients, are becoming more common. This shift is associated with the rising prevalence of obesity, overweight and non-communicable diseases (NCDs), including cardiovascular disease (CVD), type 2 diabetes, stroke and certain cancers [3, 4]. According to the World Health Organization (WHO), NCDs are responsible for 74% of deaths worldwide [5] and unhealthy diets are a major cause, particularly due to excessive consumption of sugar, salt and fat [6]. These concerning nutrients are key components of ultra-processed foods (UPF), which are industrially produced with multiple ingredients and large quantities of free sugars, oils, and salt, as well as food additives designed to mimic the sensory qualities of natural foods [7, 8]. UPF are characterized by being ready-to-eat or requiring little preparation, facilitating consumption outside regular mealtimes and encouraging individual consumption [9]. In addition to their unbalanced and poor nutritional profile, UPF are hyper-palatable, addictive, have a long shelf life, economically accessible, and often subject to marketing strategies that promote overconsumption [8].

Recently, there has been increasing evidence that UPF consumption contributes to the development of obesity and NCDs such as type 2 diabetes, cardiovascular disease, and some types of cancer [10]. In addition, the proportion of UPF defines the global nutritional quality of the diet, and a high consumption of UPF is associated with lower variety and less nutritious diet. Indeed, they have higher energy density, and the increase in their proportion in the diet is generally associated with higher intakes of saturated fat, sodium and free sugars and lower intakes of fiber, protein, potassium and other essential vitamins and minerals [11, 12]. To prevent NCDs, the World Health Organization (WHO) has identified evidence-based recommendations including, reducing intakes of total and saturated fat, sodium and free sugars to limit weight gain, waist circumference and body fat percentage, prevent coronary heart disease, and reduce the risk of developing NCDs [13–16]. However, data have also shown an association between higher dietary fiber intake and a reduced risk of developing CVD, type 2 diabetes and some cancers [17]. Moreover, other studies have demonstrated that diets rich in protein are beneficial for the heart health [18] and that high potassium intake can improve blood pressure and reduce cardiovascular risk [19].

In Senegal, studies on food consumption focus mainly on food security issues, eating habits and dietary diversity, while industrial food consumption is not well covered. These studies are essentially based on qualitative data, sometimes non-representative, which does not provide an accurate measure of food consumption. They generally rely on indicators such as dietary diversity or food consumption frequency [20–23].

However, UPF are increasingly present in the Senegalese food environment as reported by a recent study which showed that of the more than 5,000 types of packaged products available on the market, over 70% are ultra-processed [24], but their association with the alarming prevalence of NCDs is unknown. Given these concerning trends, there is a need to investigate the consumption of UPF and their impact on the population's dietary intake. To our knowledge, no comprehensive studies have yet been conducted in Senegal to assess the impact of UPF on the Senegalese diet. Therefore, this study aimed to assess UPF consumption and their contribution to dietary intakes of critical nutrients related to NCDs among urban adults in Dakar, Senegal.

METHODS

Data Sources

This cross-sectional descriptive study included a convenience sample of 301 adults, all aged between 20 and 69 years, living in urban Dakar. The training for data collection was carried out by nutritionists during the week before starting the study. Data collectors were trained in the 24-hour recall methodology, including the use of food quantification tools and understanding the Nova classification. At the end of the training, a pre-test was conducted under realistic conditions to assess the data collectors' skills. Data were collected in December 2021 using a two-stage sampling plan. First, a random selection was made in 25 urban census districts (CD), spread across nine (9) health districts in the Dakar medical region. Then, at least 12 households were randomly selected in each CD, using a sampling interval defined according to the size of the CD. Finally, one adult was randomly recruited from each household. People with special nutritional needs or any medical condition requiring a special diet were considered ineligible.

Food consumption was measured using the quantitative 24-hour dietary recall method, following the automated multiple-pass method [25]. This method allowed the step-by-step recording of all foods and beverages consumed on the previous day and the amounts of each. It consists of a continuous report of all foods and beverages consumed during the previous day. The participant was then asked, using a pre-established list of foods, about any foods that he might have omitted. Next, the person was asked to indicate the time and place of consumption, as well as the method of preparation, the quantities and any additions. At the end, a final check was performed, listing all the reported items. Given Senegalese eating habits, in which food consumption is a shared act, quantities of food were weighed directly or using non-standard measures (slice, unit, tablespoon, bag, handful, etc.) or substitutes (water, dried millet, modelling paste) to obtain the weight, which refers to the volume occupied by the quantity of food consumed. The 24-hour food recalls were performed once for each participant, on any randomly assigned day of the week, including weekends days, except for holidays or special occasions. A second recall was carried out on 20% of the sample, randomly selected to detect any significant changes in diet.

Food Classification According to the NOVA System

All food items reported as consumed by the participants were categorized according to the NOVA classification [8]. The first step was to compile a list of all foods consumed by participants. Simple or single-ingredient foods and packaged products were included directly in the list. Multi-ingredient preparations were disaggregated, and their ingredients were obtained from the Senegalese standard recipe database before being included in the list. Each food or ingredient was assigned to one of the NOVA groups. Unprocessed or minimally processed foods, which are natural or have undergone minimal treatment to make them more edible, such as fresh fruit, milk, fish, etc. Processed culinary ingredients, which are food extracts from the first group or from nature through industrial processes such as pressing, extraction or refining, including vegetable oils, butter, sugar, etc. Processed foods, which are industrially manufactured by adding at least one ingredient from the second group (such as salt, sugar, oil or fat) to one or more foods from the first group, for example, bread, cheese or tinned fruit. Ultra-processed foods which are industrially manufactured and made up of several ingredients, food substances that are rarely or never used in cooking and cosmetic additives, such as soft drinks, reconstituted meat products, etc. [8]. Ultra-processed foods were then classified according to the 23 sub-categories in the Nova-UPF tool which had been adapted to the Senegalese context [26].

Nutritional Intake Assessment

The real quantity of each food consumed was obtained by using the database of food conversion factors to convert estimates in non-standard measures or substitutes to the real weight of the food consumed in grams. Then, energy and nutritional intakes for total fat, saturated fat, free sugars, sodium, potassium, protein and dietary fiber were estimated using the 2019 West African Food Composition Table [27] and the French CIQUAL 2020 Nutritional Food Composition Table [28]. To estimate the dietary share of each category of the NOVA system, we calculated the total calories consumed by individuals, including the energy contribution of each NOVA group and subgroups of UPF, and therefore the corresponding proportion of calories from those. Average daily total energy intake (TEI), means critical nutrients intakes and the prevalence of non-recommended intakes of these nutrients, were estimated for the whole study population and by terciles of energy consumption from UPF. The following thresholds were used to identify individuals not meeting the WHO daily recommendations for the prevention of NCDs: ≥30% of TEI for total fat, ≥10% of TEI for saturated fat, ≥10% of TEI for free sugars, ≥2000 mg for sodium, <3,510 mg for potassium, <0.83 g per kg of body weight for protein and <25 g for dietary fiber [13–19].

