# THE IMPACT OF DIETARY CHANGES ON NON-COMMUNICABLE DISEASES IN LATIN AMERICA

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# THE IMPACT OF DIETARY CHANGES ON NON-COMMUNICABLE DISEASES IN LATIN AMERICA

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# Editorial: The Impact of Dietary Changes on Non-communicable Diseases in Latin America

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**Keywords: dietary changes, non-communicable disease, Latin America, plant-based foods, food choices**

**Editorial on the Research Topic**

**The Impact of Dietary Changes on Non-communicable Diseases in Latin America**

It is estimated that the four major non-communicable diseases (NCDs)—cardiovascular disease, most cancers, diabetes, and chronic respiratory diseases—will account for ∼81% of deaths in Latin America and the Caribbean by 2030 (1). According to the report of the Global Burden of Disease (2), dietary risks (e.g., low intake of unprocessed plant foods and high sodium consumption) contributed to the rise of burden from chronic diseases in Latin America and to DALY (disability-adjusted life years) worldwide. Likewise, recent reports show that total intake of dairy, fish, vegetables, fruits, legumes, whole grains, nuts, and seeds were below reference dietary intake (3) in Latin America. In fact, diet is the leading risk factor for premature death and disability in the region. However, and despite this fact, there is a lack of knowledge relating to the link between diet and major aspects of the epidemic of NCDs that are prevalent in this region, such as: factors impacting food choices and dietary changes (e.g., COVID-19 pandemic), evidence from diet and lifestyle advice, eating habits, vulnerable groups, beneficial foods and food patterns (e.g., plant-based, Mediterranean), among others. Therefore, our Research Topic is entitled: "*The Impact of Dietary Changes on Non-Communicable Diseases in Latin America*" so as to attract investigators from different Latin American countries in order to improve our understanding of the complexity of dietary risks on NCDs.

Ten papers were accepted after peer revision, including data from five Latin American countries (Argentina, Brasil, Chile, Mexico, and Peru): six cross-sectional studies (three descriptive, two population-based and one mixed-method), one tool development research article, and three reviews.

The review paper of Matos et al. assesses current trends in Latin America with respect to consumption of ultra-processed foods (UPF) which, together with other social and environmental factors, influences the prevalence of NCDs. An overview of UPS, concerns and trends in the intake, social determinants in the sales, the link between the intake of UPS and NCDs, as well as potential mechanisms are discussed. Mexico and Chile seem to be consuming the most UPF per capita.

In line with this finding, Araya et al. evaluated 960 pre-scholars from Santiago (Chile) and observed that UPF is the primary source of energy intake (49% of the total energy). Children in the highest quintile of UPF intake show higher levels of energy, saturated and monounsaturated fats, carbohydrates, total sugars and vitamin D compared to those in the lowest quintile. Conversely, there is an inverse association of UPF with consumption of proteins, polyunsaturated fats, fiber, zinc, vitamin A, and sodium.

Considering also the increase in the occurence of NCDs with advancing age, Loureiro et al. performed a population-based cross-sectional study with a sample of 621 community-dwelling

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older adults from Viçosa, Minas Gerais, Brazil. The authors constructed their food consumption profiles ("unhealthy," "less unhealthy," and "fairly healthy") from food frequency questionnaire data utilizing a two-step cluster method. They found that illiterate or semi-literate individuals, those with low income, and those who neglect to seek medical advice require greater attention and care concerning dietary habits. Therefore, these groups should be prioritized when formulating healthy eating actions and programs aiming prevention and control of NCDs.

In a cross sectional study of a Northeast Brazilian rural vulnerable community of African-descendants (*quilombola*) and *non-quilombola* adolescentes, Cairo et al. finds no difference in overweight between the two groups. Overweight is directly associated with screen time and inversely associated with breakfast consumption and school attendance, highlighting the importance of adopting a healthy lifestyle early in life and the role of school for health promotion in rural regions.

In fact, the lifestyle medicine (LM) approach includes dietary recommendations coupled with other lifestyle practices (also known as LM pillars) for the prevention and treatment of NCDs. Two papers of our Research Topic address this issue. Figueroa et al. highlight the plant-based Mediterranean diet as a LM-contextualized dietary pattern that is adaptable, feasible, and sustainable within the Chilean context with potential health impact for handling the prevalence of risk factors and NCDs in this country. Urbano et al. assessed the reception of diet and other health-related lifestyle advice (HRA) to address NCDs in a primary care context in Central Argentina. Although tailored, written, and detailed recommendations were highly appreciated by patients, it was found that such advice is still underutilized and mostly offered in the context of illness. The study emphasizes the value of using this simple tool to help address patient's needs to prevent and control NCDs in Argentina.

Low cost fermented probiotic kefir is presented in the Peluzio et al. narrative review as a potential strategy for the prevention of microbiota-related metabolic NCDs in Latin America and other parts of the world. For that purpose, it would be necessary to focus on the standardization of production protocols with careful selection of microorganisms to be present in the starter culture and the final drink.

One of the reasons for a lack of studies relating dietary-associated risk factors for NCDs in Latin American countries is the need for adequate instruments and tools to assess food consumption. For this reason, Contreras-Guillén et al. developed an open-access automated tool ($MAR_{24}$) for collecting 24-h dietary recalls using the United States Department of Agriculture (USDA) Automated Multiple-Pass Method (AMPM).

Latin American countries are also in need of adequate references for anthropometric variables to evaluate health, dietary status, disease risks (including NCD risk), and changes in body composition. Therefore, we included a study from Gómez-Campos et al. conducted in 15,436 children, youths and adults in the Maule region of Chile. The authors compare anthropometric indicators with American references and propose percentiles for evaluating nutritional status of the Chilean population between 5 and 80 years old.

The manuscript submission period for this Research Topic took place during the first wave of the COVID-19 pandemic which severely affected eating and lifestyle habits and threatened patients with NCDs in Latin America and worldwide. For this reason, the cross-sectional investigation of Enriquez-Martinez et al. is included, showing diet and lifestyle changes during the first wave of the pandemic in five Ibero-American countries. We hope that their findings can be used to guide policies to prevent consequences that may affect the incidence of chronic diseases.

All the studies included in this Research Topic either directly or indirectly explore the link between diet and NCDs in Latin America. Finally, we thank *Frontiers in Nutrition* for the opportunity to contribute to this important topic. We acknowledge our valued authors who, together with the manuscript reviewers, joined efforts to bring relevant information on the relationship between diet and chronic diseases in Latin America.

## AUTHOR CONTRIBUTIONS

MCTM drafted the manuscript. JS reviewed and edited the manuscript. Both authors contributed to the article and approved the submitted version.

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# Editorial: The Impact of Dietary Changes on Non-communicable Diseases in Latin America

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**Keywords: nutrition, obesity, diabetes, trial, diet, overweight**

**Editorial on the Research Topic**

**The Impact of Dietary Changes on Non-communicable Diseases in Latin America**

In a 2019 analysis of 479,809 adults from 13 nations in Latin America, Miranda and colleagues (1) reported sharp increases in obesity prevalence during 1998–2017, and that over time, the obesity burden is moving into the lower socioeconomic stratum. Prevention of an obesity burden shift to the lower socioeconomic stratum is identified in the report as a high-impact regional preventive goal.

Popkin and Reardon (2) have primarily attributed the increasing obesity burden in Latin America to a nutrition transition from traditional cultural whole plant foods (i.e., legumes) with minimal processing or refinement of carbohydrates to a diet that is high in (1) animal products, (2) processed/ultra-processed foods composed of refined carbohydrates, high sodium, and saturated fats, and (3) sugar-sweetened beverages.

When conceptualizing a culture-specific plant-based dietary intervention to reverse the nutrition transition in Latin America, we note that the region has a rich cultural tradition of growing, eating, and preparing regional whole plant foods with minimal processing (3–5). For example, the "Three Sisters" diet tradition emerged in Mexico as a companion planting method to optimize the yield of corn, beans, and squash (6). These practices shaped a rural Meso-American diet pattern consisting of simply prepared meals of beans, corn, and squash with minimal processing, and low in refined grains and sugars (4, 5). The Tarahumara Indians of Mexico follow a "Three Sisters" diet pattern, and in a landmark 1991 crossover trial published in New England Journal of Medicine (7), this pattern produced a lower risk of cardio-metabolic disease that was significantly and rapidly reversed by then acculturating the Tarahumara to a typical US "affluent diet."

In Bolivia, a similar tradition of plant food patterns (maize, beans, and quinoa) from rural indigenous traditions is evident, but in urban and peri-urban areas, indigenous diet is transitioning to more processed foods and animal products (8). WHO STEPS data from Cochabamba, Bolivia ($n = 10{,}704$) (9) indicate: (1) a high prevalence of abdominal adiposity (54.1%), overweight (35.8%), and obesity (20%), and (2) that the obesity burden may be attributable to a change in lifestyle pattern to physical inactivity and a nutrition transition whereby 76.7% of the population reported low consumption of fruits and vegetables. This growing obesity burden has contributed to obesity-related cancers (Gallbladder, Breast, Colorectum, Liver, Stomach), accounting for more than 35% of all incident cancers in Bolivia (10).

WHO STEPS data from Bolivia (11) also indicate a lower rate of obesity in persons of indigenous ancestry—a trend potentially indicating indigenous lifestyle patterns of higher physical activity and intake of minimally processed plant foods. It is notable that among indigenous communities in

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remote rural regions of Bolivia are forager-horticulturist groups such as the Tsimane tribe who have long been enrolled in NIH funded studies that have documented how their minimally processed plant-based/plant-forward diets and high levels of physical activity are associated with the lowest coronary artery disease risk scores ever recorded in a human population (12). The Tsimane tribe also exhibits very low rates of other NCD risk factors (obesity, type 2 diabetes, hypertension, hypercholesteremia) (13). The plant-based/plant-forward diet pattern of the Tsimane consists of a high fiber diet of starchy crops (75% of energy from plantain, rice, cassava (manioc), maize) that is supplemented by lean game, freshwater fish, and fruits (14). Interestingly, a panel study of the Tsimane conducted over 10 years did reveal that marginal exposure to market-purchased food products (oil, lard, domesticated meats) was associated with gradual increases in BMI (15). Overall, the cultural traditions of plant-based/plant-forward diets in rural Bolivia provide a rich data source for designing culturally tailored, plant-based/plant-forward diets to reverse the nutrition transition occurring in the nation and region. To date, progress in the academic sector to develop and design such diets has been slow.

In this landmark supplement of Frontiers of Nutrition, the authors from several Latin American nations provide findings that seed a plant-based research agenda for Latin America. Cairo et al. provide findings clearly showing how obesity and overweight have reached the rural areas of Brazil. The emergence of processed and ultra-processed foods in diet patterns across the lifespan in Latin America is shown in pre-schoolers in Chile by Araya et al. and reviewed for the entire region by Matos et al.. Despite these strong trends, there remains a paucity of research infrastructure in Latin America for culturally tailored dietary intervention trials to reverse the nutrition transition away from cultural diets based on minimally processed whole plant foods and fewer animal products. The supplement continues the build of this emergent research infrastructure for dietary intervention. Sanchez Urbano et al. provide evidence of the feasibility and acceptability of dietary intervention advice in the Latin American context. Loureiro et al. provide insights from diet patterns in Brazilian adults, and Contreras-Guillén et al. is innovating dietary recall methods for Argentina. Figueroa et al. tackle the question of whether a plant-based Mediterranean diet can be adapted for the Latin American region. Taken together, the supplement articles herein are a stride forward in the path to reverse the nutrition transition that is creating a sizable non-communicable disease burden in Latin America.

## AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and has approved it for publication.

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# Reception of Dietary and Other Health-Related Lifestyle Advice to Address Non-communicable Diseases in a Primary Care Context: A Mixed-Method Study in Central Argentina

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An effective way to address risk factors for non-communicable chronic diseases (NCD) and reduce healthcare costs is by using sound health-related advice (HRA) to promote healthy lifestyle habits. In Argentina, however, few studies have examined the context in which HRA is communicated and undertaken by patients at the primary care level. In this study, we assessed the reception of HRA using a mixed-method approach in a central area of Argentina. A total of 1,044 participants from the community were contacted and sociodemographic characteristics, health-related lifestyle factors, and medical history were collected. A calendar with health messages was provided to participants and its usage was assessed after 1 year. Additionally, semi-structured interviews were conducted with 34 patients attending a local primary healthcare center. The results show that HRA was given more frequently to individuals with higher mean age, lower educational level, and to females. Participants with a chronic health condition are at a higher chance of receiving advice to reduce salt intake and maintain a healthy weight. Dietary advice is offered along with other lifestyle recommendations. The use of alcohol and tobacco is usually addressed together. HRA was primarily received in the context of an NCD diagnosis and advice was directed, especially, to risky behaviors. The HRA to increase the intake of fruits and vegetables was mentioned less frequently. Patients at the healthcare center greatly appreciated receiving an HRA, especially when given in a tailored, written, and detailed form, and acknowledged its importance to prevent or control a chronic health condition as part of the medical treatment but showed concern regarding the ability to fully incorporate the advice. Lifestyle recommendations are highly appreciated by patients but are still underutilized since they are offered mostly in the context of illness. The health calendar was shown to be useful to complement health intervention programs at the community level. The findings of our study underscore the acknowledged value of HRA by participants to tackle the risk factors of chronic diseases. If properly used HRA constitutes a simple and highly valued tool to help address patient's needs to prevent and control NCD in Argentina.

**Keywords: health-related advice, non-communicable diseases, diet, lifestyle habits, mixed- method study, primary health care, Argentina**

## INTRODUCTION

Non-communicable chronic diseases (NCD) represent an important cause of mortality around the world. According to the Ministry of Health in Argentina, NCD are responsible for ∼78% of the death in the country. The most frequently diagnosed NCD in Argentina are hypertension, type 2 diabetes, and hypercholesterolemia, which are all associated with modifiable risk factors, such as an unhealthy diet, alcohol and tobacco consumption, inadequate sleep, and insufficient physical activity (1, 2).

Several studies found that an effective way to fight the risk factors associated with the development of NCD and decrease costs in healthcare is using sound health-related advice (HRA) for assisting patients with the adoption of healthy lifestyle habits (3–6). Primary healthcare centers (PHC) are in direct contact with the community and represent a strategic environment to foment healthy behaviors. The type and the way information is provided by health professionals are key aspects for supporting the patient's decision to incorporate new lifestyle habits to prevent or control NCD (7, 8).

To be effective, HRA must be clear, concise, friendly, and adapted to the individual needs considering patients' health conditions, risk factors associated with lifestyle, and sociodemographic characteristics such as the educational level, socioeconomic factors, employment status, family context, among other (9–11). Altogether, these factors may influence the patient's perception and comprehension of HRA and determine the receptivity and the understanding of the information (12, 13). The development of written and verbal communication skills by health professionals is warranted for optimal HRA conveyance (14, 15). Also, a single piece of advice may be not enough to cover all the aspects of a patient which might include multiple risk factors. For instance, Keith et al. (16) found that patients are more likely to receive advice for smoke cessation when already presenting other modifiable risk factors.

Escalating evidence underscores the recommendations associated with healthy lifestyle practices as an important part of public health strategies for the prevention, and treatment of NCD worldwide. Nevertheless, few studies in South America have examined the frequency and the form in which health-related lifestyle advice is communicated and undertaken at the primary care level. Understanding the interactions of the different individual aspects that determine the type of advice that is offered, how the advice is received, and its perceived usefulness may be investigated with a mixed-method approach. This type of study enables people's experiences to be contrasted with the numerical data, obtaining more detailed information, if working exclusively from a quantitative point of view (17–19). Thus, the objective of this research is to assess the reception of HRA in a population from a central area of Argentina and the perception of the participants about the advice received at the primary care level using a mixed methodology.

**Abbreviations:** NCD, Non-communicable Chronic Diseases; HRA, Health-Related Advice; PHC, Primary Healthcare Center; SBP, Systolic Blood Pressure; DBP, Diastolic Blood Pressure.

## MATERIALS AND METHODS

This is a mixed-method study, using a cross-sectional analysis of the qualitative and quantitative data collected from a health-promotion research program developed in a central area of Argentina (20). This research was conducted in the city of Diamante, between the years 2014 and 2017, province of Entre Ríos located in a semi-urban zone. The total population of Diamante in the year 2010 was 19,930 inhabitants. At the beginning of the project, each participant received an oral invitation followed by a written description of the main steps of the study. Participants signed the written informed consent. All procedures associated with this project were conducted following the international ethical standards proposed by the Helsinki protocol for human research and this study was reviewed and approved by the Research and Ethics Committee of the Adventist University of River Plate School of Medicine (N° 03-01-02/2012/2-2012). This committee is affiliated to the National Register of Health Research of the Ministry of Health (registered under the #0237), Argentina.

### Quantitative Data Collection

A total of 1,044 adults, including 365 men and 679 women, were enrolled in the first part of this study. Participants were contacted in person during community, door-to-door visits, or primary health care clinic visits during the years 2014 and 2015. Participants answered the core questions of the WHO STEPwise questionnaire on NCDs risk factors for the reception of a HRA by a medical or other health worker in the last 3 years advising on tobacco cessation, reducing the intake of salt, eating five daily portions of fruits and vegetables, reducing the intake of unhealthy fats, increasing physical activity, and maintaining healthy body weight (21). The question on lifestyle advice to cut down on alcohol consumption was extracted from the full version of the AUDIT questionnaire (22). Participants also provided information on sociodemographic characteristics (age, sex, level of education, and employment statues), lifestyle factors including smoking history, alcohol risk intake (risk alcohol consumption according to the AUDIT-C instrument, a score of $\geq$4 points for men and $\geq$3 points for women) (23), habitual daily intake of 5 or more portions of fruits and vegetables, physical activity (30 min or more of moderate aerobic activity at least three or more times per week on a regular basis), and medical history including the presence of chronic diseases diagnosed by a physician (12, 20, 21).

Anthropometric data (body weight, height, and waist circumference) were measured. Body mass index was calculated from weight (kg)/height ($m^2$). Central obesity was defined as ≥102 cm in men and ≥88 cm in women. Blood pressure measurements were obtained twice and averages were calculated. High blood pressure was defined as mean systolic blood pressure (SBP) ≥140 mmHg and/or mean diastolic blood pressure (DBP) ≥90 mmHg. A peripheral venous blood sample was withdrawn (∼5 mL) after overnight fasting of ∼12 h for lipid and other biochemical analyses.

### Health Calendar

Each participant of the quantitative analysis received a color-printed calendar (A3 page size) containing 365 brief health messages or tips, one per day, grouped into 12 aspects of the lifestyle, presented one per month (1. physical activity; 2. sunlight exposure; 3. adequate use of water; 4. healthy diet; 5. prevention of risk factors for mental health associated with depression and anxiety; 6. adequate rest and sleep quality; 7. environmental air and breath quality; 8. prevention of dyslipidemia; 9. prevention of hypertension; 10. prevention of type 2 diabetes mellitus; 11. prevention of risky alcohol intake and smoking cessation; and 12. hopefulness and positive emotions). The calendar contained basic health messages and notes of encouragement to improve health-related lifestyle behaviors (please, see **Supplementary Material**). Most of the messages were based on current medical literature for community-based health promotion and the recommendations of the WHO to control or reduce NCD risk factors. After 12 months of having received the calendar, the participants were visited throughout the year 2016 to assess the self-administration of the health calendar. Each participant was asked through a short questionnaire about the usage and appreciation of the messages of the calendar and if the health information was shared spontaneously with family, friends, or co-workers.

## Qualitative Analysis

To further explore the results obtained with the quantitative approach, semi-structured individual interviews were conducted in 34 persons (women and men) from the community in a local PHC center during some months of the year 2016 and 2017. Two individuals did not provide sufficient information to include in the analysis. Interviews were conducted by one of the researchers using open-ended questions focused on the circumstances and characteristics associated with the reception, understanding, and appreciation of the HRA by patients. All interviews were recorded in audio, with the prior signed consent of each participant. For the assessment of the qualitative information, a literal transcript of each interview was made. Then a manual coding based on an inductive thematic approach was executed, to organize the data into categories and detect emerging patterns. This process was carried out in parallel by three researchers. The researchers independently conducted a line-by-line analysis of each of the transcripts, then each of the phrases/quotes was compared to establish agreements and differences, which were discussed. Finally, the most representative phrases were chosen according to the three categories considered and illustrates the observed themes and sub-themes. Quotes of participants have been translated into English and translated back to Spanish to check for accuracy.

## Statistical Analysis

Frequencies, measures of central tendency, and dispersion for quantitative variables were calculated. Chi-square and t-student tests were used for independent samples to examine the relationship between sociodemographic characteristics and the advice received. To study the probabilities of receiving certain advice according to the current health condition, a multinomial logistic regression was performed. The regression model was generated with the escalated addition of independent variables to solve the issue of collinearity between them. Individual regression analysis was performed to determine the odds ratios (OR) and its statistical significance before the variables were added to the model. The variables age, gender, and academic level were included in all models given their possible influence in all of them. Once independent variables with possible influence over-dependent variables were determined, a general model was constructed. Later, some independent variables were eliminated according to adjusted OR and level of significance, until an optimal regression equation was achieved. This process was performed assuming each HRA as the dependent variable on each model and the following independent variables: sociodemographic characteristics (age, gender, and level of education), low alcoholic risk score on AUDIT-C, smoking history, previously diagnosed health conditions (hypertension, diabetes, hypercholesterolemia, and other chronic health conditions), anthropometric parameters (BMI and blood pressure), lifestyle parameters (non-ideal fruits and vegetable consumption, practicing of physical activity less than three times per week) and biochemical parameters (total cholesterol <200 mg/dL and LDL cholesterol <130 mg/dL). Lastly, each one of the HRA was set as an independent variable as well to determine the association between having received one HRA and the reception of the others. *SPSS* Inc., (Chicago, IL, USA) version 24.0 software was used, and $p < 0.05$ were considered statistically significant.