Statistical Analysis

Participants were divided into terciles, according to energy intake from UPF, to examine variation in the intake of critical nutrients and the prevalences of non-recommended intake levels for the prevention of NCDs. Each tercile represented one-third of the study population, ranging from participants with the lowest energy intake from UPF (first tercile) to those with the highest intake (third tercile). Student's t-test, Pearson's chi-square and Kruskal-Wallis test were used to evaluate differences between groups. Regression models were used to study associations between consumption of UPF, intakes of critical nutrients, energy intake and non-recommended intake levels across terciles of UPF energy contribution. All models were adjusted for the potential confounding factors including gender, age, age group, level of education and occupation. All data analyses were performed with the Stata® 16.1 software and a significance level of p-value ≤0.05 was adopted.

RESULTS

The mean age of participants was 42 years, with 49.5% aged between 20 and 39 years. The distribution by sex showed a balance between women (49.8%) and men (50.2%). In terms of educational level, 28.6% of the participants had reached university and quarter of the participants had no occupation at the time of the study, while the majority were already working (65.1%) and the remainder were students (9.6%). Considering terciles of energy contribution from UPF, there was no significant difference in the distribution of participants based on socio-demographic characteristics (**Table 1**).

Table 2 presents the TEI according to NOVA food groups and terciles of energy contribution from UPF. On average, the daily energy intake came mainly from unprocessed or minimally processed foods (1,005.9 ± 32.8 kcal; 56.9%), with the energy contribution of this category decreasing significantly with increasing UPF consumption (p < 0.001). Processed culinary ingredients accounted for an average of 353.5 ± 15.6 kcal, equivalent to 19.9% of TEI. Individuals in the highest tercile of UPF consumption had significantly lower intakes of processed culinary ingredients (p < 0.001). UPF were the third most important source of energy for our participants, with an average intake of 346.9 ± 25.8 kcal (17.4% of TEI), and the mean dietary contribution ranged from 2% to 38%, increasing significantly across terciles (p < 0.001). Processed foods contributed to an average of 91.2 ± 10.5 kcal, corresponding to 5.7% of TEI, and there was no statistical difference according to the level of consumption of UPF. Within ultra-processed products, the main energy sources were the sub-groups "Instant milk powder or instant chocolate powder" (7.2% of TEI), "Industrial mayonnaise ketchup or mustard" (3% of TEI), "Processed meats or meat spreads or nuggets" (1% of TEI), "Chocolate bars, confectionery or chewy products" (1% of TEI) and "Margarine" (1% of TEI). These combined ultra-processed sub-groups contributed twice as much as processed food overall. The contribution of ultra-processed products to intakes of critical nutrients is illustrated in **Figure 1**. A very important proportion of free sugars intake is provided by UPF (43%), and a contribution to more than a quarter of total fat (26.9%), sodium (24.4%), and potassium (24.0%). A considerable proportion of protein (18.9%) also comes from UPF, with lower percentages of dietary fiber (5.4%) and saturated fat (5.2%).

Table 3 indicates the average dietary intake of energy and critical nutrients. Participants in the highest tercile of energy contribution from UPF also consumed significantly more calories (1,995.8 ± 85.3 kcal; p = 0.001), had significantly higher intakes of total fat (78.7 ± 4.6 g; p = 0.000), free sugars (23.4 ± 3.1 g; p = 0.000), potassium (2,593.6 ± 203.3 g; p = 0.000), and protein

TABLE 1 | Socio-demographic characteristics of participants across terciles of energy contribution of ultra-processed foods in a Senegalese urban adult population (N = 301) aged 20 years and older (Dakar, Senegal. 2021).

Characteristics	All (n = 301)	Terciles of energy intake from UPF			P
		T1	T2	T3	
Mean age, M ± SD	42 ± 14	44 ± 14	40 ± 14	41 ± 14	0.947
Gender, %(n)					
Women	49.8 (150)	49.5 (50)	53 (53)	47 (47)	0.695
Men	50.2 (151)	50.5 (51)	47 (47)	53 (53)	
Group age, %(n)					
20–39	49.5 (149)	41.6 (42)	54 (54)	53 (53)	0.322
40–59	34.2 (103)	39.6 (40)	29 (29)	34 (34)	
60–68	16.3 (49)	18.8 (19)	17 (17)	13 (13)	
Level of education, %(n)					
Below University	45.8 (138)	51.5 (52)	47 (47)	39 (39)	0.752
University	28.6 (86)	26.7 (27)	28 (28)	31 (31)	
Vocational school	16.3 (49)	13.8 (14)	16 (16)	19 (19)	
Others	9.3 (28)	7.9 (8)	9 (9)	11 (11)	
Occupation, %(n)					
No occupation	25.3 (76)	29.7 (30)	27 (27)	19 (19)	0.133
Student	9.6 (29)	6.9 (7)	14 (14)	8 (8)	
Worker	65.1 (196)	63.4 (64)	59 (59)	73 (73)	

TABLE 2 | Average and relative energy intake according to NOVA groups and ultra-processed food sub-groups in a Senegalese urban adult population (N = 301) aged 20 years and older (Dakar, Senegal. 2021).

NOVA groups	Energy		Terciles of energy contribution of UPF (%)			
	Mean ± SE (kcal)	% of TEI	T1	T2	T3	P
Unprocessed or minimally processed	1,005.9 ± 32.8	56.9	65.6	63.0	42.2	<0.001
Processed culinary ingredients	353.5 ± 15.6	19.9	25.6	19.4	14.8	<0.001
Processed foods	91.2 ± 10.5	5.7	6.8	5.3	5.0	0.863
Ultra-processed foods	346.9 ± 25.8	17.4	2.0	12.3	38.0	<0.001
Instant milk powder or instant chocolate powder	151.8 ± 19.7	7.2	0.3	5.1	16.1	<0.001
Industrial mayonnaise, ketchup or mustard	60.6 ± 9.2	3.0	0.4	1.3	7.2	0.026
Chocolate bars, confectionery or chewy products	22.6 ± 9.7	1.0	0.3	0.3	2.6	0.362
Processed meats or meat spreads or nuggets	17.7 ± 4.4	1.0	0.0	0.7	2.3	<0.001
Margarine	16.2 ± 2.8	1.0	0.3	1.1	1.5	0.001
Chocolate or hazelnut paste spreads	15.3 ± 3.8	0.9	<0.1	0.8	1.8	0.004
Soda, energizing or diet beverages	11.0 ± 2.2	0.6	0.1	0.9	0.8	0.025
Cookies or biscuits with or without fillings	9.7 ± 3.1	0.6	<0.1	0.2	1.4	0.013
Iced or flavored tea, coffee milk or flavored milk	10.4 ± 5.4	0.4	<0.1	0.0	1.1	0.026
Flavored drinks, concentrates and/or fruit nectars	6.6 ± 2.1	0.4	0.1	0.3	0.6	0.579
Flavored yoghurt or industrial curdled milk	6.3 ± 1.6	0.4	0.0	0.6	0.59	0.007
Frozen fries or frozen pizza	3.5 ± 1.4	0.2	<0.1	0.3	0.2	0.246
Chips, or any other type of packaged salty snack	3.1 ± 1.5	0.2	0.0	<0.1	0.5	0.060
Spreadable cheese	2.2 ± 0.8	0.2	0.1	0.2	0.2	0.558
Frozen ready-to-eat meal	3.0 ± 3.0	0.1	0.0	0.0	0.2	0.365
Bouillons, sauces, and industrial dressings	2.7 ± 0.2	0.1	0.2	0.1	<0.1	<0.001
Industrial cakes, muffins, or pastries	1.8 ± 1.6	0.1	0.0	0.0	0.2	0.133
Instant soup powder or instant noodles	1.1 ± 1.1	0.1	0.0	<0.1	0.0	0.365
Packaged industrial bread and rusks	0.9 ± 0.7	0.1	0.0	0.0	0.2	0.133
Sweetened breakfast cereals	0.4 ± 0.4	<0.1	0.0	0.0	0.1	0.365

TEI, Total Energy Intake; T1-T3, First, second and third terciles of energy contribution of UPF.

(65.3 ± 3.8 g; $p = 0.005$) compared to those with lower energy intake from UPF. However, mean saturated fat intake was significantly lower at 4.8 ± 0.6 g ($p = 0.024$). Mean sodium and dietary fiber intakes were 2,560.7 ± 126.5 mg and 15.3 ± 0.8 g respectively, with no difference according to UPF consumption. Regression coefficients, both crude and adjusted, showed a positive association between increased proportion of UPF in the diet and dietary energy density (β = 355.6; $p < 0.01$), as well as intakes of total fat (β = 27.0; $p < 0.001$), free sugars (β = 17.8; $p = < 0.001$), potassium (β = 1,320.5; $p < 0.001$) and protein (β = 14.9; $p < 0.01$).

The prevalence of non-recommended intake levels across terciles of dietary share of UPF are shown in **Table 4**. Overall, the highest prevalences of non-recommended intakes were found

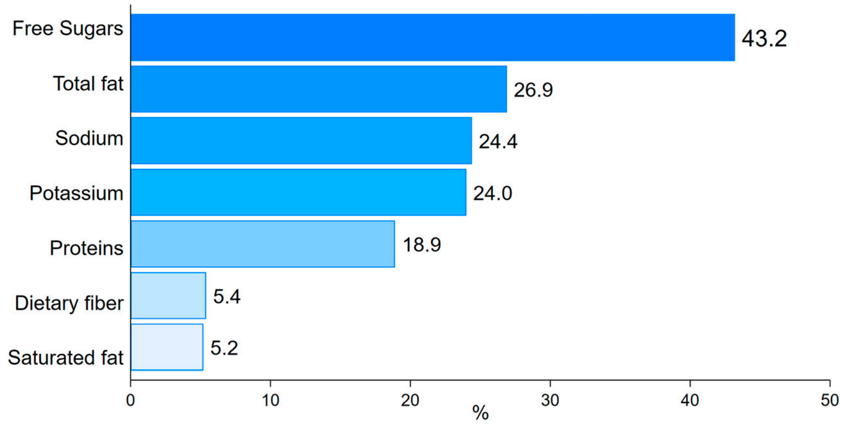

FIGURE 1 | Relative contribution of ultra-processed foods to intake of critical nutrients.

TABLE 3 | Average dietary intakes of critical nutrients according to terciles of energy contribution of ultra-processed foods in an urban Senegalese adult population (N = 301) aged 20 years and older (Dakar, Senegal. 2021).

Nutrients	Overall diet (Mean ± SE)	Terciles of energy intake from UPF (Mean ± SE)				Coefficient of regression (*β*)	
		T1	T2	T3	*P*	Crude	Adjusted
Energy (kcal)	1797.6 ± 46.6	1,636.1 ± 9	1762.7 ± 61.7	1995.6 ± 85.3	0.001	359.5[a]	355.6[a]
Total fat (g)	61.9 ± 2.3	51.8 ± 3.6	55.5 ± 2.8	78.7 ± 4.6	<0.001	26.8[b]	27.0[b]
Saturated fat (g)	5.7 ± 0.3	6.4 ± 0.6	5.8 ± 0.5	4.8 ± 0.6	0.024	–1.6	–1.5
Free Sugars (g)	12.2 ± 1.2	5.5 ± 0.9	7.8 ± 0.6	23.4 ± 3.1	<0.001	17.9[b]	17.8[b]
Sodium (mg)	2,685.3 ± 89.5	2,709.8 ± 175.9	2,785.2 ± 158.8	2,560.7 ± 126.5	0.486	–149.1	–175.3
Potassium (mg)	1914.9 ± 85.6	1,366.1 ± 84.9	1790.5 ± 101.4	2,593.6 ± 203.3	<0.001	1,227.5[b]	1,320.5[b]
Proteins (g)	58.1 ± 1.9	50.8 ± 3.1	58.3 ± 2.7	65.3 ± 3.8	0.005	14.5[a]	14.9[a]
Dietary fibre (g)	15.1 ± 0.5	14.6 ± 0.8	15.3 ± 0.8	15.3 ± 0.8	0.749	0.6	0.4

[a] *p < 0.01.*
[b] *p < 0.001.*

TABLE 4 | Prevalence (%) of non-recommended nutrient intake levels according to terciles of dietary share of ultra-processed foods in an urban Senegalese adult population (N = 301) aged 20 years and older (Dakar, Senegal. 2021).

Nutrients (thresholds)	Overall	Terciles of energy intake from UPF				OR adjusted	*P*
		T1	T2	T3	*P*		
Total fat (>30% of TEI)	49.2	40.6	43.0	64.0	0.001	2.58	0.002
Saturated fat (>10% of TEI)	2.7	5.9	1.0	1.0	0.042	0.06	0.052
Free Sugars (≥10% of TEI)	2.3	0.0	0.0	7.0	0.001	-	-
Sodium (≥2g)	33.5	32.7	30.0	38.0	0.475	1.29	0.420
Potassium (<3510 mg)	90.7	99.0	95.0	78.0	0.000	0.01	0.000
Proteins (<0.83/Kg)	60.8	71.3	58.0	53.0	0.023	0.43	0.009
Dietary fibre (<25g)	90.4	92.1	94.0	85.0	0.076	0.40	0.072

for potassium (90.7%), dietary fiber (90.4%), proteins (60.8%), total fat (49.2%) and sodium (33.5%). Non-recommended intake level of total fat intake increased significantly from 40.6% to 64% ($p = 0.001$) according to terciles of UPF consumption. However, there was a decreasing trend, with a lower prevalence of non-recommended intake levels in the upper tercile of UPF energy intake for saturated fat (1%; $p = 0.042$), potassium (78%; $p = 0.01$) and proteins (53%; $p = 0.023$). In addition, all individuals with non-recommended intake levels of free sugars were in the highest tercile, and there was no difference in dietary fiber intake. A strong positive association was found between increasing dietary share of UPF and non-recommended intake level of total fat (OR = 2.58; $p = 0.002$). Indeed, individuals in the highest tercile of UPF consumption had two times risk to exceed recommended intakes compared to the lowest tercile. In contrast, a negative association was found between terciles of energy intake from UPF and non-recommended intakes of potassium (OR = 0.01; $p < 0.001$) and protein (OR = 0.43; $p = 0.009$). Despite the elevated rate of non-recommended intake levels for potassium and protein, individuals in the highest tercile had extremely low probability of non-recommended potassium intakes and 57% less chance of non-recommended protein intakes compared to those in the lowest tercile.