# RESULTS

## Sociodemographic Characteristics and Health Advice

The 1,044 participants considered in the quantitative approach had a mean age of 43 ± 15 years old, were predominantly women, with an education level of primary school, were actively working, and married as described in a previous study with this population (20). In the bivariate analysis seen in **Table 1**, the advice to reduce the intake of salt, consume at least five daily portions of fruits and vegetables, reduce the intake of unhealthy fat, perform physical activity and maintain a healthy weight were offered to participants with a higher mean age than those participants that

**TABLE 1 |** Health-related advice according sociodemographic characteristics.

| Health-related advice | | Sex | | Level of education | | | Employment status | |
|---|---|---|---|---|---|---|---|---|
| | Age μ (DS) | Male % (n) | Female % (n) | Primary % (n) | High school % (n) | Tertiary/university % (n) | Active % (n) | Inactive* % (n) |
| Quit smoking | NS | NS | | | NS | | NS | |
| Yes | 42.7 (±14.5) | 25.3 (90) | 25.6 (170) | 29 (121) | 24.3 (97) | 20.7 (42) | 26.2 (178) | 24 (82) |
| No | 43.1 (±15.5) | 74.7 (266) | 74.4 (495) | 71 (296) | 75.7 (302) | 79.3 (161) | 73.8 (501) | 76 (260) |
| Decrease salt intake | **0.001** | NS | | | **<0.001** | | **0.006** | |
| Yes | 47.7 (±15) | 46.3 (165) | 52.5 (351) | 61.6 (257) | 45 (181) | 38.2 (78) | 47.3 (322) | 56.4 (194) |
| No | 38.2 (±14.1) | 53.7 (191) | 47.5 (318) | 38.4 (160) | 55 (221) | 61.8 (126) | 52.7 (126) | 43.6 (150) |
| Consume 5 daily portions of fruits and vegetables | **0.001** | **<0.001** | | | NS | | NS | |
| Yes | 44.3 (±15.6) | 54.6 (196) | 66.4 (445) | 64.4 (270) | 59.7 (240) | 63.4 (130) | 61.8 (424) | 63.3 (217) |
| No | 40.8 (±14.5) | 45.4 (163) | 33.6 (225) | 35.6 (149) | 40.3 (162) | 36.6 (75) | 38.2 (262) | 36.7 (126) |
| Decrease the intake of unhealthy fat | **0.001** | **0.006** | | | **0.001** | | NS | |
| Yes | 45.9 (±15.1) | 57.7 (206) | 66.3 (445) | 70.2 (249) | 58.6 (235) | 58.5 (120) | 61.5 (421) | 66.9 (230) |
| No | 37.9 (±14.2) | 42.3 (151) | 33.7 (226) | 29.8 (125) | 41.4 (166) | 41.5 (85) | 38.5 (263) | 33.1 (114) |
| Increase physical activity | **0.009** | **0.008** | | | NS | | **0.023** | |
| Yes | 43.7 (±14.8) | 61.8 (222) | 70 (470) | 66.6 (279) | 64.8 (261) | 73.2 (150) | 69.5 (477) | 62.5 (215) |
| No | 41.5 (±16.1) | 38.2 (137) | 30 (201) | 33.4 (140) | 35.2 (142) | 26.8 (55) | 30.5 (209) | 37.5 (129) |
| Maintain a healthy weight | **0.001** | **0.035** | | | NS | | NS | |
| Yes | 44.5 (±15) | 56.5 (203) | 63.3 (424) | 64.9 (272) | 56.8 (229) | 61 (125) | 60.3 (413) | 62.2 (214) |
| No | 40.6 (±15.3) | 43.5 (156) | 36.7 (246) | 35.1 (147) | 43.2 (174) | 39 (80) | 39.7 (272) | 37.8 (130) |
| Cease or decrease the intake of alcohol | **0.007** | **<0.001** | | | **0.002** | | NS | |
| Yes | 36.4 (±14.6) | 15.5 (44) | 5.3 (20) | 15.5 (34) | 7.3 (20) | 6.1 (10) | 10.3 (51) | 7.9 (13) |
| No | 41.5 (±14.4) | 84.5 (239) | 94.7 (356) | 84.5 (186) | 92.7 (254) | 93.9 (153) | 89.7 (444) | 92.1 (151) |

**inactive: students, housewife, unemployed, or retired. The bold values highlights the statistically significant values of p.*

reported not having received these advice. On the other hand, the advice to abstain or decrease alcohol intake was offered to younger participants compared with those subjects that have not received this advice. The advice to consume fruits and vegetables, decrease the intake of unhealthy fats, increase physical activity, maintain a healthy weight, and abstain from or decrease alcohol intake was offered more often to women. Regarding the level of education, the advice to reduce the intake of salt, unhealthy fat, or alcohol were offered more frequently to subjects with primary educational levels. Unemployed individuals received the advice to reduce salt intake at a higher frequency, while employed subjects received more often the advice to increase physical activity (**Table 1**).

## Analysis of Health Advice, Sociodemographic, and Health Conditions

The multivariable logistic regression analysis (**Table 2**) showed that subjects of higher age were less likely to receive the advice to quit smoking (OR = 0.9, 95% CI = 0.8–0.9) or to stop alcohol drinking (OR = 0.9, 95% CI = 0.8–0.9), as opposed with the advice to reduce the intake of salt (OR = 1.04 95% CI = 1.02–1.06) and unhealthy fats (OR = 1.03, 95% CI = 1.01–1.04), which have a higher chance to be received as the age increases. Women were 3 times more likely to receive the advice to stop drinking alcohol (OR = 3.5, 95% CI = 1.9–6.6), while subjects with a primary educational level were 2 times more likely to receive the advice to decrease the intake of unhealthy fats (OR = 2.4, 95% CI = 1.2–4.7), and to decrease or cease the intake of alcohol (OR = 2.4, 95% CI = 1.0–5.3).

Reducing salt intake is the advice with a greater association with a previous medical diagnosis, having 2 times more chance to be offered to subjects with a diagnosis of hypertension (OR = 2.2, 95% CI = 1.2–4.1) or elevated cholesterol (OR = 2.1, 95% CI = 1.2–3.7). Having a previous diagnosis of diabetes increases the odds of receiving the advice to maintain a healthy weight by 3 times fold (OR = 2.8, 95% CI = 1.2–6.4). Regarding the BMI, subjects with normal weight or overweight presented less chance to receive advice to reduce the intake of unhealthy fat (OR = 0.4, 95% CI = 0.2–0.7; OR = 0.5, 95% CI = 0.3–0.7, respectively) and to maintain a healthy weight (OR = 0.05, 95% CI = 0.01–0.2; OR

**TABLE 2 |** Multivariable logistic regression results of receipt of health-related advice.

| **Variables** | **Decrease salt intake**[a] | **Consume 5 daily portions of fruits and vegetables**[a] | **Decrease the intake of unhealthy fat**[a] | **Increase physical activity**[a] | **Maintain a healthy weight**[a] | **Quit smoking**[a] | **Cease or decrease alcohol Intake**[a] |
|---|---|---|---|---|---|---|---|
| | **OR (95% CI)** | **OR (95% CI)** | **OR (95% CI)** | **OR (95% CI)** | **OR (95% CI)** | **OR (95% CI)** | **OR (95% CI)** |
| Age | **1.04 (1.02–1.06)** | 0.9 (0.9–1.0) | **1.03 (1.01–1.04)** | 0.9 (0.9–1.0) | 0.9 (0.97–1.0) | **0.9 (0.8–0.9)** | **0.9 (0.8–0.9)** |
| Female | 1.3 (0.7–2.3) | 0.7 (0.5–1.0) | 0.9 (0.7–1.5) | 0.8 (0.5–1.3) | 0.8 (0.39–1.5) | 0.8 (0.3–1.9) | **3.5 (1.9–6.6)** |
| Primary academic level | 1.4 (0.7–3.1) | 0.8 (0.5–1.2) | **2.4 (1.2–4.7)** | **0.5 (0.3–0.9)** | 0.6 (0.24–1.5) | 1.1 (0.4–3.4) | **2.4 (1.0–5.3)** |
| High school academic level | 1.3 (0.7–2.6) | 0.9 (0.6–1.4) | 1.5 (0.8–2.7) | 0.7 (0.4–1.2) | 0.4 (0.2–1.0) | 1.1 (0.4–2.9) | 0.9 (0.4–2.0) |
| Smoking history | – | – | – | – | – | **9.0 (3.9–20.9)** | – |
| Low alcohol risk | – | – | – | **1.7 (1.0–2.7)** | – | – | **0.4 (0.2–0.8)** |
| Non–ideal fruit consumption | – | **0.5 (0.3–0.8)** | – | – | – | – | – |
| Physical activity < than 3 times/week | – | – | – | **1.7 (1.0–2.7)** | – | – | **3.8 (1.6–8.8)** |
| Previous diagnosis of HBP | **2.2 (1.2–4.1)** | – | – | – | – | – | – |
| Previous diagnosis of DBT | 1.9 (0.9–3.9) | – | – | – | **2.8 (1.2–6.4)** | – | – |
| Prevous diagnosis of HCL | **2.1 (1.2–3.7)** | – | – | – | – | – | – |
| Other chronic health conditions | – | – | – | – | **2.7 (1.0–7.2)** | – | – |
| BMI < 25 kg/m$^2$ | – | – | **0.4 (0.2–0.7)** | – | **0.05 (0.01–0.2)** | – | – |
| BMI >25 y <30 kg/m$^2$ | – | – | **0.5 (0.3–0.7)** | – | **0.3 (0.1–1.1)** | – | – |
| Normal blood pressure value | **0.3(0.1–0.5)** | – | – | | – | – | – |
| Total choresterol <200 mg/dl | – | – | – | – | **4.2 (1.5–11.3)** | – | – |
| LDL <130 mg/dl | – | – | **0.4 (0.2–0.7)** | – | **0.6 (0.1–0.7)** | **0.3 (0.1–0.7)** | – |
| Decrease alcohol intake advice | – | – | – | – | – | **5.7 (1.5–21.2)** | – |
| Quit smoking advice | **2.6 (1.3–5.0)** | **1.7 (1.1–2.4)** | – | **2.7 (1.5–4.8)** | – | – | **4.8 (2.7–8.7)** |
| Decrease salt intake advice | – | **1.9 (1.3–2.7)** | – | – | **2.2 (1.1–4.4)** | **3.8 (1.5–9.8)** | – |
| Consume 5 daily portions of fruits and vegetables advice | – | – | **3.8 (2.4–6.1)** | **3.0 (1.9–4.8)** | 1.9 (0.9–3.7) | **3.3 (0.1–0.7)** | – |
| Decrease the intake of unhealthy fat advice | – | **3.9 (2.7–5.7)** | – | **4.8 (2.9–8.1)** | **2.5 (1.1–5.4)** | – | – |
| Increase physical activity advice | **3.4 (1.6–7.2)** | **2.9 (2.0–4.1)** | **8.2 (4.7–14.2)** | – | **10.3 (4.6–22.9)** | | – |
| Maintain a healthy weight advice | **2.1 (1.1–4.0)** | | **3.2 (1.9–5.4)** | **6.1 (3.8–9.8)** | – | | – |

*Bold font: the variable is significant with $p < 0.05$.*

*OR, Odds ratio; CI, confidence Interval; HBP, High Blood Pressure; DBT, Diabetes; HCL, High Cholesterol Level; BMI, Body Mass Index.*

*[a]Each stratified model includes demographic characteristics (Age, Sex, Academic level), health behaviors (smoking history, fruits, and vegetables consumption, alcohol risk) health conditions (previous diagnosis of HBP, DBT, HCL), Biochemical and anthropometric parameter (BMI, blood pressure value, total cholesterol values, LDL values) and HRA interactions.*

= 0.3, 95% CI = 0.1–1.1, respectively). Presenting normal LDL cholesterol levels decrease the chance of receiving the advice to quit smoking (OR = 0.3, 95% CI = 0.1–0.7), decrease the intake of unhealthy fats (OR = 0.4, 95% CI = 0.2–0.7), and maintain a healthy weight (OR = 0.6, 95% CI = 0.1–0.7).

Advice related to dietary habits is more likely to be administered along with advice to increase physical activity and maintain a healthy weight. Regarding the use of tobacco, the advice to quit smoking was associated with advice related to diet and physical activity. On the other hand, the advice to decrease alcohol intake is usually provided along with the advice to quit smoking and vice-versa (**Table 2**).

## Usage of the Health Calendar

Of the 1,044 participants, 86% (*n* = 824) answered the calendar usage assessment questionnaire after 1 year or more of being first contacted. The remaining 14% (*n* = 220) could not be personally located during two or three consecutive visits, or due to an uninformed change of address or discontinuation of participation in the study. Almost 45% of participants informed having read the calendar weekly. According to the use of the calendar, 15% (*n* = 124) of all participants read it daily, 15.8% (*n* = 130) read it 2 or 3 times a week and 13.7% (*n* = 113) read it once a week. Half of the participants that read the calendar weekly used to share the health tips they considered useful with family members and friends. Of the subjects that read the calendar daily, 50% shared the health advice with family members, 17% with friends, and 9.7% with coworkers. Out of subjects that read the calendar between 2 and 3 times a week, 55.4% shared the advice with family members, 16.2% with friends, and 10% with coworkers. And out of the ones that read the calendar once a week, 38.9% shared the advice with family members, 18.6% with friends, and 10.6% with coworkers. The other half of the participants of our study read the health calendar only occasionally, every other week or monthly. Out of the 12 topics presented in the calendar, 3 of them were reported by the participants as the most relevant and were associated with healthy eating (48.7%), followed by physical activity (29.7%), and the adequate use of water (27.8%).

## Qualitative Assessment of the In-Depth Interviews

In total, thirty-two participants answered and completed the entire interview. The sociodemographic information of the interviewed participants is presented in **Table 3**. The analysis of the information collected during the interviews was classified according to the categories presented in **Table 4** and includes: (a) Context or circumstance, which refers to the health situation presented by the participant at the time of the reception of a HRA; (b) Welcoming, which aims to know if the patient appreciated the reception of HRA given by the health professional and if such was clear and detailed enough as to be put into practice; (c) Practice, to determine whether patients had applied lifestyle changes and decision-influencing factors. **Tables 5–7** shows representative quotes of the participants according to the described categories and themes.

**TABLE 3** | Sociodemographic characteristics of the interviewed participants.

| Characteristics | μ (DS) |
|---|---|
| Age | 41.9 (16.7) |
| Sex | **n (%)** |
| Female | 21 (61.8) |
| Male | 13 (38.2) |
| Level of education | |
| Primary | 20 (58.8) |
| High school | 13 (38.2) |
| Tertiary/University | 1 (2.9) |
| Employment status | |
| Active | 12 (35.3) |
| Inactive* | 22 (64.7) |

**Inactive: students, housewife, unemployed, or retired.*

**TABLE 4** | Principal categories and themes identified in the qualitative analysis.

| Principal categories | Themes |
|---|---|
| Context during the introduction to the HRA | • Health issues<br>• Thematic addressed<br>• Providers and delivery method |
| Welcoming HRA | • Patient appreciation for HRA and Professional-Patient relationship<br>• Detailed Advising |
| Turning HRA into practice | • Difficulties on practicing HRA<br>• Sharing the health advice |

*HRA, health-related advice.*

### Context During the Introduction to the HRA

We analyzed the circumstances surrounding the reception of the HRA, and key parameters were identified. The chief reason for the initial visit to the PHC centers to be seen by a physician was a perceived illness or symptom associated with NCD, while a general check-up was rarely mentioned. Most participants reported having received their first-ever HRA from a physician or a nutritionist. The visit to the nutritionists was always a referral from physicians. Most participants reported receiving verbal advice rather than written detailed instructions. The first symptoms of a NCD were often reported as the driving factor to seek medical attention. Commonly mentioned NCD were hypertension, elevated cholesterol levels, and type 2 diabetes mellitus. Other participants, usually younger ones, reported other types of health issues, such as obesity, pregnancy, and infectious diseases. The advice that participants mostly mentioned were on: (1) diet, with the reducing salt intake and decreasing the intake of unhealthy fats as the most prevalent among them, followed by the advice to increase the intake of fruits and vegetables mentioned by some individuals; (2) physical activity, which was rarely detailed, but with walking being the most recommended of them; (3) alcohol intake and (4) tobacco consumption. The advice on the last two categories was mostly about the cessation

**TABLE 5 |** Context during the introduction to the health-related advice.

| Themes | Quotations |
|---|---|
| Health issues | *"When I was diagnosed with high blood pressure, that's when they gave me all the advice. I also had elevated cholesterol, so they proposed these changes, saying that I had to start walking and all that" (62yo male).* |
| | *"When I was diagnosed with different types of diseases, such as my diabetes. I also have chronic obstructive pulmonary disease, because of my smoking issues" (63yo male).* |
| | *"[They gave me some advice] during my pregnancy. Before that, I had never received any health advice" (22yo female).* |
| | *"I received advice when I came because of my acne, I was starting to have a lot of it" (22yo male).* |
| Thematic addressed | *"Depending on the type of food, I use lemon a lot. If it's a salad or a piece of meat I give it a squeeze of lemon and it is enough to flavor it. Salt is not indispensable, it can be replaced" (50yo female).* |
| | *"I started to incorporate certain things I did not consume before, for instance, fruits and vegetables" (63yo female).* |
| Providers and delivery method | *"Well, the physicians told me orally, but the nutritionist gave me a folder with written detailed explanation and all that" (38yo male).* |
| | *"Yes, I received written advice from the nutritionist, I've seen six or seven of them, they have a lot in common. I learned, for instance, the way to prepare the food. The last nutritionist I saw thought me how to cook healthier, how to, for instance, replace frying for oven baking. She also provided me with written instruction on what to prepare for each meal of the day" (36yo female).* |

**TABLE 6 |** Welcoming health-related advice.

| Themes | Quotations |
|---|---|
| Patients appreciation for HRA and professional-patient relationship | *"They always give me advice when I come, always. They receive me and advise me truly well. I chose this place because it provides me with the best for me" (51yo male).*<br>*"What I enjoy, in the first place, is when there is good personal treatment with one that is already old and feels lonely sometimes. I feel good here, everyone treats me very well, they are excellent professionals" (75yo female).*<br>*"I think lifestyle changes are more important than the pills because my doctor told me that if I reached a certain weight my blood pressure could stabilize. She never told me to stop taking my diabetes medication, but the staff from the biochemistry lab told me they know of people that have been taken out of them" (38yo male).*<br>*"The medication is important, but I don't reach the [glycemic] levels I need with it alone. If I don't do my part, I don't reach my required levels" (51yo male).* |
| Detailed advising | *"Yes (when asked about details), she mentioned (her doctor) the risks one is exposed to when smoking. She also told me that physical activity might help normalize my blood pressure. My cardiologist told me all that. She said the blood flows better" (37yo female).*<br>*"I believe physicians need a little bit more of training on this area (when referring to lifestyle advice)" (56yo male).*<br>*"Walk, walk. That's all the advice they gave me" (57yo male).*<br>*"I would say they advised me like anyone would, like saying take care of your health or you have to quit smoking" (44yo female).* |

**TABLE 7 |** Turning health-related advice into practice.

| Themes | Quotations |
|---|---|
| Difficulties on practicing HRA | *"The doctors give you the information, all the explanation, but then it depends on oneself to make the change, the click" (45yo male).* |
| | *"It was hard for me because one is poor and has no money to prepare different kinds of meals for everyone in the house" (75yo female).* |
| | *"[I would say the reason why I'm so addicted to smoking is to] have grown up alone in the streets" (58yo female).* |
| Sharing the health advice | *"I always share my medical advice with my son" (75yo female).* |
| | *"Actually no, because you can't mind someone else's business. They might even tell you why do you care about what I do?" (65yo male).* |

of those habits. In general, the advice most of the participants mentioned practicing were: (1) Reducing the direct use of salt while or after cooking. And (2) to increase the consumption of fruits and vegetables.

## Welcoming HRA

Almost all of the participants reported having enjoyed and appreciated receiving an HRA from their providers. Some of them even associated the reception of an HRA during the visit with the perception of a better level of personal care and an improvement on the professional-patient relationship. Some participants mentioned that health-related lifestyle advice is as important as medication for the treatment of their NCD. The level of detailed explanation on the HRA varied. Most of the patients believe to have received more than enough information to help them with the treatment for the presented disease or to incorporate new habits into their lifestyle. On the other hand, some participants believed that not enough details were provided on what to eat while avoiding unhealthy fatty foods or on the type and amount of physical activity recommended. Participants believed physicians had no time or no interest in providing better details, and a few also believed professionals did not possess enough qualifications on the matter.