DISCUSSION

In this cross-sectional study conducted in a population of Senegalese adults, surveyed in 2021, we found that unprocessed or minimally processed foods contribute the most to calorie intake with 56.9%, while UPF provide 17.4% of daily TEI. This proportion of dietary energy from UPF is the same (17%) as that reported for a group of Indian adults [29] but lower than those found among other adult populations in South Africa [30], Switzerland [31], Mexico [32] and the USA [33]. These are all countries with higher incomes and eating habits that are very different from our context. The difference in proportions between unprocessed or minimally processed foods and UPF reflects a diet still heavily based on natural or minimally processed foods, which are staple foods. Processed culinary ingredients also account for a significant proportion (19.9%) due to culinary habits that involve their use in cooking or as flavor enhancers, additions or accompaniments to meals. The share of UPF also reflects the dynamic of the current nutritional transition, with cereals such as rice, wheat and maize used to account for up to 70% of caloric intake in low-income countries [34]. This proportion of minimally processed products is therefore being reduced in favor of UPF, which are becoming increasingly important in the diets of populations in developing countries.

The UPF subcategory that contributed the most to energy intake was "Instant milk powder or instant chocolate powder" unlike in other adult populations in Switzerland, Mexico, United States [31–33] and in a study in Brazil [11], where most of the ultra-processed calories came from bakery, confectionery, and other similar products. Regarding Senegalese dietary habits, this is mainly due to instant powdered milk, which occupies a very important place in the Senegalese diet, as it is widely consumed with couscous of millet, used for breakfast and in a large variety of daily preparations. It's made from skimmed milk and vegetable fat with emulsifiers and anti-caking agents. Non-industrial breads and pastries are most commonly consumed, while highly processed breads, pastries, biscuits or cakes are less commonly consumed by adults. Salty sauces (mayonnaise, mustard and ketchup), which have all become very popular, also contributed significantly to calorie intake from UPF, due to their widespread use as accompaniments to the consumption of traditional dishes, fast food or sandwiches.

UPF mainly provides the three most critical nutrients, accounting for almost half of the intake of free sugars (43.2%), around a quarter of total fat (26.9%) and sodium (24.4%). However, they do not have a major influence on dietary fiber and saturated fat intakes. Sweetened ultra-processed products are therefore the most consumed type in our study population. The percentage of free sugars provided by UPF is higher than that reported in other studies in India, Switzerland and Australia [29, 31, 35], while the percentage of protein intake in these studies is similar to that reported in our population (18.9%). The share of total fat provided by UPF is equivalent to that reported in a Brazilian study [11], but sodium intake from UPF is lower compared to that of the Indian adult population [29]. These variations can be explained by the differences in diets, availability of UPF and local public health policies towards ultra-processed products.

The associations found between increased consumption of UPF and a significant increase in energy, free sugars and total fat intakes were also reported by several studies [11, 32, 35–38]. In addition to the processing they undergo, the nutritional composition of UPF includes high levels of sugars and fats, conferring on them a high energy density. However, our results also showed a positive association between UPF consumption and both potassium and protein intakes, and a significant improvement in compliance with WHO recommendations for both, which is contrary to the results reported by other studies [11, 32, 35–38]. Indeed, UPF contributed significantly to potassium (24%) and protein (18.9%) intakes. Although unprocessed or minimally processed foods are the most commonly consumed type of food, these are mainly staple foods such as cereals and starches, while dark green leafy vegetables, pulses, nuts or seeds, and fruits, which provide better potassium intake, are the food groups least consumed by adults in Dakar [39]. Moreover, potassium chloride is used in UPF as a substitute for sodium chloride and for improving the taste of certain products [40], particularly in processed meat and processed dairy products, which are well-consumed by our study population. All this would explain why a good proportion of dietary potassium is provided by UPF and reinforces the hypothesis that the use of potassium (potassium chloride) in industrial foods could strengthen compliance with potassium intake recommendations [41]. A similar observation applies to protein intake, as adults in developing countries do not consume enough minimally processed animal products. Instant milk powder, which contains significant amounts of protein, is the most consumed UPF subgroup, providing more energy than all the category of processed foods. Ultra-processed meat products (sausages, salami, corned beef, etc.) are also widely consumed and very accessible. This would explain why UPF also significantly contributes to our population's protein intake. Greater consumption of UPF is also associated with higher non-recommended intake of total fat, which corroborates the results of a study conducted in Australia [35]. It was also found that only 7% of individuals, all in the highest tercile of energy intake from UPF, had intakes of free sugars that exceeded the WHO recommendation. This is of course due to the much higher intakes of those who consume more UPF.

The overall findings suggest that the ultra-processed products consumed by our study population are mainly characterized by their high fat and sugar content, which has a significant impact on the intake levels of our subjects. UPF are also a potential source of improved protein and potassium intakes, although not sufficient to reach recommended levels. As already shown in other contexts [11, 42, 43], this study confirms that UPF consumption is a key factor in determining the nutritional quality of diets. Given the established link between UPF consumption and NCDs, the proportion of UPF consumption in our diet is not negligible. Moreover, with the agri-food sector, under the influence of multinational companies that are aggressively expanding into African markets, favoring the growing presence of UPF, which are affordable, convenient and highly marketed, particularly in urban areas [20, 44]. There is an urgent need for public policymakers in low-income countries such as Senegal, to address the public health issue of UPF. This will make it possible to establish a regulatory framework for the marketing and promotion of these products, as well as initiatives aimed at raising awareness and limiting the consumption of unhealthy foods in order to promote a better food environment for the population.

This study is the first, to our knowledge, to address the contribution of ultra-processed foods to nutrients of concern intakes and their impact on diet quality in West Africa. The NOVA classification, which has highlighted ultra-processed products and their association with NCDs was used. In this study, the Nova-UPF tool adapted to the Senegalese context [26, 45], which identifies the different sub-categories of UPF available in Senegal, allowed us to assess in detail and accurately which types of ultra-processed products were most consumed. This study is an important starting point on which further larger-scale studies can be designed.

However, study's limitations may be its small sample size, as it is limited to a single population group and is not of national scope. There are also the biases inherent to the 24-hour recall methodology, including memory effects, intra-individual variability, and reporting errors, which were minimized by performing a second recall in a subsample and implementing rigorous standardization of the data collection protocol.

ETHICS STATEMENT

The studies involving humans were approved by National Committee of Ethics for Research in Health (CNERS) of the Ministry of Health and Social Action (MSAS) (Protocol SEN21/17–00000079MSAS/CNERS/SP). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

AD conceptualized and designed the study; PMDDS and AB contributed to the design of the study; SDK and PMDDS conducted the data acquisition and curation; SDK performed the statistical analysis and wrote the manuscript; AD, PMDDS, AB, OMM, and NID critically revised the manuscript. All authors contributed to the article and approved the submitted version.

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CONFLICT OF INTEREST

The authors declare that they do not have any conflicts of interest.

GENERATIVE AI STATEMENT

The author(s) declare that no Generative AI was used in the creation of this manuscript.

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Unhealthy Ultra-Processed Food Consumption in Children and Adolescents Living in the Mediterranean Area: The DELICIOUS Project

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Objectives: This study addressed the consumption of ultra-processed foods (UPFs) formulated with excess of energy/fats/sugars (hence deemed as unhealthy) and factors associated with it in children and adolescents living in 5 Mediterranean countries participating to the DELICIOUS (UnDErstanding consumer food choices & promotion of healthy and sustainable Mediterranean diet and LIfestyle in Children and adolescents through behavIOUral change actionS) project.

Methods: A total of 2011 parents of children and adolescents (6–17 years) participated in a survey exploring their children's frequency consumption of unhealthy UPFs and demographic, eating, and lifestyle habits.

Results: Most children consumed unhealthy UPFs daily: higher intake was associated with being older and with obesity, as well as higher parental education and younger age. Children eating more frequently out of home and with a higher number of meals were also more likely to consume unhealthier UPF. Moreover, more screen time and a lower healthy lifestyle score were associated with higher unhealthy UPF consumption.

Conclusion: consumption of unhealthy UPFs seems to be preeminent in children and adolescents living in the Mediterranean area and associated with an overall unhealthy lifestyle.

Keywords: ultra-processed food (UPF), children and adolescents, mediterranean area, eating habits, lifestyle behaviours

INTRODUCTION

Healthy eating is essential during every stage of growth and throughout life, with childhood playing an important timing for cognitive development and general health [1]. Numerous factors are involved in children's and adolescents' food preferences and eating behaviors [2]. These preferences continually change over time as they are affected by biological, environmental, and social factors [3]. Dietary choices are influenced by individual preferences accompanied by the evolution of food markets and the growing availability of industrial food products, which determine both the economic convenience and sensorial properties [4]. The so-called "nutrition transition" phenomenon results in a progressive abandonment of traditional dietary patterns in favor of "Westernized" food products characterized by increased energy and lower nutritional density [5]. Recent research involving Mediterranean countries has revealed that a large share of children and adolescents are likely to have poor adherence to traditional dietary patterns, such as the Mediterranean Diet [6], eventually preferring diets richer in foods that have undergone various industrial transformations able to improve their palatability [5].

In recent years, the level of food processing has been the focus of major attention due to its potentially adverse effects on human health [7]. According to the Nova classification, ultra-processed foods (UPFs) can be defined as industrially manufactured products containing little to no whole foods and characterized by cosmetic alterations and additives that increase sensorial properties [8]. Enhanced palatability is a common feature of most industrialized food products, including carbonated drinks and fast foods, among others [9]. Besides, enhanced palatability is not obtained at no cost, with rather important changes in sodium, added sugar, and unhealthy fat content, often accompanied by reduction in dietary fibre, protein, vitamins, and minerals, which may explain, from a mechanistic point of view, their observed detrimental effects on human health [8]. While the role of processing and additives remains unclear and not fully elucidated, the scarce nutritional quality of certain foods is known to impact one's health [10, 11]. Many studies emphasize the inadequate nutritional quality of certain UPFs and indicate that consuming them in large quantities can increase the risk of several health issues, such as metabolic disorders, overweight, and type-2 diabetes, resulting in higher risk of cardiovascular diseases [12], kidney disease and hepatic steatosis [13]. Furthermore, recent research has pointed out that consuming UPFs may be linked to a range of serious health risks beyond those typically recognized. In particular, individuals who regularly include these foods in their diets may face a heightened likelihood of developing mental health issues, such as depression [14]. Additionally, there is evidence suggesting an increased susceptibility to gastrointestinal disorders like irritable bowel syndrome [15]. Moreover, adolescents consuming high amounts of UPF might be at a greater risk for respiratory conditions, including asthma and wheezing, which can significantly impact their quality of life [14, 16]. Regarding the impact of UPFs on the health of children and adolescents, some studies have found that frequent consumption of UPFs was associated with food addiction in overweight children [17], and also, in several prospective studies, higher consumption of UPFs during childhood has been associated with a faster increase in body mass index (BMI), body fat percentage, and waist circumference in adolescence and early adulthood [18, 19]. In this context, identifying the characteristics associated with higher consumption of unhealthy UPFs might be of interest to better target children and adolescents for educational intervention studies. Several studies have been previously conducted [20, 21], but only a minority provide information concerning Mediterranean countries. The aim of this study was to investigate the consumption of unhealthy UPF in children and adolescents living in 5 Mediterranean countries participating to the DELICIOUS project ("Understanding consumer food choices & promotion of healthy and sustainable Mediterranean diet and Lifestyle in Children and adolescents through behavIOUral change actionS") [22].

METHODS

Study Population

This study is a cross-sectional analysis carried out as part of the DELICIOUS project involving a survey targeting parents of children and adolescents aged 6 to 17 from five Mediterranean countries: Italy, Spain, Portugal, Egypt, and Lebanon. Participants were recruited on a voluntary basis after invitation via a consumer database previously established by one of the study partners. The aim was to gather a minimum of 400 participants from each country. Based on recent literature aiming to the same purposes in Mediterranean countries [23–25], a target of about 400 individuals per each Mediterranean country was set. The data collection was assessed via an electronic survey and a total of 2,011 individuals were finally recruited. All procedures followed the guidelines of the World Medical Association's Declaration of Helsinki (1989), and every participant provided informed consent prior to involvement in the study.

Data Collection

Data on participants' demographic characteristics and lifestyle was collected. For parents, information on sex, age, education level, and occupation were recorded, while for children/adolescents, sex, age, and anthropometric measurements were noted. The children's ages were divided into four categories: 6–8 years, 9–11 years, 12–14 years, and 15–17 years. Parental education was categorized into three levels: low (primary school), medium (secondary school), and high (tertiary education). Employment status was classified as unemployed or currently employed. The BMI of the children/adolescents was calculated based on their weight and height and classified according to the percentile ranges of the Centers for Disease Control and Prevention (CDC) growth charts for children and adolescents aged 2–19 years [26]. Participants were categorized as normal weight (BMI 5th-84th percentile), overweight (BMI 85th-94th percentile), and obese (BMI ≥95th percentile). The quality of lifestyle was assessed using the Electronic Kids Dietary Index (E-KINDEX) [27], which includes three main areas: food group intake (13 items), food beliefs and behaviors (8 items), and eating practices (9 items). For this study, only the lifestyle domains were considered. Physical activity levels were measured using the International Physical Activity Questionnaire-Short Form (IPAQ) [28], which collects information on physical activities (walking, moderate and vigorous intensity activities) over the past 7 days, including weekly frequency and daily duration of each activity. Physical activity levels were classified as low, moderate, and high according to IPAQ guidelines. Lastly, sleep duration was categorized according to National Sleep Foundation recommendations [29] into three groups: less than 8 h, 8–10 h, and more than 10 h. Screen time was divided into less than 2 h per day, 2–4 h per day, and more than 4 h per day.