## Turning HRA Into Practice

Participants were asked open-ended questions on their opinions about what the greatest difficulties were faced in applying the HRA. According to the majority of them, the lack of personal effort was the greatest factor, followed by economic difficulties to, for instance, purchase the appropriate healthy food or to create a balanced daily menu. Other less commonly mentioned difficulties include the lack of time due to excess of work and the socioeconomic environment of prevalent constraint and toxic habits. Many participants reported sharing the received HRA with their families and friends. Some participants considered these subjects to be sensitive enough to prevent them to share.

## DISCUSSION

This study revealed that dietary and other health-related lifestyle advice is given more frequently to individuals with higher mean age, lower educational level, and to females. Patients with a chronic health condition are at a higher chance of receiving advice to reduce salt intake and maintain a healthy weight and, in general, dietary advice is offered along with other recommendations to maintain a healthy weight, increase physical activity, and quit smoking. The HRA to limit the consumption of alcohol is usually addressed along with the advice to abandon the use of tobacco. The qualitative analysis showed that HRA was primarily received in the context of a diagnosis of an NCD and that advice was directed, especially, to risk behaviors associated with reducing the intake of salt and unhealthy fats, and to avoid the consumption of alcohol and tobacco. Patients mentioned less frequently the reception of advice to increase the intake of fruits and vegetables. Patients greatly appreciated receiving an HRA, especially when they are given in a tailored, written and detailed form, and acknowledged the importance of HRA to prevent or control a chronic health condition as part of the medical treatment, but showed concern regarding the ability to incorporate them into their daily lives.

The differences in the prevalence of the HRA according to sociodemographic characteristics allow the identification of areas to reinforce to reduce such differences in the offering of lifestyle recommendations. In this study, between 60 and 70% of women received the advice to consume five daily portions of fruits and vegetables, decrease the intake of unhealthy fats, increase physical activity, maintain a healthy weight. These findings were similarly observed in other studies (24, 25). The reason for the gender-based difference in prevalence may be because women are more interested in healthcare-related information, even though men usually have more risk factors associated with NCD (26, 27), data corroborated in our previous study in this population (20). These results demand new strategies to incentive male subjects on having a greater interest in adopting healthy lifestyle habits.

In our study, while younger subjects were more frequently advised about the consumption of toxic substances, dietary and other HRA were directed to older participants and those with a chronic health condition, who had 2–3 times greater odds of receiving such advice. The younger healthy people are usually not aware of the consequences of unhealthy dietary choices, lack of physical activity, inadequate rest, and the use of toxic substances (20, 28, 29). Thus, for prevention purposes, there is a need to promote healthy habits associated with the diet and with other aspects of the lifestyle from the early stages of life, focusing on the health education of children and adolescents (30). Similar results were found by Zwald et al. (25), where only 30% of the younger subjects received advice to increase physical activity in contrast with 60% to 70% of older subjects, with even greater chances of receiving a health advice if the person presented a NCD.

Other studies have reported that subjects with a secondary education degree or higher are more likely to receive advice to increase physical activity and to reduce the intake of diets rich in unhealthy fats (31). However, in our investigation, we found that a lower educational level was associated with a 2 times greater chance of receiving the advice to decrease the intake of unhealthy fats and the advice to decrease or cease alcohol intake. It was shown that subjects with a low educational level presented a higher prevalence of NCD and its corresponding risk factors when compared with those at a higher academic level (32). It is relevant to note the majority of the subjects in our study presented a low educational level and, hence, they may be more vulnerable to risk behaviors associated with chronic diseases. We also observed that subjects currently employed were more likely to receive advice to increase physical activity than those unemployed, retired, or in an unpaid activity. The reception of such advice may be related to specific types of jobs where sedentary behaviors are common (33, 34).

Presenting a previous diagnosis of a NCD was a significant determinant for the reception of HRA. The qualitative data of this study indicated that most patients received their first professional-provided HRA at the time a chronic disease was also diagnosed. This corroborates the findings from the quantitative analysis and points to the necessity to create primary prevention interventions designed to include patients without a previous diagnosis of NCD especially those with several risk factors and behaviors (35). Recent evidence is linking unhealthy dietary and other-lifestyle habits with low chronic grade inflammation (36), which ultimately may lead to the development of NCD. Several strategies may be used in the PHC context to identify these risk behaviors, but a simple and effective approach may include the assessment of unhealthy habits for all patients by using validated widespread questionnaires such as the STEPwise of the WHO. This last is the WHO-recommended framework approach for NCD surveillance to get started in NCD prevention and control activities. It builds a common strategy for defining core variables for surveys, surveillance, and monitoring instruments. The objective is to achieve data comparability over time and between countries. It is a simplified approach providing standardized materials and methods as part of technical collaboration with countries, especially those that lack resources (21). The lifestyle advices to improve health behaviors found in the STEPwise approach concerns to the most basic, and widely reported protective factors for NCDs such as consuming 5 daily portions of fruits and vegetables (37, 38), practicing physical activity (39, 40), reducing the intake of salt (41, 42), decreasing the intake of unhealthy fats (43), maintaining a healthy body weight (44) and reducing alcohol consumption to a low/moderate amount (45), and tobacco smoking cessation (46).

To further explore the results of the quantitative analysis, a qualitative approach was used with a second independent group of persons from the same community at the PHC center. As reported by the participants of our study, the PHC physician was the health professional to offer the first advice regarding lifestyle recommendations to prevent or control risk factors for chronic health conditions. Verbal communication was the preferred way physicians used to inform a HRA. However, another health professional that assumed an important role in the communication of HRA in our study was the nutritionist and dietitians, though access to the services of such professionals may be limited in some places of Argentina (15, 47).

It is well-known and it would be expected that health professionals often provided their patients with the advice to consume, at least, 5 daily portions of fruits and vegetables (38). However, only a few interviewed patients at the PHC center mentioned the reception of this advice. Indeed, it is of note that none of the participants reported anything associated with the concept of consuming 5 portions of fruits and vegetables every day, which has been fomented by the Health Ministry of Argentina in recent years (48). In contrast, the advice to reduce the intake of salt and unhealthy fat is focused on the abandoning of a habit to avoid the development of a disease (49, 50). Consuming 5 daily portions of fruits and vegetables, on the other hand, may refer to the development of a healthy new habit. Our previous findings studying this population in Argentina indicated that only near 5% of this population had a regular intake of 5 daily portions of fruits and vegetables (20), which more recently was also observed at a larger scale through the National Health Survey of 2018 in Argentina (1, 51). These challenging data are sometimes difficult to address. A study in the UK reported that over 75% of primary care professionals acknowledged having had insufficient training to provide their patients with specific advice on nutrition and physical activity (47, 52).

According to our study, advice related to dietary habits had a higher chance to be offered along with the advice to increase physical activity and to maintain a healthy weight. Other research reported that physician advice at the primary care level is an important determinant for the practice of physical activity (52–54), which suggests the efficiency of HRA to generate lifestyle modifications and health improvements. It is of note that the current dietary guidelines of Argentina include the advice to incorporate physical activity, along with the recommended food plate, on a daily basis and also the advice to decrease the intake of salt, which average of consumption is around 11.2 grams per day in this country (55, 56).

The advice to decrease the intake of unhealthy fats and the advice to maintain a healthy weight were less likely to be offered to subjects with a BMI $< 30$ kg/m$^2$. A study from the USA reported that only between 20 and 40% of overweight subjects, free of other chronic health conditions, received any kind of HRA (29). This represents a missed opportunity to provide health advice to patients with normal weight (5), and, which is even worse, to overweight patients, showing an unnoticed risk factor that should prompt attention. Recent information shows that there is a high prevalence of overweight and obese individuals in Argentina (57). According to our previous findings, almost 69% of this population was above the normal weight, with a 35.2% prevalence of obesity (20).

Regarding the use of a calendar with health messages as a strategy to increase health literacy in the community, almost half of all participants of our study reported to be interested in reading the health tips weekly. The information was usually shared with family and, less frequently, with friends or coworkers. Interestingly, around 50% of those who regularly read the calendar were prone to share their information. A study found that attractive health messages used to be shared with friends or relatives (58). In contrast with this, the other half of the participants of our study from the community read the health calendar only occasionally. This may suggest a lack of interest in health subjects by a significant part of this population where risk factors for NCD are highly prevalent (20). Fomenting health literacy with the use of different strategies has proven to be useful to reduce health disparities in the community (59, 60) since the information not only remains on an individual level, but it is shared throughout the social environment. The use of different mediums to share health information, such as newspapers, magazines, or using e-health tools has been positively associated with the adoption of healthy lifestyle habits (11). The choice of delivering health information using a printed-material was made based on the assumption that this would reach a larger part of this population instead of using e-health tools. In the previous study of this population, only about 55% of the participants were able to interact with the investigators via Web (20). It was also interesting to see that the more rated topics pointed by participants were associated with advice on the field of diet, physical activity, and the use of water. Coincidently, the advice on similar areas was repeatedly mentioned by patients interviewed at the PHC center, although they had not previously participated in the quantitative part of this study.

The qualitative analysis indicated that patients considered most of the HRA relevant to their current medical condition, acknowledging the role such advice has on the improvement of their health. Some of them even declared that practicing the suggested lifestyle changes was more effective than taking a prescribed drug, which is a relevant fact that has already been mentioned in weight reduction studies (10). It is also been suggested that the information considered important by the health professionals will be the one to generate more interest in the community (59). The satisfaction with the detailing on the information given varied among participants, with some suggesting a perceived lack of training from the professionals on the subjects. It is important to mention that perceived satisfaction may depend on the individual educational level (61) and that even non-detailed lifestyle advice has been shown to have a certain level of effectiveness (62).

Health information alone is not enough to induce lifestyle changes (63, 64), but according to the participants of our study, the perceived quality of the relationship between health professionals and patients appeared to have an impact on the acceptance and practice of the HRA. Reported barriers to practicing the received HRA included the lack of personal effort, financial restrictions, lack of time to prepare meals or to exercise, and the lack of support from the social environment (family, friends, or neighbors). Nevertheless, participants were able to recognize most of these could be overcome with some effort on their part. Physicians providing HRA should recognize the patient's specific difficulties and attempt to tailor every advice to the patient's needs and help them to create a concrete plan to achieve new habits and promote lifestyle changes.

The limitations of this study include the evaluation of only those advice included in the STEPwise questionnaire used to quantitatively access the HRA reception in this community, and it does not take into account other types of useful advice in the prevention of NCDs such as the reduction in the intake of ultra-processed foods and processed meats, sugary foods, soft drinks, adequate intake of water, proper rest, stress management, etc. Besides, the STEPwise questionnaire asks for information regarding the last 3 years of the participants' lives, which they have to remember to answer, leading to memory-dependent bias. Regarding the calendar, we reached out to the participants after a year or more to assess the usage of the health calendar, and thus a part of them was not found. Also, this study was performed in a restricted area of Argentina, hence the results cannot be generalized to the entire population, even though the data on the prevalence of NCDs show similarities between our participants and the general population. It is valid to note that our study only considered the patient perspective on the reception of HRA, leaving aside the opinion of the healthcare professionals what may be explored in a future investigation.

The strengths of this study included the use of a mixed-method approach to assess HRA in a primary health care context of Argentina with a previously detected high prevalence of risk factors for NCD. The qualitative approach sheds light on the patient's perceptions of well-recognized health advice prescribed by medical doctors and nutritionists and expands the understanding of how HRA is seen by patients, making decisions more operative in the context of PHC. The obtained data may be strategically leveraged for prevention at all levels of health attention, including prevention, treatment, and control of chronic health conditions. The study addresses the topic of dietary and other lifestyle-related factors influencing NCD in a population of South America, a topic that needs greater attention in low-and-middle-income countries, as highlighted by a 2015 research which showed that only 0.5% of all health interventions targeting multiple risk factors for NCD were conducted in South America (65). This research highlights the importance that patients place on receiving health counseling, recognizing lifestyle changes as a key part of the prevention and treatment of NCD, and indicates the need for the training of the interdisciplinary team to fulfill with excellence the role of primary health care.

In the population of this central area of Argentina, patients previously diagnosed with chronic health conditions were more likely than others to report receiving advice to adopt healthy lifestyle recommendations. While HRA for those with hypertension, elevated cholesterol, or diabetes is an important public health goal, the results of this investigation suggest that health professionals may be missing the opportunity to engage in broader primary prevention strategies. The data also showed that a large proportion of the population, who could benefit from these recommendations, are not being advised to adopt them. It is estimated that, for instance, 65% of cardiovascular events could be prevented by the adoption of lifestyle recommendations (66) as also indicates the recently released medical consensus for the primary prevention of cardiovascular diseases (67). Thus, the information reported in this investigation may be helpful for healthcare professionals and providers in Argentina and across the world, especially in those countries with similar socioeconomic and cultural characteristics, since, according to the qualitative data, patients consider their physician's advice important, appreciate receiving them, and are prone to share the information with others. The findings of our study may be used to foster tailored-prevention strategies at the public health level using HRA to address NCD risk factors in Argentina and neighboring countries of Latin America and other areas of the world with similar challenges. Tackling lifestyle-related risk factors may provide an important boost for the economic development and if properly used HRA may constitute a simple and highly valued tool to help address patient's needs to prevent and control NCD.

## DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Research and Ethics Committee of the Adventist University of River Plate School of Medicine (N° 03-01-02/2012/2-2012). This committee is affiliated to the National Register of Health Research of the Ministry of Health (registered under the #0237), Argentina. The patients/participants provided their written informed consent to participate in this study.

## AUTHOR CONTRIBUTIONS

FP and SP were responsible for the design of the study. RS, AP, FV, FP, and DO participated in data collection. RS, AP, FV, FP, PG, DO, and SP participated in data analyses. BS participated in the design of the health calendar and data analyses. RS, FV, FP, PG, and SP participated in manuscript preparation. All authors contributed to the article and approved the submitted version.

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## SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fnut.2021.622543/full#supplementary-material

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# Overweight in Rural *Quilombola* and *Non-quilombola* Adolescents From the Northeast of Brazil

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**Introduction:** Overweight is an emerging problem among children and adolescents that leads to the development of several morbidities and health risks. Overweight occurs differently in different populations, especially in vulnerable groups like the rural and *quilombola* communities (an African-descendant population). This study aimed to estimate the prevalence of overweight and to investigate the possible associated factors in rural adolescents living in both *quilombola* and *non-quilombola* communities in Northeast Brazil.

**Methods:** This study is a population-based cross-sectional study with a household approach carried out in 2015 with 390 adolescents (age 10–19 years) living in rural *quilombola* and *non-quilombola* communities. The nutritional status was gauged using z-scores calculated for body mass index (BMI) and varies with gender and age. Prevalence ratios (PRs) and 95% confidence intervals (95% CIs) were used to establish associations between the results and explained variables. The multivariate analysis followed a model with a hierarchical entry of covariables controlled by gender and age.

**Results:** The study showed that 18.5% of rural adolescents were overweight, of which 17.9% were *quilombolas* and 19.0% were *non-quilombolas*. A significant difference in overweight between the samples was not found. In the multivariate-adjusted model, age ≥16 years (PR: 0.51; 95% CI: 0.28–0.95), the habit of having regular breakfast (PR: 0.58; 95% CI: 0.35–0.98), and process of attending school (PR: 0.35; 95% CI: 0.17–0.71) were associated with a lower prevalence of overweight. Stationary screen time, in contrast, was associated with a higher prevalence (PR: 1.61; 95% CI: 1.05–2.46). The process of attending school was associated with a lower prevalence of overweight (PR: 0.26; 95% CI: 0.09–0.69), even for the *quilombolas*.

**Conclusions:** A low prevalence of overweight was identified in rural adolescents. Overweight was significantly associated with the habit of having regular breakfast, older age, stationary screen time, and the process of attending school. The results reveal

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that school is a potential space for health promotion interventions, specifically in the most vulnerable rural regions, such as the *quilombola* communities. Besides, the study emphasizes the importance of adopting a healthy lifestyle early in life, including cultivating the habit of having regular breakfast and reducing stationary screen time.

**Keywords: adolescents, African continental ancestry group, Brazil, overweight, rural communities, vulnerable population**

## INTRODUCTION

Adolescence is a period in which physical and psychological changes that contribute to vulnerability occur in one's life cycle (1). During this period, there is a great change in body composition due to many factors, such as eating habits, physical activities, age, and gender (2).

In the adolescent population, an increase in sedentariness and a decrease in physical activity are frequently observed; poor eating habits, including a high intake of ultra-processed foods, long intervals between meals, low intake of fruits and vegetables, and replacement of traditional meals with fast food are common (3, 4). These behaviors contribute to weight gain and metabolic alterations, besides being risk factors for nutritional deficiencies and non-communicable chronic diseases. Poor eating habits and decreased physical activity have both short- and long-term effects on adulthood (5).

Overweight and obesity are considered the most direct consequences of these bodily changes and emerging problems among children and adolescents (6). A study that gathered and analyzed data from 2,416 population-based studies included 31.5 million children and adolescents worldwide between 5 and 19 years of age and showed that the prevalence of obesity increased from 0.7 to 5.6% in girls and 0.9 to 7.8% in boys between 1975 and 2016 (7). Obesity was prevalent in more than 30% of children and adolescents living in Oceania and around 20% of children and adolescents in Polynesia and Micronesia, the Middle East, north of Africa, the Caribbean, and the USA (7). In Brazil, results of the *Pesquisa Nacional de Saude do Escolar (PeNSE)*, a national school-based health survey carried out in 2015, showed that 23.7 and 7.8% of adolescents between 13 and 17 years of age were overweight or obese, respectively, in the capitals and metropolitan areas of the country (8). In the Northeast region, 20.5% were overweight and 6.4% were obese (8).

However, such problems can occur in different ways in different populations. Considering the social and economic contexts, especially in the urban/rural Brazilian scenario, access to education and health services in the rural area affects people in all age groups (9). In the traditionally vulnerable groups like the *quilombola* communities, the health conditions are poor (10), especially concerning bad eating habits and overweight (11). *Quilombola* communities are distributed throughout Brazil, and most of them are located in rural areas of the Northeast (12). These communities still live with social inequities (13, 14) and suffer the effects of historical racial segregation and expropriation (12).

Among the *quilombola* adolescents, discrimination can influence growth issues, including health, in a negative way (15). A study carried out in the Northeast of Brazil showed differences in the intake of healthy food between *quilombola* and *non-quilombola* rural adolescents. *Quilombola* adolescents had a lower intake of milk, vegetables, and fruits when compared to the *non-quilombola* adolescents (16), which may adversely impact the weight of this population.

Considering that adolescence is a vulnerable period for human development, healthy habits, and learned behaviors during this period can have long-term consequences extending to adulthood. Therefore, it is necessary to investigate the occurrence of and factors causing overweight in this age group. Identifying overweight in rural adolescents can help prevent health problems, specifically among the *quilombolas*. Therefore, this study aimed to estimate the prevalence of overweight and the factors associated with it in rural adolescents from the Northeast of Brazil.

## METHODS

### Study Design, Population, and Sample

This is a population-based cross-sectional study with a household approach carried out with adolescents, 10–19 years old (17), from rural communities of Vitoria da Conquista, State of Bahia, Northeast of Brazil. The study analyzes data from the research "*Adolescer: saude do adolescente da zona rural e seus condicionantes*" (Adolescer: Rural Adolescent Health and Its Conditioning) carried out in 2015.

To carry out the population estimate, we collected data from Brazilian Primary Health Care forms used by the community health workers during the household visits. The Program of Community Health Workers covered 97.4% of the rural area of Vitoria da Conquista at the time of the study.

We used a sampling strategy that took into account the territorial extension of rural communities and populations of adolescents to ensure viability and representativeness of the research. The sampling principles used were as follows: (1) the number of households was selected proportionally to the number of adolescents per community and (2) only one adolescent was interviewed per household. Moreover, in order to obtain valid estimates for *quilombola* and *non-quilombola* populations, the sample size was calculated separately for each stratum.

We calculated the sample size using the following criteria: a prevalence of 50%, given the heterogeneity of the events measured in the main project; an accuracy of 5%; a confidence level of 95%; a design effect equal to 1.0; and an addition of 15% for possible losses. However, as only one adolescent per household was interviewed and because the number of households was smaller for the *quilombola* communities, 7.1% of losses were added to the *quilombola* stratum. OpenEpi, version 3.01 (open source epidemiological statistics for public health) (18), was used for this estimation. The presence of severe mental disorders among adolescents was used as an exclusion criterion.

Sampling for *non-quilombola* adolescents was carried out in two stages: (1) random selection of households with adolescents according to the proportional distribution of adolescents per community and (2) random selection of adolescents in each household. For the *quilombola* sample, only random selection of adolescents in each household was used. All adolescents had the same probability of inclusion in the study.

The research was approved by the Institutional Review Board of the Federal University of Bahia *(Comite de Etica em Pesquisa com Seres Humanos da Universidade Federal da Bahia–Instituto Multidisciplinar em Saude–Campus Anisio Teixeira)* under rule number 639.966. The participants received information about the research objectives and data confidentiality prior to study initiation. They were required to read and sign the free informed consent form and informed consent form for adolescents under 18 years of age.

## Data Collection Survey

For data collection, a semistructured survey was formulated based on questionnaires from national inquiries, such as *Pesquisa Nacional de Saude do Escolar (PeNSE)* by the national school-based health survey and *Pesquisa Nacional de Saude (PNS)* by the National Health Survey (19, 20). The software, Questionnaire Development System (QDS™; NOVA Research Company) version 2.6.1, was used for constructing and visualizing the questionnaires.

The survey was divided into two parts: (i) the first part was answered by the adolescents or their legal representatives and addressed general characteristics regarding the residence, income, and schooling of the householder; (ii) the second part was answered only by the adolescents (in the absence of their parents and in a comfortable place that guaranteed confidentiality of the answers and minimized potential information bias) and addressed the characteristics of the adolescents, support from society, characteristics of their work, lifestyle, perception of health conditions and self-image, deficiencies (intellectual, physical, hearing, and visual), use of illicit drugs, accidents and violence, sexual and reproductive health, oral health and hygiene, and use of health services.

The final version of the survey was evaluated after the pretests and a pilot study. The vocabulary and response options were adapted and normalized for the rural context while retaining the original validated structure for better understanding and ensuring comparability of information. Pretests were performed, and the survey was normalized based on (1) language, (2) sequence of and coherence between questions, (3) instructions on questions to be skipped, and (4) the time required to finish the survey. After the pilot study, new changes were made to the language to obtain the final version.

The pilot study was carried out in December 2014 in a rural community that was originally not a participant in the main study; the population was equal to 10% of the sample size of the main study. The exclusion criteria included situations in which both the adolescents or their legal representatives were unable to answer the questions because they were drunk at the time of data collection or had serious mental health problems and cognitive interference.

## Data Collection

The data were collected between January and May 2015. To ensure the credibility of the data, interviews were repeated for 5% of the samples within 7 days after the interview. The interviewers received training to conduct the interviews and used portable computers (HP *Pocket* Rx5710).

The interviewing team was composed of 15 undergraduate students from nursing, pharmacy, nutrition, medicine, and psychology branches, who had previously participated in rural research projects. They received a 20-h training conducted by the coordination team and focused on the following aspects: approaching adolescents, conducting interviews, ethical aspects, measuring anthropometric measures, handling and using equipment and software, mapping territories, and identifying households.

The anthropometric measurements were done according to *Normas Técnicas do Sistema de Vigilância Alimentar e Nutricional (SISVAN) do Brasil*—Brazilian Technical Rules of Diet and Nutrition Surveillance System (21). The weight was measured in kilograms (kg) for barefoot individuals wearing light clothes using a portable scale (*Marte*, model LC 200pp) having a maximum capacity of 200 kg and precision of 0.05 kg. The height was measured in centimeters (cm) for barefoot individuals in a standing posture using a portable stadiometer (*CauMaq*, model est-22) with lateral readings, a maximum height of 2 m, and graduations in millimeters (mm).

## Variables

The nutritional status was gauged by calculating the body mass index (BMI) and height deficit. BMI was classified according to the curves proposed by World Health Organization (WHO) using *WHO AntroPlus* version 1.0.4. The software calculates Z-scores for BMIs based on gender and age (22). The cutoff points include low weight ($-2 >$ z-score $\geq -3$), eutrophy ($+1 \geq$ z-score $\geq -2$), overweight ($+2 \geq$ z-score $> +1$), and obesity (z-score $> +2$) (23). Based on the cutoff points, overweight and obesity were identified through responses in the questionnaire; the responses were categorized as "*yes*" (z-score $> +1$) and "*no*" (z-score $\leq +1$). The height deficit for age was evaluated with the following cutoff points: deficit present ($-2 >$ z-score $\geq -3$) and deficit absent (z-score $\geq -2$) (23).

The independent variables were gender; age; race/color (non-black—white, Asian, Brazilian indigenous; black—mulatto and black); school years; economic level (A/B and C/D— *Associacao Brasileira de Pesquisas e Mercados*—Brazilian Association of Market Research) (24); currently attending school; family composition; the number of close friends; experience with bullying; the practice of physical activities (active, $\geq$300 min/week; inactive, $<$300 min/week) (25); stationary screen time (the time spent in front of the TV daily $>$2 h) (26); regular intake of unhealthy food (intake of typically unhealthy food $\geq$5 days per week, such as processed meats, crackers, cookies, fried

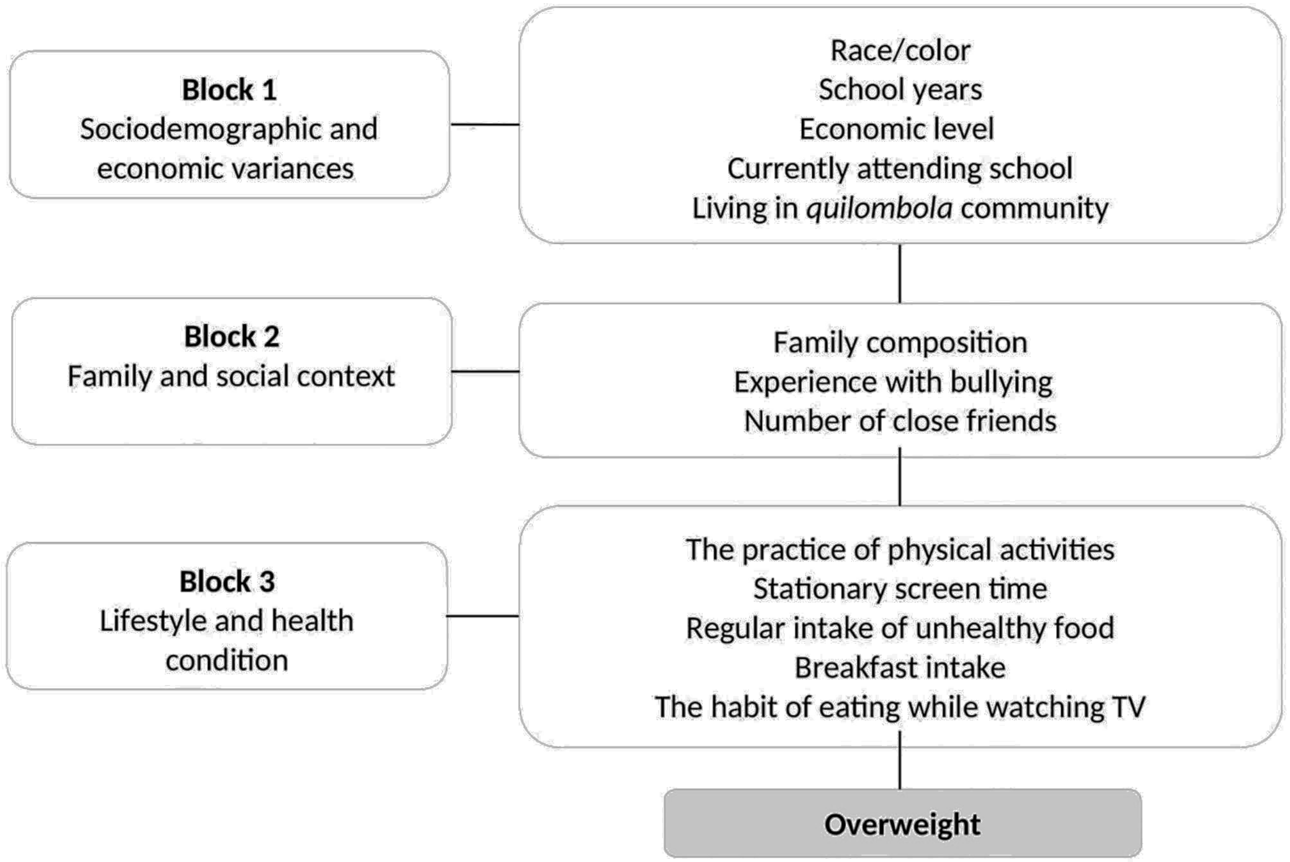


**FIGURE 1 |** Conceptual model of multivariate analysis for overweight among *quilombola* and *non-quilombola* rural adolescents.

chips, dainties, and soda); breakfast intake (frequency ≥5 days per week) (27); habit of eating while watching TV (frequency ≥5 days per week) (27).

## Statistical Analysis

Simple frequencies were calculated, and the differences between *quilombola* and *non-quilombola* samples were compared using Pearson's chi-square or Fisher's exact test. Differences between proportions were assessed using Pearson's chi-square or Fisher's exact test. The prevalence ratio (PR) and 95% confidence interval (95% CI) were used to estimate the association between the results and explained variables. Poisson regression with robust variance was used for the multivariate model to obtain better estimates of PR for very frequent results.

The multivariate analysis followed the model of hierarchical entry of co-variables in blocks controlled by gender and age according to the following sequence: social demography and economic status; family and social context; lifestyle and health conditions (**Figure 1**). Models were built with samples from each community (*quilombola* and *non-quilombola*), and all the co-variables that presented associations with the results, with significance levels under 20% in the bivariate analysis, were included in the initial models. A level of significance under 5% was used in all the tests and for the permanence of variables in the final model. The models were compared through the Akaike criterion, and the adequacy of the predicted values was assessed by the chi-square test, since the models were nested and had different covariables, and followed a chi-square distribution.

To evaluate the effect of losses on the outcome, the natural expansion factors were calibrated (28). Overweight estimates were compared using the test of proportions for the entire sample and each stratum. The Stata program, version 15.0 (Stata Corporation, College Station, USA), was used for data analysis.

# RESULTS

The study interviewed 390 adolescents; 167 lived in *quilombola* and 223 lived in *non-quilombola* communities, with losses of 15.2 and 7.9%, respectively. The losses varied with sex, with a higher prevalence in males for *non-quilombola* adolescents ($p = 0.038$). However, the estimated outcomes, with and without the calibration factor for this variable for the entire sample and for each stratum, did not present significant differences. Therefore, the variable was considered in the analyses performed.

Of the 390 adolescents who participated in the research, data on the nutritional status were missing in seven (three losses for height and four for weight), resulting in a total

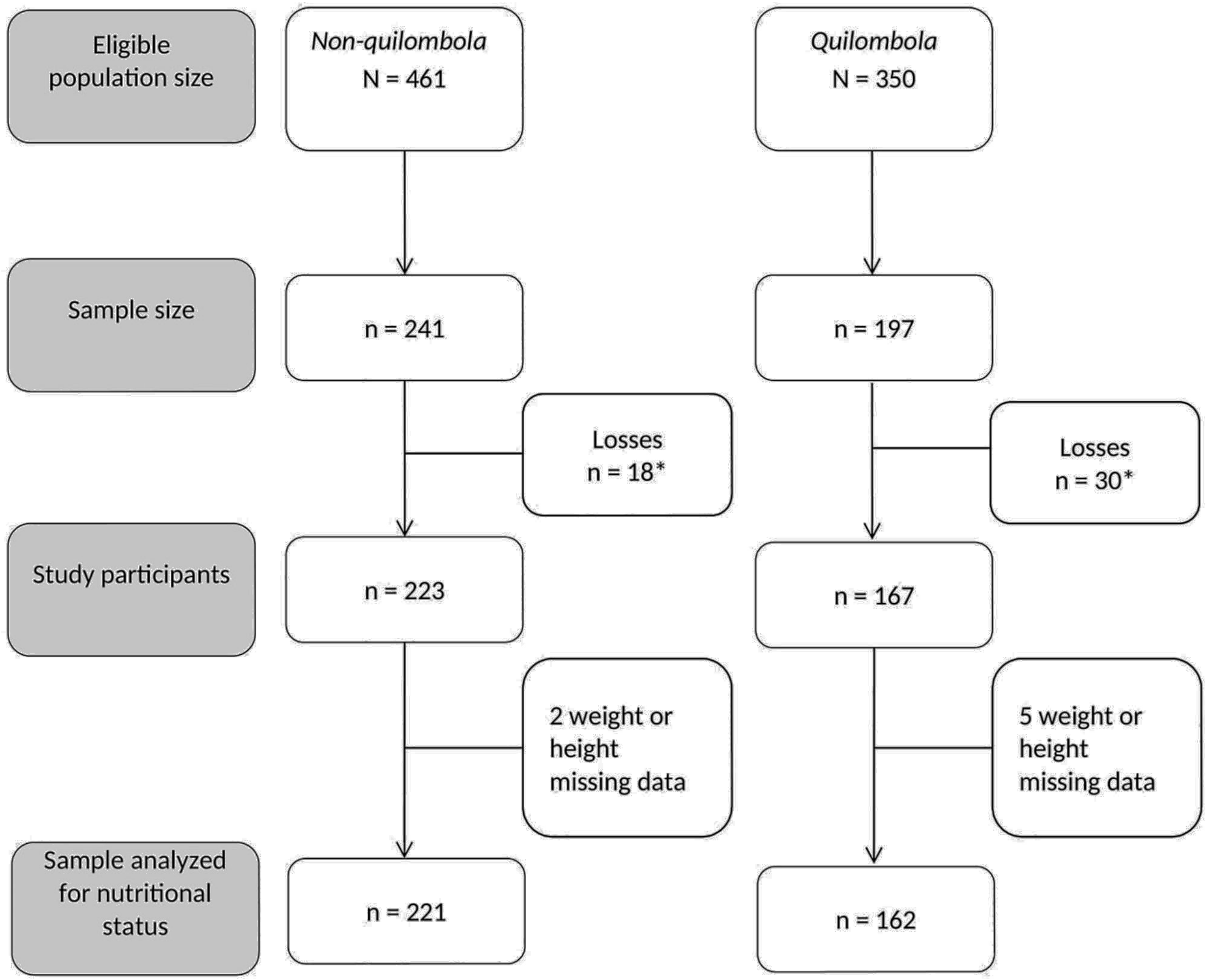


**FIGURE 2 |** Flow-chart of the final sample for the *quilombola* and *non-quilombola* stratum. Research *Adolescer*, Bahia, 2015. *Losses due to: closed household, adolescent not found after three visits and refusals.

sample size of 383 adolescents. Among them, 162 (42.3%) were from *quilombola* communities and 221 (57.7%) were from *non-quilombola* communities (**Figure 2**).

Among the participants, 18.5% (95% CI: 14.9–22.8%) presented overweight (overweight/obesity)—17.9% (95% CI: 12.7–24.6%) were *quilombolas* and 19.0% (95% CI: 14.3–24.8%) *non-quilombolas.* Height deficiency occurred in 4.4% (95% CI: 2.7–6.9%) of rural adolescents—6.7% (95% CI: 3.7–11.7%) were *quilombolas* and 2.7% (95% CI: 1.2–5.9%) were *non-quilombolas* (**Figure 3**).

In the bivariate analysis, the prevalence of overweight was significantly higher among adolescents with stationary screen time (PR: 1.58; 95% CI: 1.03–2.41). The prevalence was lower in those who attended school (PR: 0.50; 95% CI: 0.30–0.83) and had the habit of having breakfast regularly (PR: 0.59; 95% CI: 0.36–0.96). The *quilombola* adolescents who attended school had a lower prevalence of overweight (PR: 0.33; 95% CI: 0.17–0.63). No association was observed between overweight and explained variances among *non-quilombolas* (**Table 1**).

In the multivariate-adjusted model, overweight among rural adolescents was negatively associated with age ≥16 years (PR: 0.51; 95% CI: 0.28–0.95), the habit of having breakfast regularly (PR: 0.58; 95% CI: 0.35–0.98), and the condition of attending school (PR: 0.35; 95% CI: 0.17–0.71). Stationary screen time increased the occurrence of overweight (PR: 1.61; 95% CI: 1.05–2.46). For *quilombolas*, overweight remained associated with attending school (PR: 0.26; 95% CI: 0.09–0.69). In the adjusted model for *non-quilombolas*, despite the absence of statistical significance, stationary screen time (PR: 1.61; 95% CI: 0.92–2.83) was important to explain the results (**Table 2**).

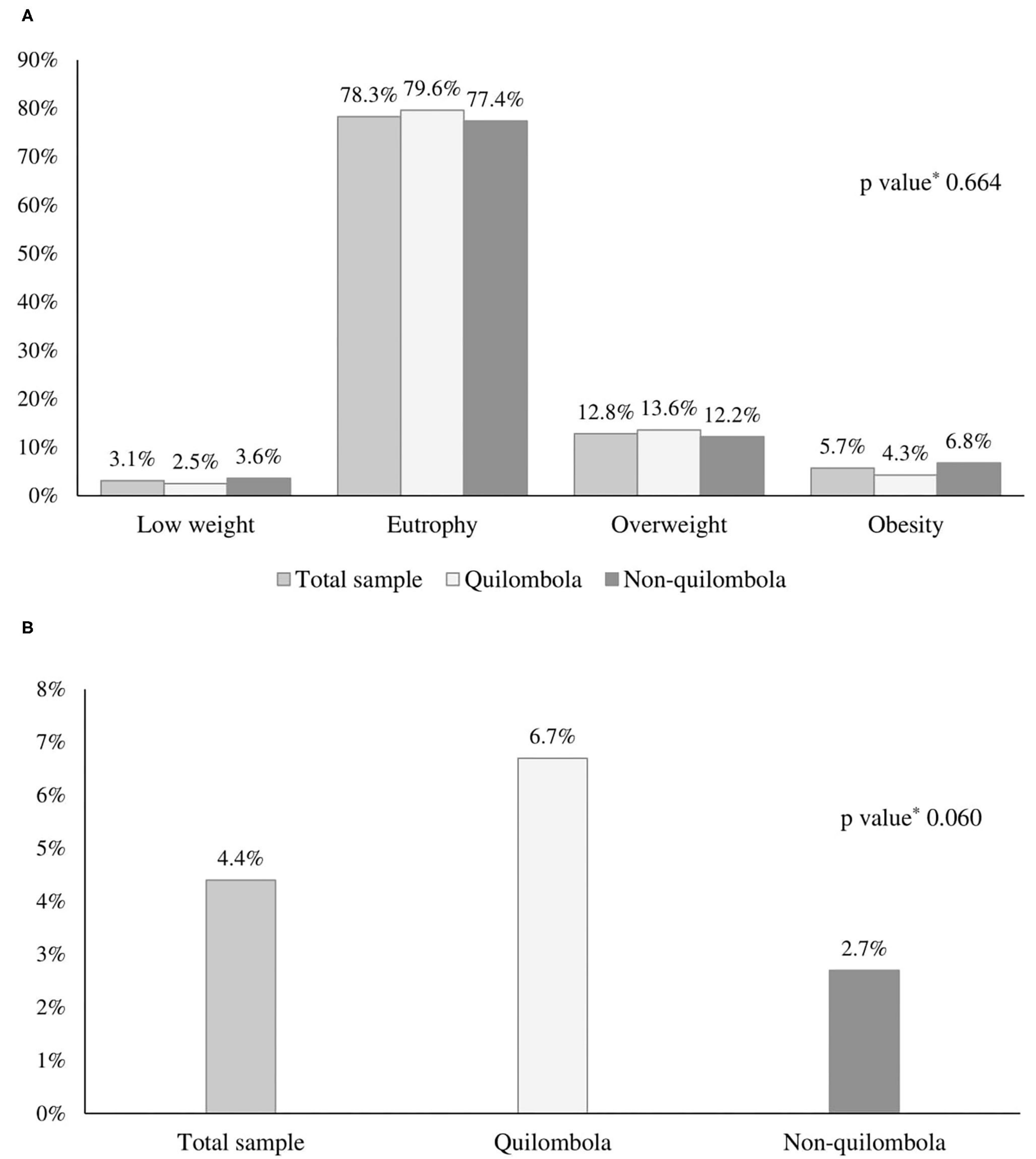


**FIGURE 3 |** Nutritional status (*A* – $n = 383$) and occurrence of height deficit (*B* – $n = 387$) of adolescents from a rural area of the Northeast of Brazil. Research *Adolescer*, Bahia, 2015. **p* value calculated by Pearson's chi-squared test to compare *quilombola* and *non-quilombola*.

## DISCUSSION

The present study evidenced a low prevalence of overweight among rural adolescents, in line with data recorded previously for the adolescent population in Brazil (23.7%) (8). Aspects such as having breakfast regularly, attending school, and being in the age group ≥16 years reduced the prevalence of overweight, whereas stationary screen time increased the prevalence.