Dietary Assessment

The consumption of UPF was assessed through a food frequency questionnaire (FFQ) comprising 13 questions investigating the intake of known unhealthy food groups from group 4 of the Nova classification, such as sweets and candies, salty snacks, fast food, soft drinks, commercial sauces, etc. For this study, the median frequency consumption of all items was calculated, and participants were categorized as frequent consumers if they fell into the upper median consumption range, or daily consumers if at least one item was reported to be consumed with daily frequency.

Statistical Analysis

Categorical variables are presented as frequencies and percentages, with the Chi-square test used to assess differences between groups of UPF consumption. Continuous variables are expressed as means and standard deviations (SDs), with the ANOVA test used to examine differences between groups. Multivariate logistic regression models were applied to calculate odds ratios (ORs) and 95% confidence intervals (CIs) for variables potentially associated with UPF consumption. All reported P-values were based on two-sided tests and compared to a significance level of 5%. SPSS 21 software (SPSS Inc., Chicago, IL, USA) was used for all statistical calculations.

RESULTS

The median unhealthy UPF consumption in the study sample was 1.8 servings/day, while 95% of children and adolescents resulted in daily consumption of unhealthy UPFs. The main demographic characteristics of the parents and children/adolescents enrolled in the study according to the consumption of UPF are presented in **Table 1**. A higher proportion of children/adolescents overweight and with obesity ($p < 0.001$) among those consuming more UPF was observed (**Table 1**). Also, there was a higher proportion of younger parents ($p < 0.001$) with higher educational status ($p < 0.001$) among children/adolescents characterized by a higher consumption of UPF (**Table 1**). A multivariate analysis for demographic variables showed that there was a significant association between being older and with obesity and high UPF consumption (OR = 2.74, 95% CI: 1.94, 3.88 for category 15–17 years, and OR = 1.97, 95% CI: 1.39, 2.80, respectively) and daily consumption of UPF (OR = 3.78, 95% CI: 2.12, 6.75 for category 15–17 years, and OR = 2.02, 95% CI: 1.09, 3.72, respectively) (**Table 1**). Similar findings were found for higher parental educational level, yet related only to high UPF consumption (OR = 2.23, 95% CI: 1.15, 4.31). On the contrary, in participants with questionnaires filled by a female parent and with older parents a significant inverse association with both high (OR = 0.66, 95% CI: 0.51, 0.85; OR = 0.20, 95% CI: 0.14, 0.29, respectively) and daily (OR = 0.47, 95% CI: 0.30, 0.73; OR = 0.38, 95% CI: 0.21, 0.71, respectively) consumption of UPFs was found (**Table 1**).

The eating behaviours of participants according to the consumption of UPFs are presented in **Table 2**. There were significant differences in the consumption of UPFs, with higher rates of participants always eating breakfast, never/seldom eating out of home, daily eating with family, never/seldom eating alone and at school, not eating advertised food, and never/seldom eating snacks among lower UPF consumption group ($p < 0.001$, respectively for all variables, **Table 2**). Multivariate analysis showed that one or 2 or more times eating out of home was significantly associated with high (OR = 2.25, 95% CI: 1.80, 2.81; OR = 4.42, 95% CI: 2.88, 6.77, respectively) and daily (OR = 2.34, 95% CI: 1.61, 3.40; OR = 20.73, 95% CI: 2.85, 150.65; respectively) UPF consumption (**Table 2**). In line, eating advertised foods was significantly associated with both high (OR = 2.40, 95% CI: 1.93, 2.99) and daily (OR = 5.03, 95% CI: 3.24, 7.82) UPF consumption (**Table 2**). However, often eating snacks was also significantly associated with high UPF consumption (OR = 1.95, 95% CI: 1.02, 3.71). When considering often eating alone and often eating at school, a significant association was found only for high UPF consumption (OR = 1.81, 95% CI: 1.35, 2.43; OR = 1.47, 95% CI: 1.14, 1.91, respectively, **Table 2**), but not for daily UPF consumption.

The distribution of lifestyle habits of children/adolescents according to the consumption of UPF is presented in **Table 3**. Among the low UPF consumption group, there were higher rates of participants reporting lower screen time ($p < 0.001$) and higher healthy lifestyle score ($p < 0.001$; **Table 3**). Spending >4 h/day or 2–4 h/day on screen was significantly associated with UPF

TABLE 1 | Demographic characteristics of parents and children/adolescents participating in the DELICIOUS project according to the level of ultra-processed food consumption (Italy, Spain, Portugal, Egypt, and Lebanon. 2023–24).

	Consumption of UPF		P-value	High consumption of UPF	Daily consumption of UPF
	Low	High		OR (95% CI)[a]	OR (95% CI)[a]
Age groups, (n, %)			0.165		
6–8 years	251 (28.5)	294 (26.0)		1	1
9–11 years	230 (26.1)	272 (24.0)		1.68 (1.19, 2.36)	2.11 (1.27, 3.52)
12–14 years	205 (23.3)	273 (24.1)		2.01 (1.42, 2.85)	1.95 (1.18, 3.22)
15–17 years	194 (22.0)	292 (25.8)		2.74 (1.94, 3.88)	3.78 (2.12, 6.75)
Sex, (n, %)			0.064		
Male	456 (51.8)	539 (47.7)		1	1
Female	424 (48.2)	592 (52.3)		1.14 (0.90, 1.45)	1.38 (0.94, 2.03)
Weight status, (n, %)			<0.001		
Normal weight	551 (75.4)	536 (63.0)		1	1
Overweight	107 (14.6)	156 (18.3)		1.36 (0.97, 1.90)	1.55 (0.87, 2.77)
Obese	73 (10.0)	159 (18.7)		1.97 (1.39, 2.80)	2.02 (1.09, 3.72)
Parents age, (n, %)			<0.001		
<44 years	96 (10.9)	327 (28.9)		1	1
≥45 years	784 (89.1)	804 (71.1)		0.20 (0.14, 0.29)	0.38 (0.21, 0.71)
Parents occupational level, (n, %)			0.495		
Unemployed	678 (78.1)	855 (76.8)		1	1
Current working	190 (21.9)	258 (23.2)		1.20 (0.87, 1.66)	0.91 (0.55, 1.49)
Parents educational level, (n, %)			<0.001		
Low	56 (6.6)	35 (3.2)		1	1
Medium	399 (47.0)	351 (32.4)		1.57 (0.82, 3.02)	1.03 (0.34, 3.10)
High	394 (46.4)	699 (64.4)		2.23 (1.15, 4.31)	0.83 (0.28, 2.51)

[a]*Analyses were adjusted for all variables presented in the table.*

TABLE 2 | Eating behaviors of children/adolescents participating in the DELICIOUS project according to the level of ultra-processed food consumption (Italy, Spain, Portugal, Egypt, and Lebanon. 2023–24).