**TABLE 1 |** Overweight among *quilombola* and *non-quilombola* adolescents, according to studied variables, from a rural area of the Northeast of Brazil ($n = 383$).

| Variances | Total sample | | | | *Non-quilombola* | | | | *Quilombola* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *n* (%) | *p*-value | PR | 95% CI | *n* (%) | *p*-value | PR | 95% CI | *n* (%) | *p*-value | PR | 95% CI |
| **Living in *quilombola* community** | | 0.784 | | | | | | | | | | |
| No | 42 (19.0) | | 1.00 | – | | – | | | | – | | |
| Yes | 29 (17.9) | | 0.94 | 0.61–1.45 | | | | | | | | |
| **Economic level** | | 0.147 | | | | 0.160 | | | | 0.625 | | |
| B/C | 33 (22.2) | | 1.00 | – | 25 (22.7) | | 1.00 | – | 8 (20.5) | | 1.00 | – |
| D/E | 38 (16.2) | | 0.73 | 0.48–1.12 | 17 (15.3) | | 0.67 | 0.39–1.18 | 21 (17.1) | | 0.83 | 0.40–1.73 |
| **Gender** | | 0.124 | | | | 0.125 | | | | 0.558 | | |
| Male | 29 (15.4) | | 1.00 | – | 17 (15.0) | | 1.00 | – | 12 (16.0) | | 1.00 | – |
| Female | 42 (21.5) | | 1.40 | 0.91–2.14 | 25 (23.2) | | 1.54 | 0.88–2.69 | 17 (19.5) | | 1.22 | 0.62–2.40 |
| **Age** | | 0.404 | | | | 0.100 | | | | 0.674 | | |
| ≤12 years old | 29 (22.1) | | 1.00 | – | 21 (26.6) | | 1.00 | – | 8 (15.4) | | 1.00 | – |
| 13–15 years old | 18 (15.8) | | 0.71 | 0.42–1.21 | 10 (15.4) | | 0.58 | 0.29–1.14 | 8 (16.3) | | 1.06 | 0.43–2.61 |
| ≥16 years old | 24 (17.4) | | 0.79 | 0.48–1.28 | 11 (14.3) | | 0.54 | 0.28–1.04 | 13 (21.3) | | 1.39 | 0.62–3.09 |
| **Race/color** | | 0.877 | | | | 0.454 | | | | 0.417 | | |
| Not black | 16 (18.0) | | 1.00 | – | 10 (15.9) | | 1.00 | – | 6 (23.1) | | 1.00 | – |
| Black | 55 (18.7) | | 1.04 | 0.63–1.72 | 32 (20.3) | | 1.28 | 0.67–2.44 | 23 (16.9) | | 0.73 | 0.33–1.63 |
| **School years** | | 0.086 | | | | 0.142 | | | | 0.562 | | |
| Under 5 years old | 29 (19.5) | | 1.00 | – | 16 (19.3) | | 1.00 | – | 13 (19.7) | | 1.00 | – |
| 6–9 years old | 35 (21.1) | | 1.08 | 0.70–1.70 | 21 (22.8) | | 1.18 | 0.66–2.12 | 14 (18.9) | | 0.96 | 0.49–1.90 |
| 10 years old or more | 6 (9.0) | | 0.46 | 0.20–1.06 | 4 (8.90) | | 0.46 | 0.16–1.30 | 2 (9.1) | | 0.46 | 0.11–1.90 |
| **Family composition** | | 0.760 | | | | 0.568 | | | | 0.409 | | |
| Lives with parents | 48 (18.4) | | 1.00 | – | 27 (17.3) | | 1.00 | – | 21 (20.0) | | 1.00 | – |
| Lives with father or mother | 18 (20.5) | | 1.11 | 0.68–1.81 | 11 (22.5) | | 1.30 | 0.69–2.42 | 7 (18.0) | | 0.90 | 0.41–1.95 |
| Does not live with parents | 5 (14.7) | | 0.80 | 0.34–1.87 | 4 (25.0) | | 1.44 | 0.58–3.62 | 1 (5.6) | | 0.28 | 0.04–1.95 |
| **Currently attending school** | | 0.012* | | | | 0.538 | | | | 0.005* | | |
| No | 12 (34.3) | | 1.00 | – | 4 (23.5) | | 1.00 | – | 8 (44.4) | | 1.00 | – |
| Yes | 59 (17.0) | | 0.50 | 0.30–0.83 | 38 (18.6) | | 0.79 | 0.32–1.96 | 21 (14.6) | | 0.33 | 0.17–0.63 |
| **Experience with bullying** | | 0.356 | | | | 0.396 | | | | 0.413 | | |
| Never | 45 (18.2) | | 1.00 | – | 25 (17.4) | | 1.00 | – | 20 (19.4) | | 1.00 | – |
| Rarely/sometimes | 19 (17.3) | | 0.95 | 0.58–1.54 | 13 (20.6) | | 1.19 | 0.65–2.17 | 6 (12.8) | | 0.66 | 0.28–1.53 |
| Often/always | 7 (29.2) | | 1.60 | 0.81–3.15 | 4 (30.8) | | 1.77 | 0.73–4.32 | 3 (27.3) | | 1.40 | 0.49–4.00 |
| **Number of close friends** | | 0.761 | | | | 0.920 | | | | 1.000 | | |
| Until 2 | 11 (17.2) | | 1.00 | – | 7 (18.4) | | 1.00 | – | 4 (15.4) | | 1.00 | – |
| 3 or more | 60 (18.8) | | 1.09 | 0.61–1.96 | 35 (19.1) | | 1.04 | 0.50–2.16 | 25 (18.4) | | 1.19 | 0.45–3.16 |
| **The practice of physical activity** | | 0.598 | | | | 0.450 | | | | 0.929 | | |
| Active | 31 (17.4) | | 1.00 | – | 17 (16.8) | | 1.00 | – | 14 (18.2) | | 1.00 | – |
| Inactive | 40 (19.5) | | 1.12 | 0.73–1.71 | 25 (20.8) | | 1.24 | 0.71–2.16 | 15 (17.7) | | 0.97 | 0.50–1.88 |
| **Stationary screen time** | | 0.034† | | | | 0.068 | | | | 0.257 | | |
| No | 31 (14.8) | | 1.00 | – | 18 (14.8) | | 1.00 | – | 13 (14.8) | | 1.00 | – |
| Yes | 40 (23.3) | | 1.58 | 1.03–2.41 | 24 (24.5) | | 1.66 | 0.96–2.88 | 16 (21.6) | | 1.46 | 0.75–2.85 |
| **Regular intake of unhealthy food** | | 0.634 | | | | 0.908 | | | | 0.540 | | |
| No | 26 (19.9) | | 1.00 | – | 14 (19.4) | | 1.00 | – | 12 (20.3) | | 1.00 | – |
| Yes | 45 (17.9) | | 0.90 | 0.58–1.39 | 28 (18.8) | | 0.97 | 0.54–1.72 | 17 (16.5) | | 0.81 | 0.42–1.58 |
| **Breakfast intake** | | 0.040* | | | | 0.206 | | | | 0.137 | | |
| No | 15 (28.9) | | 1.00 | – | 8 (27.6) | | 1.00 | – | 7 (30.4) | | 1.00 | – |
| Yes | 56 (16.9) | | 0.59 | 0.36–0.96 | 34 (17.7) | | 0.64 | 0.33–1.25 | 22 (15.8) | | 0.52 | 0.25–1.08 |
| **The habit of eating while watching TV** | | 0.509 | | | | 0.607 | | | | 0.109 | | |
| No | 44 (19.6) | | 1.00 | – | 24 (17.9) | | 1.00 | – | 20 (22.2) | | 1.00 | – |
| Yes | 27 (17.0) | | 0.86 | 0.56–1.33 | 18 (20.7) | | 1.16 | 0.67–2.00 | 9 (12.5) | | 0.56 | 0.27–1.16 |

*Research Adolescer, Bahia, 2015.*
*n (%), absolute and relative frequency; p-value calculated by Pearson's chi-square or Fisher's exact test; PR, prevalence ratio; 95% CI, 95% confidence interval.*
*Economic level: B and C, R$ 1,277.00 (US$ 481.89) to R$ 6,006.00 (US$ 2,266.41) average gross family income/month; D and E, up to R$ 895.00 (US$ 337.73) average gross family income/month. Estimate US commercial dollar values based on the quote currency on December 31, 2014 (US$ 1.00 = R$ 2.65).*
*Statistically significant ($p < 0.05$).*
*†Associated with a higher prevalence of overweight.*
**Associated with a lower prevalence of overweight.*

**TABLE 2 |** Factors associated with the occurrence of overweight, according to multivariate analysis, for the total sample, *non-quilombola* and *quilombola*.

| Variances | Total sample | | *Non-quilombola* | | *Quilombola* | |
|---|---|---|---|---|---|---|
| | PR | 95% CI | PR | 95% CI | PR | 95% CI |
| **Gender** | | | | | | |
| Male | 1.00 | – | 1.00 | – | 1.00 | – |
| Female | 1.17 | 0.76–1.81 | 1.38 | 0.78–2.44 | 1.29 | 0.67–2.48 |
| **Age** | | | | | | |
| ≤12 years old | 1.00 | – | 1.00 | – | 1.00 | – |
| 13–15 years old | 0.70 | 0.42–1.19 | 0.55 | 0.28–1.07 | 1.04 | 0.42–2.58 |
| ≥16 years old | 0.51 | 0.28–0.95* | 0.53 | 0.28–1.02 | 0.77 | 0.27–2.16 |
| **Breakfast intake** | | | | | | |
| No | 1.00 | – | – | – | – | – |
| Yes | 0.58 | 0.35–0.98* | – | – | – | – |
| **Stationary screen time** | | | | | | |
| No | 1.00 | – | 1.00 | – | – | – |
| Yes | 1.61 | 1.05–2.46† | 1.61 | 0.92–2.83 | – | – |
| **Currently attending school** | | | | | | |
| No | 1.00 | – | – | – | 1.00 | – |
| Yes | 0.35 | 0.17–0.71* | – | – | 0.26 | 0.09–0.69* |

*Research Adolescer, Bahia, 2015.*
*PR, adjusted prevalence ratio; 95% CI, 95% confidence interval.*
*Statistically significant ($p < 0.05$).*
*†Associated with a higher prevalence of overweight.*
**Associated with a lower prevalence of overweight.*

Attending school reduced the prevalence, specifically, among *quilombola* adolescents.

A cross-sectional study that used data from *III Pesquisa Estadual de Saude e Nutricao (PESN)* (III State Research of Health and Nutrition) carried out in 2006 showed that 13.3% of children and adolescents of Pernambuco in the Northeast of Brazil were overweight (29). Ramires et al. (30) found a higher prevalence of overweight/obesity (24.0%) among children and adolescents between 5 and 19 years of age in the Northeast. Similar to our study, Cordeiro et al. (31) showed that 17.2% of *quilombola* children and adolescents registered in urban and rural schools in 12 cities in Goias in the Midwest of Brazil were overweight.

International studies showed a great variation in the percentage of overweight adolescents. Kułaga et al. (32) researched on school children and adolescents in Poland and found that 19.4% boys and 13.0% girls were overweight. López-Sánchez et al. (33) evaluated children and adolescents living in Southern Europe between 7 and 19 years of age and estimated that 37.3% were overweight. Results obtained in three cross-sectional studies on children and adolescents in 1985, 1995, and 2005 in China showed that the prevalence of overweight and obesity was significantly higher in urban adolescents aged between 13 and 18 years (2.7, 10.9, 19.1%, respectively) compared to the rural ones (0.6, 2.5, 10.1%, respectively). However, another Chinese cross-sectional study in 2014 displayed a substantial increase in the prevalence of overweight in rural areas (10.1% in 2005 to 17.1% in 2014) in comparison to urban areas (19.1% in 2005 to 19.5% in 2014) (34).

Sedentary lifestyle and the lack of physical activity are the most important risk factors for noncommunicable chronic diseases, such as obesity, cardiovascular diseases, hypertension, and diabetes mellitus (35). Despite the adolescent being classified as active in our study, an association between sedentary behavior and poor lifelong health conditions may prevail (36). Sedentary behavior in relation to stationary screen time is defined as the time a resting individual spends in front of a screen, including TV, computer monitor, cellphone, and tablet (26). In this study, the stationary screen time increased the prevalence of overweight by 61% in rural adolescents.

Due to engrossing technological advances, adolescents often replace active leisurely activities with resting activities related to screen time (37). The PeNSE (2015) showed that around 60% of Brazilian students have the habit of watching TV for more than 2 h on a weekday (8). This leads to overweight and obesity because of a lower calorie burn and higher intake of high-calorie food (38, 39). In Brazil, overweight children and adolescents often indulge in sedentary behavior (40). In rural areas, besides social and economic vulnerabilities, the lack of an appropriate environment for physical activities can contribute to a higher screen time and a consequent weight gain among adolescents (41).

Prevention of unhealthy behavior was important to avoid overweight. The importance of regular physical activity, reducing sedentariness, and a healthy diet should be highlighted. Besides, attending school lowered the prevalence of overweight by promoting a healthy lifestyle and changing inadequate behaviors through education (42). In Brazilian schools, *Base Nacional Comum Curricular (BNCC)*—the National Common Curricular

Basis—elaborated by the Ministry of Education, allocates designated spaces and promotes physical education classes to encourage physical activities in children and adolescents (43). WHO advises adolescents to practice moderate- to high-intensity physical activities for 60 min or more per day (25). This can be achieved with an appropriate calorie burn during the physical education classes occurring in opposite shifts, especially during the sports matches and championships promoted by schools. However, a new law states that high school students can be exempted from mandatory physical education classes. This will gradually reduce the rights and contribute negatively to the nutritional status of adolescents.

In contrast, the rural scenario and their physical activities are relevant factors for this study. A study on adolescents in Pernambuco, a Brazilian Northeastern state, presented higher levels of physical activities, lower preference for passive leisure, and lower sedentariness in rural adolescents than in urban ones. Rural adolescents often take up jobs earlier and involve themselves in activities that require physical strength in the countryside/agriculture and household chores; these contribute to their active lifestyles (44). Our research on the rural *quilombola* and *non-quilombola* communities revealed poor access to public transportation and poorly accessible roads; these drive them to resort to other modes of transport including walking or riding a bicycle. These may be associated with the lower prevalence of overweight among rural adolescents.

Regarding healthy nutritional habits, the regular intake of breakfast reduced the prevalence of overweight by 42% in rural adolescents. This practice is also related to a more regular consumption of meals and reducing the habit of snacking on high-carb foods throughout the day (45). Besides, healthy diet and weight control have been associated with a low intake of fat and balanced intake of grains, fruits, and dairy at breakfast (46, 47).

According to Sousa et al. (16), adolescents from the same rural regions investigated in the present study presented healthier food intake and diet than urban adolescents. The *quilombola* adolescents had a high intake of beans but a low intake of more expensive foods, like milk, vegetables, and fruits, which correlate with the higher vulnerability of these communities by impacting their access to a healthier and more varied diet (16).

Concerning the school environment, in the public school, rural adolescents have access to a subsidized diet with good nutritional quality as per the *Programa de Alimentação Escolar (PNAE)*—School Diet Program—from the Brazilian Ministry of Education. In schools with more vulnerable groups, like the indigenous Brazilians and *quilombolas*, a different budget is calculated and food is offered in the elementary school with the aim of improving the nutritional status and valuing the diet culture of these adolescents (48).

*Programa de Saude na Escola (PSE)*—Health at School Program—is also a Brazilian public policy that influences schools and aims at developing projects that help children and adolescents to face vulnerabilities in their daily lives (49). Therefore, a partnership between the health and education sectors is an important way to reduce the main health risk factors because many actions that promote adolescents' health still do not cover their needs (50).

The adolescents' age can also influence their choices, life habits, and developmental changes of the body and metabolism. According to our results, adolescents who are ≥16 years are 49% less overweight compared to the younger ones; this was in accordance with the trends observed in Brazilian adolescents where a higher prevalence of overweight was observed among younger adolescents between 13 and 15 years of age (25.1%) (8). Another study on abdominal obesity showed that the older adolescents (13–15 and 16–19 years of age) had an inverse correlation with abdominal obesity; older adolescents showed a lower prevalence of abdominal overweight (51). Boricic et al. (52) seconded this with evidence suggesting that overweight reduced as age increased in adolescents considered in their study, in both genders.

Growth spurts are characteristic of the adolescence period and work against fat gain. They result in a consequent increase of bone and muscles mass (53). These metabolic alterations can help lower the prevalence of overweight, accompanied with the adoption of a healthy lifestyle. Besides these, older adolescents may have already taken up jobs. Working in jobs that require greater physical activity reduces sedentariness.

The prevalence of overweight (18.5%) and height deficit (4.4%) was low among rural adolescents in our study. However, the characteristics of an incomplete nutrition transition process were not examined. A nutritional deficit may show a progressive and meaningful reduction while there is a gradual increase in overweight/obesity (30, 54). The high speed of nutrition transition was evidenced by Azzopardi et al. (55) when they identified a 120% increase of overweight or obese cases in adolescents worldwide between 1990 and 2016. Abarca-Gómez et al. (7) mentioned that an unhealthy nutrition transition can contribute to height deficit and overweight in children, adolescents, and adults, resulting in a high BMI and poor lifelong health conditions. A study with data from the *Pesquisas Estaduais de Saude e Nutricao no Pernambuco* (1997 and 2006)—State Researches on Health and Nutrition in Pernambuco—showed that even with the reduction of height deficit during this period, there was a significant percentage (10.9%) of adolescents with height issues (56).

Even without assessing malnutrition history in our study, the height deficit in these communities indicate past malnutrition. This is because compromised nutritional status, including the low intake of specific nutrients, is one of the most significant determiners of height deficit (57). Besides that, the height deficit is usually associated with poor social and economic conditions. Therefore, height deficit can be considered a useful sign to demonstrate the health conditions of a population (58). The *quilombola* adolescents who were assessed showed a higher prevalence of height deficit (6.7%) compared to the *non-quilombolas* (2.7%), and although not statistically significant, this difference reemphasizes the worrying scenario of vulnerability among *quilombola* communities who continue to be exposed to racial and ethnical discrimination. Another study conducted in these communities showed that despite the absence of malnutrition, food shortage still exists among *quilombola* families in the Northeast. This may have a negative influence on the health, perspectives, and behaviors of these adolescents (13).

### Study Strengths and Limitations

This study features a comprehensive population as, assesses health aspects of communities that are traditionally vulnerable, mainly from the social and economic points of view and their accessibility to health policies and services. Certain methodological aspects of this study, such as (i) sample calculation that guarantees valid estimates for both groups (*quilombolas* and *non-quilombolas*); (ii) partnership with health teams of the region, allowing access to residences that resulted in a fewer number of refusals, show that our results could be broadly applicable.

Nevertheless, our study has some limitations. As this is a cross-sectional study, it is not possible to infer the temporal nature of some observed associations. We also did not consider the stage of sexual maturation of adolescents [as measured by the Tanner scale (59)], which may have resulted in fewer discrepancies. However, BMI curves of age and gender that we used as nutritional status marks are commonly used in population studies and are recommended by the WHO.

## CONCLUSION

The adolescents in the study showed a low prevalence of overweight among the *quilombola* and *non-quilombola* rural adolescents. The habit of having breakfast regularly, old adolescents, and attending school negatively influences overweight, while stationary screen time positively influences overweight. Evidence suggests that school is an important space for interventions that improve the quality of life of these individuals, minimizing their vulnerability. In addition, our results reinforce the importance of early adoption of healthy lifestyle habits such as regularly having breakfast and reducing stationary screen time.

Considering the negative consequences of overweight on health, not only in adolescence but also in adulthood, it is still necessary to carry out some actions. These include periodic monitoring of the nutrition status of children and adolescents, providing incentives to encourage the intake of healthy foods and practice of physical activities, and respecting the diversity, culture, beliefs, and dietary habits of the rural populations.

## DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## ETHICS STATEMENT

The research was approved by the Institutional Review Board of the Federal University of Bahia (Comite de Etica em Pesquisa com Seres Humanos da Universidade Federal da Bahia—Instituto Multidisciplinar em Saude—Campus Anisio Teixeira), under rule number 639.966. The participants received previous information about the research objectives and data confidentiality, through the reading and signature of Free Informed Consent Form and Informed Consent Form for adolescents under 18 years old. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

## AUTHOR CONTRIBUTIONS

SC, CT, TdS, and DdM reviewed the literature and had primary responsibility in the final content of this article. SC, CT, TdS, EdS, PM, VB, and DdM wrote the article, analyzed, and interpreted the results. All the authors read and approved the final version of the manuscript.


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REVIEW
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# Kefir and Intestinal Microbiota Modulation: Implications in Human Health

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In the last decades changes in the pattern of health and disease in Latin America and in the world has been observed, with an increase in cases of chronic non-communicable diseases. Changes in intestinal microbiota composition can contribute to the development of these diseases and be useful in their management. In this context, the consumption of fermented foods with probiotic properties, such as kefir, stands out due to its gut microbiota-modulating capacity. There is an increasing interest in the commercial use of kefir since it can be marketed as a natural beverage containing health-promoting bacteria and has been gaining international popularity in Latin America. Also the consumption of these drinks in Latin America seems to be even more relevant, given the socioeconomic situation of this population, which highlights the need for disease prevention at the expense of its treatment. In this narrative review, we discuss how kefir may work against obesity, diabetes *mellitus*, liver disease, cardiovascular disorders, immunity, and neurological disorders. Peptides, bioactive compounds and strains occurring in kefir, can modulate gut microbiota composition, low-grade inflammation and intestinal permeability, which consequently may generate health benefits. Kefir can also impact on the regulation of organism homeostasis, with a direct effect on the gut-brain axis, being a possible strategy for the prevention of metabolic diseases. Further studies are needed to standardize these bioactive compounds and better elucidate the mechanisms linking kefir and intestinal microbiota modulation. However, due to the benefits reported, low cost and ease of preparation, kefir seems to be a promising approach to prevent and manage microbiota-related diseases in Latin America and the rest of the world.

**Keywords: kefir, probiotics, health, fermented foods, gut microbiota**

## INTRODUCTION

In the last decades, a major change in global health has been observed (1), with changes in the intestinal microbiota. The formation of intestinal microbiota during childhood is believed to be a key factor in the development of human diseases, such as allergies, neurological disorders and obesity (2–4), which indicates that the intestinal microbiota has a crucial role in the progress of new strategies for maintaining health.

The intestinal microbiota is a set of microorganisms that inhabit the human intestinal tract, and is composed by archaea, bacteria, fungi, helminths, and others (5). In a healthy adult individual, it is believed to be composed of more than $10^{14}$ microorganisms (6). According to the World Gastroenterology Organization stomach and duodenum have very low number of microorganisms, mainly lactobacilli and streptococci. Jejunum and ileum have an intermediate amount ($10^4$-$10^7$ cells per gram) (7) while large intestine has the largest amount with more than $10^{12}$ cells per gram, especially anaerobic microorganisms (7, 8). This microbial diversity also suggests the importance of the role that the intestinal microbiota plays in human health, indicating that—unlike what was thought in the past—microorganisms are not necessarily negative or the cause of diseases. On the contrary, it is increasingly clear that they co-evolved with human hosts and the presence of microorganisms can be important for maintaining health (1–4).

Knowledge on the importance of bacteria for human health dates back over 150 years (9), and fermented foods are important in this context. Through fermentation, food has contributed to the evolution of humanity due to its increased conservation capacity and shelf life, development of flavors, and health benefits (10, 11).

Able to resist to the digestive system, beneficial microorganisms occurring in fermented foods are able to act in the intestine. Fermented foods are able to modify the composition of the intestinal microbiota, improve the control of intestinal permeability, increase its barrier function (10–12), activate digestive enzymes, and assist in the production of short-chain fatty acids and vitamins. In addition, fermented foods have bioactive compounds and peptides with prebiotic, antimicrobial, anti-inflammatory, and anti-oxidant activities. Thus, the consumption of fermented foods has been reported to reduce the risk of incidence of certain diseases, such as metabolic syndrome, cardiovascular diseases, diabetes, and cancer; relieves lactose intolerance symptoms; and increases immunity and health in general (10, 11).

Probiotics stand out among fermented foods (10). According to the definition, probiotics are living microorganisms that provide health benefits to those who consume them (13, 14). From the beginning of Elie Metchnikoff's studies (1907) to the present day, *Lactobacillus* and *Bifidobacteria* are important species of lactic acid bacteria used as probiotic with evidence of their importance in human health (9, 10). In addition, in the scenario of diseases caused by changes in the intestinal microbiota, the use of probiotics stands out since the probiotics are capable of promoting homeostasis of the intestinal microbiota through mucin production, competition for pathogen adherence, inflammation control, pH change, cytokine production, as well as having immunomodulatory and anti-inflammatory properties, which results in a better healthy condition (7, 15).

Kefir is a fermented product (11, 16) formed by a single culture composed of lactic and acetic acid bacteria and yeast (17). It is a low-cost food, accessible to the general population, easy to handle and with great functional potential (18) due to its bioactive compounds (11, 18) like exopolysaccharides, conjugated fatty acids and peptidases (11, 16). Kefir consumption does not seem to result in negative effects (18) for adult humans (19) or animals (20). In kefir produced with whole milk, high cholesterol content can be observed, and in individuals with intolerance to lacteal proteins, allergic reactions may be observed, that can be avoided by replacing the milk matrices for water and sugar, which reinforces the absence of adverse effects of kefir (21).

Kefir peptides are able to improve parameters related to obesity in Sprague Dawley rats with diet-induced obesity. They act to inhibit lipogenesis by downregulating the fatty acid synthase (FAS) enzyme and increasing the phosphorylated acetyl coenzyme A carboxylase (p-ACC) protein; rising lipid oxidation and the expression of AMP-activated protein kinase (p-AMPK), peroxisome proliferator-activated receptor alpha (PPAR-α) and carnitine palmitoyltransferase 1 (CPT1); and decreasing the inflammatory response and oxidative modulation—with a reduction in tumor necrosis factor alpha (TNF-α), interleukin-1 beta (IL-1β) and transforming growth factor beta (TGF-β) cytokines (22) (**Table 1**). In addition, the strains found in kefir, such as *Lactobacillus harbinensis, Lactobacillus paracasei,* and *Lactobacillus plantarum*, have a role in the tolerance to bile acids and salts, in the adhesion of the intestinal mucosa and in antimicrobial resistance, indicating that bacteria occurring in kefir are capable of standing the gastrointestinal tract, as well as having probiotic and antioxidant activities (43).

Given the above, we will discuss studies with animals and humans that reported the role of kefir and its bioactive compounds on the treatment of diseases characterized by shifts in intestinal microbiota.

## KEFIR IN LATIN AMERICA

Non-communicable diseases are those diseases with a long duration and multifactorial causes which include genetic, psychological, environmental and behavioral factors. Also known as chronic diseases, some examples are cardiovascular disease, cancer and diabetes (44).

The consumption of milk-based fermented drinks is related to the prevention of chronic non-communicable diseases, with an

**Abbreviations:** AST, aspartate aminotransferase; ALT, alanine aminotransferase; CPT1, carnitine palmitoyltransferase 1; ELANS, American study of nutrition and health; EPM, elevated plus maze; FAS, fatty acid sintase enzyme; FST, forced swim test; GABA, gamma aminobutyric acid; GLP-1, glucagon-like peptide; HOMA-IR, insulin resistance index; IFN-γ, interferon-gama; IL-1β, interleukin-1 beta; mL, mililiter; OFT, open field test; p-AMPK, AMP-activated protein kinase; PPAR α, peroxisome proliferator-activated receptor alpha; TGF-β, transforming growth factor beta; TMAO, trimethylamine N-oxide; TMF, transplantation of fecal microbiota; TNF-α, tumor necrosis factor alpha.

**TABLE 1 |** Main results of kefir intervention studies.

| References | Population | Disease/condition | Kefir consumption | Main outcomes in kefir groups |
|---|---|---|---|---|
| **Human studies** | | | | |
| Bellikci-Koyu et al. (19) | - Humans | - Metabolic syndrome | - 180 mL kefir/day;<br>- 12 weeks of intervention time; | - ↑ Actinobacteria, fasting insulin and HOMA-IR;<br>- ↓ pro-inflammatory cytokines, such as TNF-α and IFN-γ, and in systolic and diastolic pressure. |
| Fathi et al. (23) | - Women aged 25–45 years | - Obesity | - 2 servings/day;<br>- 8 weeks of intervention time. | - ↓ serum levels/ratios of lipoproteins (TC, LDL, Non-HDL, TC/HDL, and LDL/HDL). |
| Ostadrahimi et al. (24) | - Humans aged 35–65 years | - Type 2 diabetes mellitus | - 600 mL/day of probiotic fermented milk containing *Lactobacillus casei*, *Lactobacillus acidophilus* and *Bifidobacteria*;<br>- 8 weeks of intervention times. | - ↓ HbA1C |
| Ozcan et al. (25) | - Post-menopausal women | - Sleep quality, quality of life and depression | - 500 mL kefir daily (instructed to drink 250 mL in the morning and in the evening);<br>- 30 days of intervention time. | - MENQOL, BDI, and WHIIRS scores showed significant changes |
| Praznikar et al. (26) | - Humans | - Obesity/intestinal integrity | - 300 mL of kefir/day;<br>- 3 weeks of intervention time. | - ↓ serum zonulin levels, glucose and HDL cholesterol, and self-reported appetite perceptions;<br>- ↑ the positive affect or mood. |
| St-Onge et al. (27) | - Humans (men) | - Hypercholesterolemy | - 500 mL kefir/day;<br>- 2 periods of 4 weeks of intervention time. | - ↑ fecal isobutyric, isovaleric and propionic, the total amount of fecal short chain fatty acids, and fecal bacterial content. |
| **Animal studies** | | | | |
| Bourrie et al. (28) | - C57BL/6 female mice | - Obesity induced by diet | - 100 μL kefir by gavage/day;<br>- 12 weeks of intervention time. | - ↓ weight gain, plasma cholesterol, and hepatic triglyceride deposit. |
| Chen et al. (29) | - Sprague Dawley rats | - Hepatic steatosis induced by high-fat diet | - $10^7$ to $10^{10}$ CFU of *Lactobacillus mali* APS1 by gavage/day;<br>- 12 weeks of intervention time. | - ↓ HOMA index, hepatic lipid accumulation;<br>- ↑ GLP-1, hepatic antioxidant activity, butyrate and Bacteroidetes/Firmicutes. |
| Choi et al. (30) | - C57BL/6J mice | - Obesity induced by high-fat diet | - 0.1 to 0.2% kefir powder-supplemented high-fat diet<br>- 8 weeks of intervention time. | - ↓ body weight, epididymal fat pad weight, adipocyte diameters, genes related to adipogenesis and lipogenesis, proinflammatory marker levels in epididymal fat, hepatic triacylglycerol concentrations, serum alanine transaminase, aspartate transaminase activities, serum triacylglycerol, total cholesterol, low-density lipoprotein-cholesterol. |
| Golli-Bennour (31) | - Wistar rats | - Hepatotoxicity | - Not informed | - Normalized the elevated serum levels of AST, ALT, total bilirubin, and cholesterol; |
| Kim et al. (32) | - Female BALB/c mice | - Obesity | - 0.2 mL kefir milk orally/day;<br>- 3 weeks of intervention time. | - ↓ Firmicutes, Proteobacteria, Enterobacteriaceae and Firmicutes/Bacteroidetes ratio;<br>- ↑ Bacteroidetes, Lactobacillus, and Lactococcus, and total yeast;<br>- Suppressed proliferation of the opportunistic pathogen Enterobacteriaceae. |
| Kim et al. (33) | - Male C57BL/6 mice | - Obesity and non-alcoholic fatty liver disease induced by 60% high-fat diet | - 0.2 mL of saline with 2 × $10^8$ CFU of *L. kefiri* DH5;<br>- 0.2 mL of saline with 2 × $10^8$ CFU of *Leuconostoc. mesenteroides* DH4<br>- 0.2 mL of saline with 2 × $10^8$ CFU of *L. kefiri* DH7<br>- 6 weeks of intervention time. | -↓ body weight, epididymal adipose tissue weight, blood triglyceride, LDL-cholesterol levels, hepatic steatosis, adipocyte diameter;<br>- Modulated gut microbiota;<br>- Upregulated PPARα, FABP4, and CPT1 expression in the epididymal adipose tissues |

*(Continued)*

**TABLE 1 |** Continued

| References | Population | Disease/condition | Kefir consumption | Main outcomes in kefir groups |
|---|---|---|---|---|
| Kim et al. (20) | - Dogs | - Quality of life | - 200 mL of kefir once a day (*ad libitum*);<br>- 2 weeks of intervention time. | - ↑ lactic acid bacteria and lactic acid bacteria: Enterobacteriaceae ratio;<br>- ↓ Firmicutes: Bacteroidetes ratio. |
| Le Barz et al. (34) | - C57BL/6 mice | - Obesity induced by diet | - 1 of 3 Lactobacillus strains (Lb38, *L. plantarum*; L79, *L. paracasei/casei*; Lb102, L. *rhamnosus*) or *Bifidobacterium* strains (Bf26, Bf141, 2 different strains of B. *animalis* ssp. *lactis*) administered with diet at $10^9$ CFU/day;<br>- 8 weeks of intervention time. | - ↓ diet-induced obesity, visceral fat and inflammation;<br>- ↑ glucose tolerance, insulin sensitivity and intestinal integrity. |
| Lim et al. (35) | - C57BL/6J mice | - Obesity induced by high-fat diet | - 5% water-soluble EPS and 8% resides after EPS removal from the probiotic kefir in diet;<br>- 4 weeks of intervention time. | - ↓ body weight gain, adipose tissue and plasma very low-density lipoprotein cholesterol;<br>- ↑ *Akkermansia spp*. in feces. |
| Noori et al. (36) | - Rats | - Nicotine cessation-induced anxiety, depression and cognition impairment | - 5 mg/kg/day of cow milk kefir or soy milk kefir;<br>- 7 days of intervention time. | - Improved anxiety, learning and memory impairment;<br>- ↓ the severity of depression. |
| Rosa et al. (37) | - Spontaneously Hypertensive Rats | - Metabolic syndrome | - 1 mL kefir/day;<br>- 10 weeks of intervention time. | - ↓ plasma triglycerides, liver lipids, liver triglycerides, insulin resistance, fasting glucose, fasting insulin, thoracic circumference, abdominal circumference, products of lipid oxidation, pro-inflammatory cytokine expression (IL-1β);<br>- ↑ anti-inflammatory cytokine expression (IL-10). |
| Sun et al. (38) | - Kunming male mice | - Depression | - *L. kefiranofaciens* ZW3 a dose of $10^7$ CFU, $10^8$ CFU and 109 CFU/mouse/day;<br>- 6 weeks of intervention time. | - Improved depression-like behavior and independent exploration ability;<br>- Regulated biochemical disorders in the hypothalamic–pituitary–adrenal axis, immune system and tryptophan metabolism caused by stress;<br>- Modulated the composition of the gut microbiota, and alleviate constipation. |
| Tiss et al. (39) | - Wistar rats | - Obesity, type 2 diabetes, hyperlipidemia and liver-kidney toxicities in high-fat-high-fructose diet | - 10 mL/kg of body weight of a fermented soymilk by kefir;<br>- 90 days of intervention time. | - ↓ pancreas lipase and alpha-amylase;<br>- Reverted back all these histological toxicities. |
| Tung et al. (22) | - Sprague Dawley rats | - Obesity induced by high-fat diet | - 164 mg/kg of body weight of kefir peptides;<br>- 8 weeks of intervention time. | - ↓ FAS enzyme, inflammatory response and oxidative modulation (TNF-α, IL-1β and TGF-β cytokines);<br>-↑ p-ACC protein, fatty acid oxidation and expression of p-AMPK, PPAR-α and CPT1. |
| Tung et al. (40) | - ApoE knockout mice | - High fat diet-induced atherosclerosis | - 100 mg/kg low-dose kefir peptides powder;<br>- 400 mg/kg high-dose kefir peptides powder;<br>- 12 weeks of intervention time. | - Improved atherosclerotic lesion development by protecting against endothelial dysfunction;<br>- ↓ oxidative stress, aortic lipid deposition, inflammatory immune response, fibrosis;<br>- Attenuating macrophage accumulation. |
| Vinderola et al. (41) | - BALB/c mice | - Immunomodulation | - 3.1 ± 0.3 ml/kefir daily;<br>- 2, 5, or 7 consecutive days of intervention time. | - Modulated the mucosal immune system in a dose-dependent manner |
| Wouw et al. (42) | - C57BL/6J mice | - Brain physiology and behavior | - 0.2 mL/kefir daily;<br>- 3 weeks of intervention time. | - Ameliorated the stress-induced;<br>- ↓ serotonergic signaling;<br>- ↑ fear-dependent contextual memory;<br>- Stimulate the production of GABA neurotransmitter. |

*Where: ALT, alanine aminotransferase; AST, aspartate aminotransferase; BDI, beck depression inventory; CFU, colony forming unit; CPT 1, carnitine palmitoyltransferase 1; EPS, exopolysaccharides; FABP4, fatty acid-binding protein 4; FAS, fatty acid synthase enzyme; GABA, gamma aminobutyric acid; GLP-1, glucagon-like peptide; kg, kilogram; HbA1C, glycated hemoglobin; HDL, high-density lipoprotein cholesterol; HFD, high fat diet; HOMA-IR, insulin resistance index; IFN-γ, Interferon-gamma; IL-1β, interleukin-1 beta; IL-10, interleukin−10; IT, intervention time; LDL, low-density lipoprotein cholesterol; MENQOL, menopause-specific quality of life questionnaire; mg, milligram; mL, milliliters; p-AMPK, AMP-activated protein kinase; PPAR α, peroxisome proliferator-activated receptor alpha; TC, total cholesterol; TGF-β, transforming growth factor beta; TNF-α, tumor necrosis factor alpha; WHIIRS, the women's health insomnia rating scale; μL, microliters; ↑, increase; ↓, decrease.*

association between the consumption of yogurt and a reduction in weight gain, and lower risk of obesity and cardiovascular diseases (45). Fermented milks also aid in the digestion of lactose and are a source of calcium and protein, therefore presenting interesting nutritional value (18, 46).

The consumption of yogurt and fermented drinks varies widely among countries: Brazil has a consumption similar to the United States (46) being, Argentina and Chile the countries with the highest consumption in Latin America (45).

According to data from the American Study of Nutrition and Health (ELANS), which aims to identify the consumption of food directly related to the occurrence of chronic non-communicable diseases, $< 3.5\%$ of the Latin American population has a good consumption of yogurt (45). This consumption is considered low and indicates that there is a consumption gap to be filled, since fermented drinks can contribute to improving the health of those who consume it (46), contributing to the prevention and treatment of chronic non-communicable diseases.

In Brazil, the consumption of yogurt has been increasing among populations with higher income, being typically consumed outside home (47) and, in Latin America, a similar movement is observed, with consumption mainly among the youngest and with highest socioeconomic level (45). Therefore, as an alternative to the consumption of yogurt, we highlight the use of milk kefir, which is also a fermented product, with health benefits due to its probiotic content and the presence of bioactive compounds (18).

Medicines and supplements for the treatment of chronic non-communicable diseases, such as probiotics, can have significant costs for the Latin American population, which may turn their consumption impossible (48). Kefir, on the other hand, can be produced by the consumer himself, using baits acquired by donation, which significantly reduces production and consumption costs (18, 49–51). This allows the use of kefir by a larger portion of the Latin American population. In addition, among the high-income population, kefir consumption also stands out, as there is a tendency, in this audience, to seek healthier and more nutritious foods, such as kefir (52).

The benefits of kefir have not yet been widely publicized among the Latin American population. However, scientific interest in this fermented product is gaining more researchers in Latin America. The antifungal property of kefir, for example, has been studied both in the production of cereals and in the preservation of food. In a study by Gamba et al. (53) there is significant resistance to natural and artificial fungal contamination in arepas (typical dish from Venezuela, Colombia, Bolivia, and Panama) cooked in kefir. In addition, the arepas maintained the organoleptic characteristics of the traditional product after adding kefir, with an improvement in the product's useful life.

The use of kefir to treat diseases has also been studied by Latin American researchers, observing reductions in pre-neoplastic lesions in the intestinal colon (54) and improvement of parameters related to obesity after consumption of this fermented drink (37) in animal models. Better quality of life for individuals with lactose intolerance and osteoporosis (55) has been also observed.

Studies analyzing the effects of kefir on the modulation of the intestinal microbiota (56) and the immune system (57) have also been carried out. In addition, the microbial non-kefir fraction, known as post-biotics (metabolites produced in the fermentation process of dietary components as well as the endogenous components generated by bacteria-host interactions that influence human health) have been widely studied due to their antagonism against pathogenic bacteria such as *Escherichia coli*, *Salmonella* spp. and *Bacillus cereus* (58, 59). This indicates that kefir produced in Latin America is indeed a food with health potential, being interesting its use by the Latin American population.

## MODULATION OF THE INTESTINAL MICROBIOTA

The components of intestinal microbiota, that is, archaea, fungi, helminths, bacteria and other microorganisms (5), can take two forms: in balance or not. In the first case, known as eubiosis, microbiota tolerates small changes, which may come from the environment, the diet or the water consumed, presenting flexibility to maintain its balance. Cases of major changes, however, such as translocation or growth of a specific bacterial groups, colonization by pathogenic bacteria, use of antibiotics, and changes in lifestyle, lead to imbalance, that is, dysbiosis (60, 61).

Regardless of balance, intestinal microbiota affects the functionality of various organs such as brain, liver, pancreas, intestine, and heart (60, 61). Furthermore, the intestinal microbiota participates in the development and maturation of organs and physiological processes (60), which suggests that modulation of gut microbiota may be a key event for the treatment of diseases and maintenance of health.

Fortunately, modulation of the intestinal microbiota is a reality. Through technological advances, such as interventions with bariatric surgery (62) or fecal transplant (63), or via food (19, 20, 32), the obtained results are promising, showing, in fact, changes in the composition of the intestinal microbiota.

In a longitudinal study that evaluated obese patients undergoing bariatric surgery, body weight reduction and metabolic improvements occurred via modulation of the intestinal microbiota. Compared to individuals of normal weight, patients who underwent bariatric surgery had variation in the *Firmicutes*, *Fusobacteria,* and *Verrucomicrobia* phyla. In addition, after bariatric surgery, the presence of *Akkermansia muciniphila* was observed. It is a species positively associated with lipid metabolism and negatively associated with adipose tissue inflammation and with circulating levels of glucose, insulin, leptin, and triglycerides, which suggests that its presence indicates improvement in the expression of healthy metabolism markers (62).

Fecal microbiota transplantation also shows its potential modulating role. In a double-blind study with 22 obese patients [body mass index (BMI) $\geq$ 35 kg/m$^2$] without associated metabolic changes, such as type 2 diabetes, non-alcoholic hepatitis, and metabolic syndrome, the researches worked by offering the transplantation of fecal microbiota (TMF) of a thin donor using capsules (63).

The consumption of TMF capsules was considered safe. A positive modulation of the intestinal microbiota was observed. At the beginning of the experiment, obese individuals had an intestinal microbiota with a specific profile; however, after TMF intake, it was observed a similarity between the microbiota profile of obese patients and that of the thin donor, as well as changes in beta diversity, that is, changes in the species composition of the microbiota (63).