	Consumption of UPF		P-value	High consumption of UPF	Daily consumption of UPF
	Low	High		OR (95% CI)[a]	OR (95% CI)[a]
Breakfast habit, (n, %)			<0.001		
Never/seldom	80 (9.1)	197 (17.4)		1	1
Often	79 (9.0)	269 (23.8)		1.42 (0.94, 2.16)	1.18 (0.58, 2.40)
Always	721 (81.9)	665 (58.8)		0.90 (0.64, 1.28)	0.95 (0.54, 1.67)
Eating out of home, (n, %)			<0.001		
Never/seldom	592 (67.3)	340 (30.1)		1	1
Often/always	288 (32.7)	791 (69.9)		2.69 (2.18, 3.72)	1.74 (0.84, 3.61)
Eating with family, (n, %)			<0.001		
Seldom	16 (1.8)	25 (2.2)		1	1
Often	126 (14.3)	475 (42.0)		1.39 (0.66, 2.93)	2.27 (0.79, 6.50)
Daily	738 (83.9)	631 (55.8)		1.01 (0.48, 2.11)	1.81 (0.66, 5.01)
Eating alone, (n, %)			<0.001		
Never/seldom	693 (78.8)	554 (49.0)		1	1
Often	125 (14.2)	472 (41.7)		1.81 (1.35, 2.43)	1.17 (0.72, 1.90)
Daily	62 (7.0)	105 (9.3)		1.25 (0.85, 1.83)	1.22 (0.64, 2.32)
Eating at school, (n, %)			<0.001		
Never/seldom	438 (49.8)	393 (34.7)		1	1
Often	180 (20.5)	442 (39.1)		1.47 (1.14, 1.91)	1.31 (0.87, 1.98)
Almost daily	262 (29.8)	296 (26.2)		1.14 (0.90, 1.46)	0.93 (0.65, 1.32)
Eating advertised foods, (n, %)			<0.001		
No	631 (71.7)	400 (35.4)		1	1
Yes	249 (28.3)	731 (64.6)		2.40 (1.93, 2.99)	5.03 (3.24, 7.82)
Eating snacks, (n, %)			<0.001		
Never/seldom	158 (18.0)	94 (8.3)		1	1
Often/always	232 (26.4)	659 (58.3)		1.95 (1.02, 3.71)	2.88 (2.00, 4.16)

[a]*Analyses were adjusted for all variables presented in the table.*

TABLE 3 | Lifestyle habits of children/adolescents participating in the DELICIOUS project according to the level of ultra-processed food consumption (Italy, Spain, Portugal, Egypt, and Lebanon. 2023–24).

	Consumption of UPF		P-value	High consumption of UPF	Daily consumption of UPF
	Low	High		OR (95% CI)[a]	OR (95% CI)[a]
Sleep duration, (n, %)			0.025		
Less than 8 h	139 (15.8)	232 (20.5)		1	1
8–10 h	698 (79.3)	844 (74.6)		0.91 (0.71, 1.18)	1.04 (0.70, 1.56)
>10 h	43 (4.9)	55 (4.9)		0.81 (0.49, 1.33)	0.54 (0.28, 1.05)
Screen time, (n, %)			<0.001		
<2 h/day	597 (67.8)	534 (47.2)		1	1
2–4 h/day	234 (26.6)	489 (43.2)		2.14 (1.74, 2.63)	2.61 (1.82, 3.76)
>4 h/day	49 (5.6)	108 (9.5)		2.32 (1.59, 3.38)	2.64 (1.31, 5.34)
Physical activity level, (n, %)			0.047		
Low	470 (53.4)	547 (48.4)		1	1
Medium	182 (20.7)	279 (24.7)		1.27 (1,00, 1.63)	1.23 (0.83, 1.83)
High	228 (25.9)	305 (27.0)		1.19 (0.94, 1.50)	0.92 (0.65, 1.29)
Healthy lifestyle score[b], (n, %)			<0.001		
Low	181 (20.6)	597 (52.8)		1	1
Medium	279 (31.7)	297 (26.3)		0.33 (0.26, 0.42)	0.62 (0.41, 0.94)
High	420 (47.7)	237 (21.0)		0.18 (0.14, 0.23)	0.34 (0.23, 0.49)

[a]*Analyses were adjusted for all variables presented in the table.*
[b]*Referring to the lifestyle items of the E-KINDEX.*

consumption when considering both high (OR = 2.32, 95% CI: 1.59, 3.38 and OR = 2.14, 95% CI: 1.74, 2.63, respectively) and daily UPF (OR = 2.64, 95% CI: 1.31, 5.34 and OR = 2.61, 95% CI: 1.82, 3.76, respectively) consumption (**Table 3**). Conversely, there was a significant inverse association between medium and high healthy lifestyle score and high (OR = 0.33, 95% CI: 0.26, 0.42 and OR = 0.18, 95% CI: 0.14, 0.23, respectively) and daily (OR = 0.62, 95% CI: 0.41, 0.94 and OR = 0.34, 95% CI: 0.23, 0.49, respectively) UPF consumption (**Table 3**).

DISCUSSION

This research sought to explore the consumption of unhealthy UPFs among the younger populations in the Mediterranean region. The study specifically targeted children and adolescents from five countries: by examining dietary habits in these diverse areas, the study aimed to provide a comprehensive understanding of how unhealthy UPFs are consumed across different cultural and geographical contexts within the Mediterranean basin. The study found that a majority of children eat unhealthy UPF every day, raising concerns about public health. This issue is notably more severe among older children and those struggling with obesity.

Childhood obesity is alarming due to its potential long-term health effects, such as higher risks of heart disease, type-2 diabetes, and other chronic conditions [30]. Comprehensive overviews of the scientific literature suggest that UPF consumption is associated with higher BMI in both adults [31] and younger individuals [21]. With specific reference to some studies conducted in the Mediterranean region, a cross-sectional study conducted in Greece between 2014 and 2016 on a sample of 1,718 pre-adolescents, with an average age of approximately 11 years, revealed that those who were categorized as overweight or obese were also identified as high consumers of junk food [32]. Another study conducted in Portugal on 1175 children of the population-based birth cohort Generation XXI, with the aim to investigate UPF consumption, appetitive traits and BMI in children between the ages of 4 and 7, has demonstrated that the early consumption of UPF negatively impacts children's BMI [33]. Although there is substantial research linking UPF consumption to health outcomes in adults, it is crucial to further explore its impact on children and adolescents [20]. Our study showed that adolescents are more likely to consume more unhealthy UPFs than children. This finding is consistent with other European studies on this matter: the study conducted within the Upper Project demonstrated that a higher percentage of older children from European countries was also allocated to a "sweet and processed" model, whereas a greater proportion of Spanish adolescents was observed in a "health-conscious" model [34]. The study also revealed that higher consumption of these foods is associated with higher parental education levels and younger age. This suggests that socioeconomic and demographic factors significantly influence children's dietary choices [35], from the very first months of life [36]. In families with higher educational attainment, there may be greater exposure to nutritional information as well as increased financial means to purchase packaged and ready-to-eat foods [37]. Parents provide the food environments for their children's early experiences with food and eating. These family food environments include the parents' eating behaviors and their feeding practices with their children [38]. For example, the results of a research on the behavioral mediators of family patterns of overweight indicate that parents' eating behaviors and their parenting practices influence the development of children's eating behaviors, mediating family patterns of overweight. In particular, overweight parents who struggle to control their own food intake or are concerned about the risk of their children becoming overweight may adopt controlling feeding practices in an attempt to prevent overweight in their children [38].