Reduction of taurocholic acid was also observed in the feces of individuals who received TMF (63), and this change is related to the alterations seen in the composition of the intestinal microbiota. Secondary bile acids, for example, are produced in the colon and are influenced by the microbiota present on it. This production varies according to the colonic microbiota and may contribute to a state of health or disease (64).

In addition, bile acids have antibacterial capacity. They also participate in the progression of diseases associated with changes in intestinal microbiota, such as obesity and gastrointestinal diseases, contributing to the modulation of inflammatory processes and signaling energy metabolism events and through their performance as a biological detergent (64). Hence, there is a two-way path where both gut microbiota influences the production of bile acids, and bile acids contribute to intestinal modulation performance.

In a study that sought to evaluate the role of kefir in the modulation of the intestinal microbiota of mice, it was observed that the consumption of this drink was not able to change the total number of bacteria in intestinal microbiota; however, when evaluating the phyla in the group that consumed kefir, a reduction in Enterobacteriaceae and an increase in *Lactobacillus* and *Lactococcus* contents were observed during the 3-week intervention period; also, a decrease in Firmicutes and Proteobacteria and an increase in Bacteroidetes, *Lactobacillus* and *Lactococcus* at the end of the experiment was observed. On the other hand, there was a significant increase in fecal yeasts after the consumption of kefir (32) (**Table 1**).

Such results indicate that kefir was able to improve the intestinal microbiota of mice that consumed it, with an emphasis on Enterobacteriaceae reduction. This is considered a pathogenic family, usually dysregulated in situations of behavioral and metabolic changes—such as the consumption of diets which are high in fat and low in fiber, during aging, and in cases of inflammation—(32) emphasizing that such eating habits and inflammation are characteristic of obesity (62, 65–67).

Similarly, a study with dogs confirmed that kefir was able to modulate intestinal microbiota. It decreased the Firmicutes:Bacteroidetes ratio and increased the lactic acid bacteria:Enterobacteriaceae ratio, which suggests an improvement in the animal's health. There were also changes in phylum, family and species level, which indicates that kefir was able to modulate the canine intestinal microbiota (20) (**Table 1**).

In humans, modulation of intestinal microbiota also occurs after the consumption of kefir, as discussed by Bellikci-Koyu et al. (19) who investigated individuals with metabolic syndrome that were supplemented with kefir for 12 weeks (**Table 1**). After the intervention, there was a significant increase in *Actinobacteria*, as well as changes in the genera of the phyla Bacteriodetes and Firmicutes, in the group that consumed kefir (19).

This intestinal modulation interferes with metabolic parameters, characteristic of metabolic syndrome, showing improvement in fasting insulin and insulin resistance index (HOMA-IR), and a decrease in pro-inflammatory cytokines, such as TNF-α and interferon-gama (IFN-γ), and in systolic and diastolic pressure. Moreover, a correlation was observed between these parameters and the intestinal microbiota: body weight gain and BMI were positively correlated with the relative abundance of Firmicutes and Proteobacteria and negatively correlated with the relative abundance of Clostridia. Correlations between the composition of the intestinal microbiota and the amount of fat mass, waist circumference, LDL-cholesterol, homocysteine, insulin, and blood pressure were also found (19).

There are many factors that can alter the composition of the intestinal microbiota in humans, such as age, sex, initial formation of intestinal microbiota, food consumption—with emphasis on fiber consumption–, lifestyle, and use of medications—especially antibiotics (1–4). Therefore, the results observed by Bellikci-Koyu et al. (19) are relevant, paving the way for further studies that prove the modulation of the human intestinal microbiota through the use of kefir in individuals with metabolic syndrome.

## KEFIR AND OBESITY

Dysbiosis and other determinants of intestinal microbiota formation in childhood, such as birth via cesarean section or formula feeding, are associated with a higher risk of developing obesity, both in child and adulthood (3, 68). Children treated with antibiotics, specially macrolides, amoxicillin, cefdinir, vancomycin, and tetracyclines (69) had a higher incidence of obesity (3), since antibiotics can alter the composition of the intestinal microbiota, leading to a dysbiotic state (3, 70). In addition, the intestinal microbiota is demonstrably different in obese and eutrophic conditions (62, 71), which reinforces the relationship between intestinal microbiota and obesity. Thus, obesity and overweight, characterized by the excess or accumulation of body fat with a consequent increase in health risk (72), can also be influenced by the intestinal microbiota.

Kefir could act against obesity by inhibiting enzymes related to the digestion of carbohydrates and lipids, which will result in less energy release. For example, Tiss et al. (39) using a fermented drink with kefir produced from soymilk, evaluated the activity of lipase and α-amylase *in vitro* and in the intestine and pancreas of rats under high-calorie diet-induced obesity (**Table 1**).

In the *in vitro* analysis, the study showed the ability of kefir to inhibit α-amylase and pancreatic lipase. Authors assumed that this ability is related to the presence of isoflavone aglycones, such as genistein, daidzein and glycitein, present in the drink after the fermentation process. In the *in vivo* section, the obese animals treated with the fermented drink were more stimulated to perform physical activity. Intestinal and pancreatic lipase activity decreased in the groups receiving kefir, leading to a reduction in total cholesterol and LDL-cholesterol, and an increase in HDL-cholesterol rates, as well as body weight loss. Inhibition of intestinal and pancreatic α-amylase activity and, consequently, decreased blood glucose and protection of liver and kidney tissues from toxicity were also observed after kefir consumption; that is, this fermented drink was able to reverse parameters related to obesity (39).

Bourrie et al. (28) also evaluated kefir regarding the reduction of weight gain and plasma cholesterol in C57BL/6 female mice with obesity induced with a diet of 40% calories from fat and 1.25% cholesterol. The animals received 100 μL of kefir or milk over a period of 12 weeks, with 4 different drinks of traditional kefir and 1 of commercial kefir (28) (**Table 1**).

Among traditional kefir, two types decreased weight gain and plasma cholesterol and one type reduced hepatic triglyceride deposit, which indicates its potential in controlling obesity with improved metabolic function. The difference between the results is due to the different microbiological compositions, viscosity, and pH of fermented drinks (28).

Kim et al. (33) evaluated the anti-obesity effects of kefir in C57BL/6 mice with high-fat diet-induced obesity and non-alcoholic fatty liver disease (**Table 1**). The *Lactobacillus kefiri* DH5 strain was able to decrease body weight, adipose tissue and plasma lipid parameters, acting through the reduction of cholesterol in the intestinal lumen and the upregulation of PPARα in adipose tissue. PPARα is a transcription factor involved in the process of lipid oxidation and consequent metabolism of carbohydrates and lipids, noting that its activation is related to an increase in hepatic steatosis and inflammation (73).

Moreover, the animals that consumed this strain presented a variation in the composition of their intestinal microbiota, with a lower number of Proteobacteria and Enterobacteriaceae, when compared to the non-supplemented animals. These results indicate that *Lactobacillus kefiri* DH5 is a potential probiotic strain for the treatment of obesity (33).

Lim et al. (35) evaluated the effect of exopolysaccharides derived from kefir grains, showing that the beneficial effects found could be related to the viscosity of exopolysaccharides produced by the bacteria present in kefir (**Table 1**). Authors observed that exopolysaccharides were able to suppress obesity *in vitro*, through the supply of adipogenesis. Also, reductions in body weight gain, adipose tissue weight and plasma very low-density lipoprotein cholesterol concentration (VLDL) occurred *in vivo* (35).

Such *in vivo* results were explained by both the presence of bacterial metabolites and by the product's viscosity, which generates appetite suppression and reduces energy consumption as well as glucose and lipid absorption. Furthermore, the supply of kefir exopolysaccharides was able to increase the abundance of *Akkermansia* (35). *Akkermansia muciniphila* undergoes changes according to the diet consumed, modulates the intestinal microbiota, changes inflammatory conditions in adipose tissue, and improves metabolic parameters, like body weight, adiposity, inflammation markers and biochemical parameters, which suggests a great potential for the treatment of obesity (74).

## KEFIR AND DIABETES MELLITUS

The development of diabetes mellitus is associated with low-grade chronic inflammation. Changes in intestinal permeability, which are favored by an imbalance in the intestinal microbiota, encourage the occurrence of this inflammation, which leads to resistance to systemic insulin, with consequent development of diabetes (3, 75). In addition, factors that affect the formation of the intestinal microbiota—such as maternal health during pregnancy, birth via cesarean section, the use of antibiotics during childhood, and the presence of intestinal dysbiosis in childhood—are also related to the development of diabetes (3).

In a study with Wistar rats with monosodium glutamate-induced metabolic syndrome, it was observed that whole milk kefir (via gavage, for 10 weeks) was able to reduce insulin resistance. Such results were attributed to the calcium content consumed by the animals, as well as the bioactive compounds produced during the fermentation of kefir. Moreover, kefir stimulated uptake of glucose by muscle cells, which contributed to the reduction of insulin resistance (37) (**Table 1**).

*Lactobacillus mali* APS1 is a strain isolated from kefir grain that may be useful in the treatment of diabetes. In a study (**Table 1**) with mice consuming a high-fat diet, the administration of this strain was able to reduce serum glucose and HOMA index, increasing the levels of glucagon-like peptide (GLP-1) and butyrate (29). The reduction in the HOMA index indicates glycemic control (76) and the increase in GLP-1 indicates control of hunger and possible protection of pancreatic beta cells, which are insulin-producing cells, essential for maintaining glycidic homeostasis (77). In addition, a recent review discusses the decrease in butyrate content as a characteristic of intestinal dysbiosis in diabetes (78). Therefore, these results are positive.

In humans, a beneficial role of kefir in the treatment of diabetes mellitus has been also observed, as discussed in a work with 60 diabetic patients, aged 35–65 years. The patients were divided into 2 groups: the kefir probiotic group and the conventional fermented milk group, and both received 600 mL/day of the treatment drink for 8 weeks. After the intervention, patients supplemented with kefir presented lower values of fasting glucose and glycated hemoglobin than those that received the other fermented drink (24) (**Table 1**).

The healthy outcomes generated by kefir were attributed to its probiotic composition, mainly *Lactobacillus* and *Bifidobacterium.* These bacteria present a hypoglycemic effect since they stimulate the production of insulinotropic peptides and glucagon-like peptides, leading to an increase in the uptake of glucose by muscle cells, as well as stimulating the production of hepatic glycogen, which uses the glucose available in the bloodstream (24).

## KEFIR AND LIVER DISEASES

Toxins produced by intestinal microbiota and a picture of metabolic endotoxemia—that is, altered intestinal permeability—allow the development of a low-grade chronic inflammation. This inflammatory condition stimulates the activation of toll-like receptors and macrophages, which generates hepatic and systemic inflammation, explaining the relationship between the intestinal microbiota and the occurrence of liver diseases (75).

In addition to its effect on obesity, the consumption of *Lactobacillus kefiri* DH5 presented a hepatoprotective effect. The visual aspect of the liver of the animals that consumed this strain was similar to the animals that did not consume a high-fat diet, as well as presenting, microscopically, less lipid accumulation and smaller fat cells (33).

The hepatoprotective capacity of kefir was also assessed by Golli-Bennour et al. (31) who studied the effect of kefir on hepatotoxicity caused by a pesticide: deltamethrine (**Table 1**). In Wistar rats, the authors observed that deltamethrine altered liver parameters, such as aspartate aminotransferase (AST), alanine aminotransferase (ALT), bilirubin, and cholesterol, when compared to control groups without the pesticide; however, with kefir intake, these parameters were lower. Furthermore, the supply of pesticide and kefir was able to decrease the levels of carbonylated protein and malondialdehyde, as well as increasing the levels of catalase and superoxide dismutase when compared to the group that received only deltamethrine. These protein and lipid peroxidation disorders indicate oxidative stress and toxicity development by the pesticide. On the other hand, kefir was not able to induce oxidative stress by itself, and was able to revert the inflammatory condition (31).

Less histological and DNA damage was also observed in groups treated with pesticide and kefir when compared to the groups that received only deltamethrine, with this histological and genetic disarchitecture resulting from the inflammatory process previously described. It was concluded that kefir was not only able to revert the inflammatory condition but did not generate any damage, since the group treated with kefir alone obtained similar results to the control group. This finding indicates that kefir has a good antioxidant capacity (31), being a potential tool in the prevention and treatment of liver damage caused or mediated by oxidative stress.

The effect of *Lactobacillus mali* APS1, isolated from sugary kefir grains, was also tested in the fatty liver of rat fed with a high-fat diet, showing a significant reduction in weight, weight gain, hepatic lipid accumulation, and serum levels of AST and ALT. This strain acted through changes in intestinal microbiota composition, reducing the proportion of bacteria associated with non-alcoholic liver diseases and regulating lipid metabolism and oxidative stress response, which leads to suppression of hepatic steatosis progression (29).

## KEFIR AND CARDIOVASCULAR CHANGES

Cardiovascular diseases are also related to obesity's intestinal dysbiosis (4). In addition, changes in the intestinal microbiota can lead to the production of compounds such as trimethylamine N-oxide (TMAO), which increase the risk of developing cardiovascular diseases (79, 80).

Tung et al. (40) evaluated the effect of kefir peptides in Apo E –/– mice with high-fat diet-induced atherosclerosis (**Table 1**). After a 12-week intervention, the consumption of kefir led to a decrease in the evolution of atherosclerotic lesions, with less lipid deposition at the root of the aorta and suppression of the inflammatory immune response, through a reduction in oxidative stress, the accumulation of macrophages and the release of IL-1β and TNF-α cytokines. Moreover, kefir prevented the endothelial adhesion of monocytes, decreasing the evolution of the atherosclerotic lesion. These results indicate that the consumption of kefir could be useful in the prevention and treatment of atherosclerosis (40).

One of the risk factors for the occurrence of cardiovascular diseases is dyslipidemia. In this sense, in the host, there is less diversity of intestinal microbiota and a greater chance of dysbiosis. That is, a greater chance of inflammation and changes in intestinal permeability is observed, with negative consequences for the health of the host (81).

In dyslipidemia, changes in the production of short-chain fatty acids and bile acids have been observed. Short-chain fatty acids are metabolite substrates that participate in energy production, lipogenesis, gluconeogenesis, and cholesterol synthesis. On the other hand, primary bile acids can bind to the farnesoid X receptor, and this molecule is also related to the development of obesity. Both factors participate in lipid metabolism and intestinal microbiota change (81), indicating that modulation of intestinal microbiota may be a therapeutic alternative to prevent dyslipidemia.

Kefir may be an option in the treatment of dyslipidemia. Choi et al. (30) observed that kefir prevented the increase of lipid parameters in mice fed with an obesogenic diet, proposing that kefir acted by preventing lipid intestinal absorption (**Table 1**). In humans, the consumption of kefir drink (250 ml) for 8 weeks also improved the lipid profile, which was similar to the control group that consumed low-fat milk. This improvement in the lipid profile was related to the loss of body weight, achieved with the consumption of kefir, as well as to the changes generated in the intestinal microbiota, which led to an increase in the production of short-chain fatty acids and bile acids (23) (**Table 1**); however, it is noteworthy that the amount of kefir offered and the intervention time are fundamental to achieve the desired result for improving dyslipidemia (27) (**Table 1**).

## KEFIR AND IMMUNITY

The correct formation of intestinal microbiota during childhood is fundamental for the complete development of the baby, since the intestinal microbiota is part of the immune system, being important especially in the first months of life, when the rest of the immune system is still forming. In this context, premature babies may have immaturity in the immune, respiratory and neurological systems, suggesting a possible relationship between them (3). In addition, the immune system and the intestinal microbiota play a symbiotic function, maintaining a picture of non-inflammatory homeostasis: in cases of intestinal dysbiosis, there is an activation of the immune system, which leads to changes in the host's immunity. These changes can impair the maturation of the innate immune system or lead to autoimmune diseases, such as type 1 diabetes (61).

The immunomodulatory capacity of kefir has been tested in BALB/c mice by using different concentrations of commercial kefir (diluted at 1/10, 1/50, 1/100, or 1/200 proportions) and pasteurized kefir (diluted at 1/6, 1/10, 1/50, 1/100 proportions). The results show that kefir modulates the immune response in a dose-dependent manner by stimulating intestinal IgA production and inhibiting the Th1-type immune response (41) (**Table 1**).

Le Barz et al. (34) also evaluated kefir for probiotic strains with immunometabolic properties (**Table 1**). *Lactobacillus rhamnosus* Lb102 and *Bifidobacterium* Bf141 showed good results in the treatment of obesity and in metabolic syndrome, with a reduction in visceral fat and inflammation, and an improvement in glucose tolerance and insulin sensitivity. These results were explained by a modulation of the intestinal microbiota and the maintenance of intestinal integrity by the probiotics (34).

In humans, the action of kefir on intestinal integrity has also been observed. A study encompassing 28 healthy, overweight and asymptomatic adults found that the use of kefir modified serum zonulin concentration (26) (**Table 1**). Zonulin is a protein that participates in the integrity of tight junctions, that is, the maintenance of intestinal integrity. In the presence of tight junctions, there is control of the passage of molecules through the paracellular content, which prevents the development of inflammatory processes and the occurrence of diseases. However, the increase in zonulin production leads to loss of function of the intestinal barrier with consequent passage of antigens through the paracellular content and activation of the innate immune response (82).

The probiotic capacity of kefir was able to modulate intestinal microbiota composition, which prevented excessive intestinal permeability by increasing serum zonulin concentrations. Consequently, there was a control of low grade chronic inflammation generated in cases of altered intestinal permeability, as has been proposed in obesity (26).

## KEFIR AND NEUROLOGICAL CHANGES

Neurological changes have multifactorial causes and intestinal microbiota also participates in this process. The composition of intestinal microbiota impacts the health of the microglia and the development of neuronal circuits, which contribute to neurological health (4). In addition, individuals with autism have a characteristic intestinal microbiota, which strengthens the relationship between intestinal microbiota and neurological disorders (1–4).

Noori et al. (36) assessed the role of kefir, fermented in both soy and cow's milk, in the treatment of depression, anxiety and cognitive impairment in an animal model subjected to stress due to the use of nicotine (**Table 1**). For this purpose, the animals were submitted to elevated plus maze (EPM) to assess anxiety, open field test (OFT) to assess locomotor activity and anxiety and forced swim test (FST) to assess depression. Both types of kefir were able to improve anxiety, decrease the severity of depression, and improve cognitive function throughout the treatment. Since kefir is a food rich in tryptophan, which is the precursor of serotonin, it is believed that kefir may be able to act on serotonin metabolism (36). Depression is related to changes in neuroplasticity being serotonin a neuromodulator capable of stimulating the development of neuronal plasticity (83). So, modulation in serotonin is a classic way of treating depression (36, 83).

Kefir has been reported to protect neurons from degradation through its anti-inflammatory capacity. Additionally, kefir may be able to activate receptors in the brain that stimulate learning and memory. So, in view of the cognitive improvement found, kefir can be potentially used for both prevention and treatment of depression and anxiety, especially in cases related to nicotine consumption. The authors believed that the results can be extrapolated to humans; however, further studies are needed to confirm this hypothesis (36).

The ability to modulate the intestinal microbiota and, consequently, anxiety and depression also suggests a positive role of kefir in these diseases (38, 42) (**Table 1**). Animals fed with kefir presented a specific intestinal microbiota composition, which presumably acts positively on the gut-brain axis. In addition, through analysis of the microbiome, authors suggest that kefir was able to stimulate the production of the gamma aminobutyric acid (GABA). It is hypothesized that *Lactobacillus reuteri* possibly converted 2-oxoglutarate to glutamate, which was subsequently converted into GABA, because of modulation of the intestinal microbiota by kefir, that leads to an increase in the production of *Lactobacillus reuteri*, a bacterial strain with benefits to the host's immune and metabolic system (42).

Kefir was also evaluated in an animal model simulating human depression, with stress induced through 7 stressors during 6 weeks. Mice supplemented with *Lactobacillus kefiranofaciens* ZW3 strain, isolated from kefir, had more movement (which indicates an increase in the ability to explore the environment and socialize), a greater preference for sucrose (which indicates that the animals returned to have pleasure) and a higher amount of water in their stools (which indicates a lower probability of having constipation, which is a condition associated with the occurrence of depression). In addition, there was an improvement in tryptophan metabolism, an increase in anti-inflammatory cytokines, a reduction in pro-inflammatory cytokines, and changes in the composition of the intestinal microbiota, with an increase in Actinobacteria, Bacteroides, Lachnospiraceae, Coriobacteriaceae, Bifidobacteriaceae *and Akkermansia,* and reduction in Proteobacteria (38).

All of these benefits indicate that the consumption of kefir was able to alter the metabolic pathways that led to the development of depression; however, further studies are needed to identify the optimal dosage to be consumed, so that the benefits of kefir are acquired by the host that consumes it (38).

The role of kefir on neurological diseases has also been studied in humans. For example, Ozcan et al. (25) assessed the consumption of kefir on sleep quality, quality of life and depression in post-menopausal women (**Table 1**). The consumption of kefir was positively correlated with the quality of life and quality of sleep, which might be a simple strategy, with good cost benefit and an alternative for the treatment of menopause; however, there were no promising results regarding to depression (25).