Examining dietary habits, it was observed that children who eat out more frequently, such as at restaurants or fast food establishments, also tend to consume a greater amount of unhealthy UPFs. This behavior could be attributed to the greater availability and accessibility of these foods outside the home, and the fact that restaurants and food chains often offer large portions and calorie-dense foods high in fats and sugars, which can be very appealing to children [39]. Additionally, consuming more meals per day appears to be associated with increased UPF consumption, likely because more meals provide more opportunities to choose unhealthy foods [40]. In this regard, a study conducted using data from the Portuguese National Food, Nutrition and Physical Activity Survey (IAN-AF 2015/2016), which aimed to describe and compare energy intake, nutrient intake, and food consumption, showed that eating patterns in places other than home were strongly associated with higher energy intake and, in particular, restaurants and other locations, with poorer dietary adequacy [41]. This suggests that the external food environment and meal frequency can significantly influence children's food choices, leading them to prefer less healthy options. For instance, a child who snacks frequently throughout the day may be more inclined to choose UPF snacks over fresh fruit or vegetables [42]. These eating patterns have undergone significant changes over the years. Indeed, regarding food availability, research conducted many years ago demonstrated that when young children were provided with a variety of healthy foods without adult intervention to control or influence their eating, they tended to choose diets that supported proper growth and health [43]. The key to the children's success was the assortment of healthy, unseasoned, and unprocessed foods made available to them [44].

The overall diet quality of the study sample has been reported in recent study to be relatively good and in line with traditional Mediterranean pattern in a large share of participants [45, 46]. Although not significant in the multivariate analysis, there was a lower percentage of UPF consumption among children and adolescents eating with family compared with those eating alone. We hypothesize that higher diet quality may be the result of cultural habits rather than a direct health conscious choice. Restricting access to appealing snacks or "junk" food might seem like a simple method for teaching children moderation in consuming foods that are high in sugar, fat, and energy density but low in essential nutrients. However, studies indicate that well-meaning efforts by parents to help their children manage their food intake may inadvertently contribute to the development of potentially unhealthy eating habits [47, 48]. Utilizing both experimental and observational research methods, previous studies showed that limiting preschoolers' access to specific foods increased their attention to and consumption of those restricted items when they became available, even if they had not been present previously. Similarly, girls' perceptions of pressure and restriction were linked to the emergence of dietary restraint and disinhibition in these young girls [49].

Concerning lifestyle behaviors, the study found a strong link between increased screen time, such as time spent watching TV, using computers, and mobile devices, and higher consumption of unhealthy UPF. This connection may stem from the fact that children who see advertisements for unhealthy foods, which are often heavily promoted through media and TV commercials, might be more inclined to crave and consume these products [50]. These ads frequently use bright colors, cartoon characters, and catchy phrases to attract children to consume food that, however, is not nutritionally healthy or suitable for the needs of this age group [51]. The aforementioned study conducted on 1,718 pre-adolescents in Greece, regarding this aspect, demonstrated that the television environment, and particularly the advertising environment, has a significant and negative impact on the eating habits of pre-adolescents. Specifically, those who claim that their lifestyle and food choices are mainly influenced by advertising are 45% more likely to be heavy consumers of junk food [32]. Additionally, excessive screen time may limit opportunities for engaging in healthy physical activities, further contributing to an overall less healthy lifestyle [52]. A study conducted in Portugal aimed at investigating UPF consumption and its association with risk of obesity and sedentary behaviors in Portuguese adolescents demonstrated that adolescents who consumed more ultra-processed foods also had a sedentary lifestyle [53]. Another study carried out in several European countries, including Spain and Greece, examined the connection between food and beverage consumption and television viewing habits among adolescents. The study, known as the Healthy Lifestyle in Europe by Nutrition in Adolescence (HELENA), revealed that spending excessive time watching TV may lead to an increased likelihood of consuming high-calorie snacks and sugary beverages simultaneously [54]. This behavior highlights a potential link between screen time and unhealthy dietary habits in adolescents [55]. Similarly, an overall unhealthier lifestyle (evaluated with the E-KINDEX, which includes factors like regular physical activity, good sleep quality, and effective stress management) is associated with higher intake of UPF. This indicates that children with generally poorer health habits are also more likely to make less nutritious food choices. In line with this, adolescents also have poor adherence to the Mediterranean diet, as demonstrated by a study conducted in Morocco that investigated adherence to the Mediterranean diet among high school students, revealing a low level of adherence [56]. In other words, there is a noticeable correlation between a generally unhealthy lifestyle and a diet high in UPF. A higher consumption of UPF was also associated with lower diet quality in the Italian "I.Family" study, which aimed to investigate the association between UPF intake and the nutritional quality of the diet among European children and adolescents [57].

Limitations

To the best of our knowledge, this study has the strength to evaluate the association between the consumption of unhealthy UPFs and the behavioral patterns of children and adolescents in five Mediterranean countries using a common methodology. However, the conclusions of this study should be considered in light of some limitations. The cross-sectional design of the study does not allow for causal associations to be drawn. Another limitation could be the reporting bias due to the questionnaires completed by the parents of the children regarding dietary frequencies and eating habits. Furthermore, the amount of UPF derived from the FFQ may not provide an accurate estimate of the quantity consumed. Additionally, since this study only focuses on junk foods, the level of processing is considered a proxy for unhealthy formulations that could, in fact, affect detrimental health outcomes.

Conclusion

In conclusion, the consumption of unhealthy UPF is notably high among children and adolescents living in the Mediterranean region. A range of factors, including the child's age, obesity status, parental education, eating habits, and overall lifestyle play a significant role in influencing how much unhealthy UPF children consume on a daily basis. All such factors represent a lifestyle pattern that is hard to disentangle, making it nearly impossible (with the available data) to establish direct connections with individual variables. This situation underscores the necessity for a well-rounded approach that considers both dietary choices and lifestyle behaviors in order to foster healthier eating patterns among children. Addressing these factors comprehensively is crucial for promoting better nutrition and overall health. To achieve this, it is imperative that parents, educators, and healthcare professionals collaborate closely. By working together, they can help create a supportive environment that encourages nutritious food choices and an active lifestyle. Such an environment should provide resources, education, and practical strategies that enable children and their families to make healthier decisions. This collective effort aims to not only improve dietary habits but also enhance physical activity, ultimately contributing to better health outcomes and wellbeing for children.

ETHICS STATEMENT

The studies involving humans were approved by Institutional Review Board (or Ethics Committee) of Mondragon University (protocol code no. IEB-20230704, approval date 04.07.2023). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

Conceptualization, GG; methodology, GG, and PB; formal analysis, AR, FG and GG; resources, AM, AC and PB; data curation, AM, AC, PB and GG; data visualization, AR and EF-T; writing–original draft preparation, AR, FG, and GG; writing–review and editing, AR, FG, OA, MA, AA, EF-T, JP, LV-A, AS, ND, AL, FML, LM, AM, AC, PB and GG; supervision, GG; project administration, JP; funding acquisition, OA, JP, LV-A, PB and GG.

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CONFLICT OF INTEREST

The authors declare that they do not have any conflicts of interest.

GENERATIVE AI STATEMENT

The author(s) declare that no Generative AI was used in the creation of this manuscript.

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