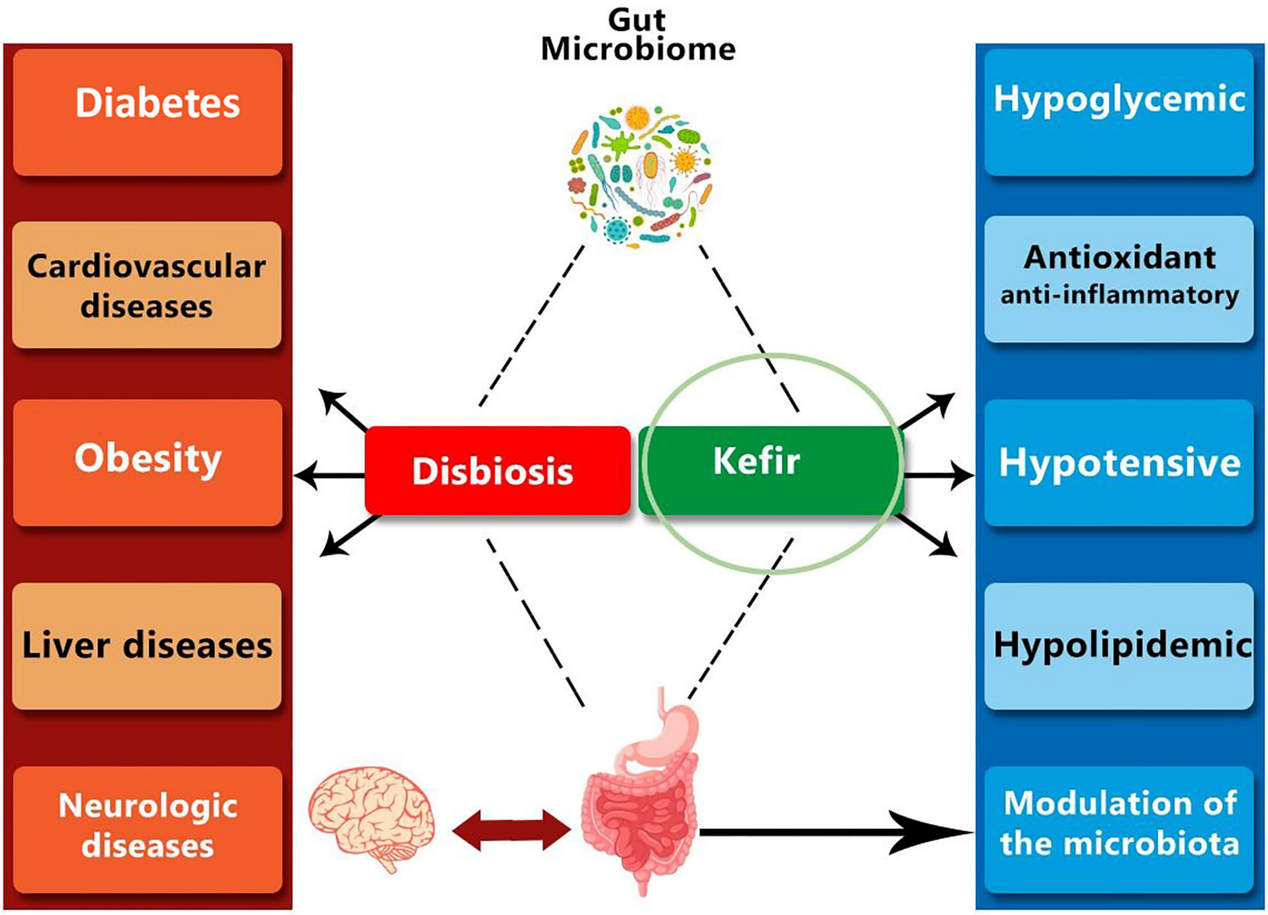


**FIGURE 1 |** The dynamics of changes in the intestinal microbiome can lead to undesirable modifications, such as dysbiosis, triggering low-grade inflammation-related chronic diseases. On the other hand, the use of probiotics and fermented drinks, such as kefir, can have an impact on the regulation of organism homeostasis, with a direct effect on the gut-brain axis, being a possible strategy for the prevention of metabolic diseases.

Studies that evaluate the psychobiotic activities of kefir on depression may be of great relevance, since the consumption of most antidepressants can generate side effects such as weight gain. In a study performed in Canada, for example, there was an association between obesity and high prevalence of antidepressants' prescription. Moreover, a greater prescription of antidepressants in the most severe grades of obesity (classes II and III) is commonly observed. The use of kefir, in this case, is particularly interesting since the use of medications can worsen obesity and decrease the chance of a positive response to treatment (84). Kefir could also be useful for the care of obese and depressed patients, although more intervention studies should be undertaken to properly evaluate its potential.

## CONCLUSIONS

The inclusion of kefir in the Latin American market presents a good alternative as an adjuvant therapy in non-communicable diseases and may display an economic prognosis, since, in 2016, the value of kefir market in Latin America was amounted to 150.8 million U.S. dollars and it is expected to rise to about 204.7 million U.S. dollars by 2021 (85).

Alterations in gut microbiota, in the form of dysbiosis or metabolic endotoxemia shows systemic activity (**Figure 1**), since they allow the occurrence of low-grade chronic inflammations that affect the organism as a whole.

The modulation of the intestinal microbiota, thus, stands out as a good strategy for the prevention and treatment of diseases. The use of fermented foods with probiotic activity is a nutritional alternative to drug treatments, and kefir, due to the absence of harmful effects regarding its consumption—in animals and humans–, low cost, ease of preparation, and microbiological composition—rich in bioactive compounds, metabolites, and peptides—stands out as a potential food with functional benefits. Besides that, promising effects as immunomodulatory, hypocholesterolemic, antihypertensive and glycemic control are expected. However, it is mandatory to deepen into the molecular mechanisms and the microorganisms involved, and more well-controlled human intervention studies are required.

**TABLE 2 |** Microbiological and nutritional characterization of the kefir used in the different studies and production protocols (when available).

| References | Concentration | Microbiological and nutritional composition | Production protocol |
|---|---|---|---|
| Bellikci-Koyu et al. (19) | – | - Culture DC1500I;<br>- *Lactococcus lactis* subsp. *lactis, L. lactis* subsp. *cremoris*, *L. lactis* subsp. *diacetylactis, Leuconostoc mesenteroides* subsp. *cremoris, Lactobacillus kefiri, Kluyveromyces marxianus, Saccharomyces unisporus*. | - Produced in whole milk 3.5%;<br>- Distribution to volunteers twice a week. |
| Bourrie et al. (28) | 1% (w/v) | For commercial kefir:<br>- *Streptococcus thermophilus*, *Lactobacillus delbrueckii subsp. bulgaricus*, *L. casei*, *L. acidophilus*, *L. delbrueckii subsp. lactis*, *L. rhamnosus*, *Bifidobacterium lactis*, *Lactococcus lactis* subsp. *lactis* biovar *diacetylactis*, *L. lactis* subsp. *cremoris*, *Leuconostoc mesenteroides* subsp. *cremoris*;<br>- $8.0 \times 10^6$ CFU/ml.<br>For traditional kefir:<br>- No information. | - Produced daily in cow's milk 2%;<br>- Fermentation at 22°C for 18 h. |
| Chen et al. (29) | – | - *Lactobacillus mali* APS1;<br>- $10^7$ to $10^{10}$ CFU/mg. | - Fermentation at 30°C for 12 h. |
| Fathi et al. (23) | – | – | - Produced by Fars Pegah Dairy Co., Shiraz, Iran. |
| Golli-Bennour (31) | – | - Traditional Tunisian culture, containing lactic acid bacteria;<br>- Predominant population are lactic acid bacteria ($9.5 \pm 0.15 \times 10^{10}$ CFU/g) and yeast ($9.2 \pm 0.14 \times 10^6$ CFU/g). | - Daily production. |
| Kim et al. (32) | 10% | - Each mL contains: 9.62 ± 0.19 Log CFU of lactic acid bacteria, 9.52 ± 0.12 Log CFU of acetic acid bacteria and 7.67 ± 0.30 Log CFU of yeast. | - Fermentation at 25°C for 24 h. |
| Kim et al. (33) | 5% (w/v) | - *Lactobacillus kefiranofaciens, L. kefiri, L. lactis, Leuconostoc mesenteroides*. | - Fermentation at 25°C for 24 h. |
| Kim et al. (20) | 10% | - Each mL contains: 9.32 ± 0.23 Log CFU of lactic acid bacteria and 7.12 ± 0.36 Log CFU of yeast. | - Fermentation at 25°C for 24 h. |
| Lim et al. (35) | 1:10 (w/w) | - Grains from the KU Center for Food Safety, College of Veterinary Medicine, Konkuk University. | - Produced in UHT milk;<br>- Fermentation ate 30°C overnight;<br>- Production for 6 continuous weeks followed by lyophilization and storage at - 20°C. |
| Noori et al. (36) | – | - pH: 4.8 | - Cow's milk UHT or soy milk;<br>- Fermentation at 25°C for 24 h followed by storage at 4°C to interrupt the process. |
| Ostadrahimi et al. (24) | – | - *Streptococcus thermophiles*, *Lactobacillus casei*, *L. acidophilus, Bifidobacterium lactis*;<br>- Fat: 0.3%. | - Weekly production. |
| Ozcan et al. (25) | – | - Kefir produced by Altinkiliç Company, Turquia;<br>- No sugar and no flavor. | - Stored at 4°C and delivered to volunteers weekly. |
| Praznikar et al. (26) | – | - *Lactobacillus parakefiri*, *L. kefiri*, *L. kefiranofaciens* ssp. *kefirgranum*, *Kluyveromyces marxianus*, *Kazachstania exigua*, *Rhodosporidium kratochvilovae;*<br>- 80% water;<br>- pH 4.03. | - Produced by Ljubljanske mlekarne (Ljubljana, Slovenia) |
| Rosa et al. (37) | 5% (w/w) | - Lactic acid bacteria: $2.78 \times 10^7$ CFU/ml;<br>- Yeast: $2.94 \times 10^8$ cell/ml;<br>- Lactic acid 0.806 ± 0.04 g/100 g;<br>- Fat: 3.03 ± 0.16 g/100 g;<br>- Protein: 3.03 ± 0.01 g/100 g;<br>- pH 4.10 ± 0.10. | - Produced in pasteurized milk (3.5% protein, 5% carbohydrate and 3% fat);<br>- Fermentation at 25–28°C for 24 h. |
| St-Onge et al. (27) | – | – | - Produced by Liberty Co, Candiac, Québec. |
| Sun et al. (38) | – | - Culture Collection Center of the Institute of Microbiology, Chinese Academy of Sciences (accession number CGMCC2809);<br>- *Lactobacillus kefiranofaciens* ZW3. | – |

*(Continued)*

**TABLE 2 |** Continued

| References | Concentration | Microbiological and nutritional composition | Production protocol |
|---|---|---|---|
| Talib et al. (43) | 10% (w/v) | - Mainly: *Lactobacillus harbinensis*, *L. paracasei*, *L. plantarum*;<br>- All: *L. harbinensis* B22, HBUAS5305, NBRC 100982, FQ003; *L. brevis* HDRS2; *L. sp* MS6; *L. plantarum* Gt2, ZDY36a, HBUAS52249, NWAFU1558, Akhavan-Q3, Y-2-9, MSD1-4, DSR M2, LQ80; *L. paracasei* HBUAS52231, HBUAS53273; *L. casei* YQ116, H19.9. | - Produced in water solution with brown sugar;<br>- Fermentation at room temperature for 24 h. |
| Tiss et al. (39) | 5% (w/v) | – | - Soy milk;<br>- Fermentation at 24 h;<br>- Storage at 4°C (Produced every 7 days before consumption). |
| Tung et al. (40) | 10% (w/v) | – | - Fermentation at 20°C for 20 h;<br>- Kefir undergoes two fermentation processes: First at 5% w/v concentration and then at 10% w/v concentration. |
| Vinderola et al. (41) | – | – | - Produced in pasteurized milk with 1.8% fat by Les Produits de - Marque Liberté (Candiac, Québec, Canada) |
| Wouw et al. (42) | 2% (w/v) | – | - Produced in whole milk from Irish cows;<br>- Fermentation at 25°C for 24 h. |

*Where: CFU, colony forming unit; g, gram; mg, milligram; mL, milliliters; pH, hydrogen potential; UHT, ultra-high temperature; v, volume; w, weight.*

## FUTURE PERSPECTIVES

Kefir is a low-cost fermented product that is gaining interest due to its potential impact in the prevention and treatment of non-communicable diseases. Yet, the microbiological composition of kefir varies according to the geographical location, fermentation matrix (water solution with sugar, whole cow's milk, skimmed cow's milk, goat's milk, donkey milk, among others), environmental conditions (temperature and fermentation time), and grain (g)/drink (mL) ratio used in the fermentation of the product. Also, the presence of yeasts and their proportion in the drink, as well as the production conditions, among others, can generate drinks with different compositions and characteristics (**Table 2**). Consequently, as a future perspective, it is believed that the next studies will focus on the development of a unified production protocol, as well as on the determination of which microorganisms should be present in the starter culture and the drink, in order to consider that the final product, in fact, can be classified as a kefir.

## STUDY LIMITATIONS

As previously discussed, there are many factors involved in the production and dosage of kefir. This variability hinders the reproducibility of the results discussed in this narrative review and impairs future meta-analyses, considering this factor as a limitation.

## AUTHOR CONTRIBUTIONS

MCGP has been responsible for conception of this article. MCGP and MMD have been involved in aquisition, analysis and interpretation of data, as well as in drafting the manuscript, and revising it critically. JAM and FIM have revised the manuscript critically, giving important intelectual content. All authors have read and approved the final manuscript.

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REVIEW
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# Review: The Consumption of Ultra-Processed Foods and Non-communicable Diseases in Latin America

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The objective of this article is to assess current trends in Latin America with respect to the consumption of ultra-processed foods and non-communicable diseases. This review addresses the rapid growth of the ultra-processed foods market in Latin America which, along with other social and environmental factors, has been shown to be highly influential in the prevalence of non-communicable diseases such as obesity, type 2 diabetes, hypertension and cardiovascular disease, cancer, and all-cause mortality. Ultra-processed foods represent a health concern for a number of reasons. They are generally calorically dense and high in sodium, sugar, and saturated and *trans* fats, and low in fiber and protein. Additionally, they may contain additives and neoformed compounds that affect health in ways that have not been adequately researched. Furthermore, the packaging of ultra-processed foods may contain hormone disruptors whose effects on humans are not entirely clear. Associations between ultra-processed foods and cardio-metabolic dysfunction, as well as several plausible mechanisms, will be evaluated.

**Keywords: ultra-processed foods, chronic disease, metabolic disease, cardiovascular disease, diabetes, Latin America**

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## INTRODUCTION

Ultra-processed foods (UPF) are food products that have been manufactured through the use of multiple industrial techniques (1). These techniques can include hydrogenation, extrusion, pre-frying and/or the addition of colorants, emulsifiers, and preservatives. Employing ultra-processing techniques allows manufacturers to create products that are hyper-palatable, cheap to produce, easy to market, and able to sit on store shelves or remain in the kitchen cabinet for years without spoiling.

While these foods are not new, their consumption is becoming increasingly widespread in Latin America. At the same time, the prevalence of excess adiposity and the cardio-metabolic sequelae commonly associated with it have also risen (2–4). Latin Americans are becoming increasingly westernized in their food preferences, and the health consequences of this cultural shift are overwhelmingly harmful.

Evidence from cross-sectional and prospective studies points to a strong association between UPF consumption and overweight/obesity (5–7), hypertension (8), cardiovascular disease (CVD) (9), type-2 diabetes (10), cancer (11), and all-cause mortality risk (12–14). UPF deliver a poor

**TABLE 1** | NOVA food classification system according to its level of processing.

| Food classification | Food example |
|---|---|
| Unmodified or minimally processed foods | Fresh/frozen fruits and vegetables, fresh meat, fresh milk, grains, eggs, fresh fish, nuts, granola, rice, beans, tubers, whole grain flour, herbs and spices, etc. |
| Processed foods as processed culinary ingredients | Extracted vegetable oils, substances isolated or modified by various preservation methods, salt, sugar, oil, fat, flour, white rice, pasta, butter extracted from fresh milk, extracted honey, starches extracted from corn and other plants, etc. |
| Processed foods | Vegetables and legumes modified or preserved with additives, salty or sugary nuts and seeds, canned meats and fish, canned fruits, fresh whole grain breads, fresh cheese, etc. |
| Ultra-processed foods | Industrial formulas with multiple ingredients, including: soft drinks, energy drinks, fruit nectar drinks, alcoholic beverages, distilled beverages, beer, refined cereal, breads, ready-to-eat meals, instant cereals, cookies, candy, sugary drinks, margarine, mayonnaise, chips, instant soups, confectionery, jams, chocolate, ice cream, cake, energy bars, dairy drinks, yogurts, processed cheese, pizza, pasta dishes, instant sauces, processed meat products, meat analogs, infant formulas, weight loss products such as meal replacement shakes and powders, etc. |

*Source: Adapted from Monteiro et al. (1).*

nutrient profile (15) and their additives disrupt gut function (16–18). The packaging, while attractive, may be adding additional health risks (19, 20). To date, only one randomized controlled trial assessing the impact of UPF on cardio-metabolic health has been published, and the findings suggest that UPF consumption can lead to passive overeating and subsequent weight gain (21).

The objective of this article is to assess current trends in Latin America with respect to UPF consumption and cardio-metabolic diseases, highlighting the importance of this unfavorable connection as well as possible mechanisms.

## AN OVERVIEW OF ULTRA-PROCESSED FOODS

Multiple classification systems have been developed for the purpose of distinguishing the level of processing a food has received. For research purposes, the most commonly utilized system (22) is the NOVA food classification system (23). This system places foods into one of four categories: unprocessed/minimally processed, processed culinary ingredients, processed foods, and ultra-processed foods (**Table 1**).

Foods which carry the distinction of being ultra-processed share a few defining characteristics. From the point of view of the consumer, they are convenient, hyper-palatable, and cheap. From the manufacturer's point of view, these foods are economical to produce, easy to advertise, and have a long-shelf life, all of which favor profit. Nutritionally, high concentrations of sodium, sugar, hydrogenated oils, and additives are common to UPF. They tend to be energy dense and contain more saturated fat, *trans* fat, and free sugar along with lower levels of fiber, protein, sodium, and potassium when compared to minimally processed foods (24).

Critics of the NOVA system claim that its simplicity is inadequate to contribute to dietary guidelines, and that a dietary pattern which contains UPF may not necessarily be micronutrient-poor and hyper-palatable (25).

## CONCERNS SURROUNDING THE INTAKE OF ULTRA-PROCESSED FOODS

Putting whole foods through any type of processing fundamentally alters their food matrix, typically in a detrimental manner. For one, UPF are generally dense in calories from sugar and saturated fat but poor in fiber and micronutrients, a combination which contributes unfavorably to a healthy diet pattern (15). They are also more likely to contain *trans* fats, which have been definitively classified as harmful for cardiovascular health (26).

The additives found in these foods also have questionable effects on health. Carrageenan and carboxymethylcellulose (CMC), thickening agents commonly employed in meat and dairy product formulations, have been shown to be associated with intestinal inflammation (18). It has been posited that the underlying mechanisms are likely to involve damage to the endothelial barrier, upregulation of pro-inflammatory cytokines, and interference with the immune response. Non-caloric artificial sweeteners, often used in the place of sugar in products that are advertised as being low in sugar or sugar-free, may also contribute to metabolic dysfunction by causing gut dysbiosis (16). Emulsifiers, a ubiquitous class of stabilizers commonly added to processed foods, have been shown to induce metabolic syndrome and colonic inflammation in mice (17).

The packaging of ultra-processed and processed foods adds an additional layer of concern. Synthetic compounds like bisphenol A (BPA) are omnipresent in food packaging, and BPA in particular has been shown to act as a xenohormone with the potential to impair reproductive function in men and increase cancer risk (19). While some manufacturers have responded to the public's concerns about BPA exposure by switching to bisphenol S (BPS), research indicates that this alternative may actually be more readily absorbed into the body (27). Phthalates are another class of synthetic chemicals commonly used in food packaging, and like BPA and BPS, they have the potential to act as xenohormones. Among individuals in the National Health and Nutrition Examination Survey (NHANES) 2013–2014 cohort, intake of UPF was correlated with increased exposure to phthalates (20).

Nevertheless, it is important to recognize that food processing has provided many benefits to society. Nutritious foods such as whole grain bread, canned beans, and frozen spinach are all examples of processed foods. Processes such as pasteurization decrease the risk of microbial contamination. Applying heat to food prior to consumption makes many foods easier to digest, and it has been theorized that cooking with fire contributed significantly to human evolution and advancement (28). Phytonutrients such as lycopene are significantly more bioavailable after heat-processing (29). The enrichment and fortification of processed foods provides micronutrients which certain vulnerable populations may have trouble consuming sufficient amounts of (30, 31). Additionally, many processed foods are designed to cater to specific sub-populations with chewing and swallowing difficulties, such as people living with dysphagia (32). Processing food is not inherently bad, but the displacement of minimally processed foods in favor of these foods warrants concern.

## CONCURRENT TRENDS IN THE INTAKE OF ULTRA-PROCESSED FOODS AND CHRONIC DISEASES IN LATIN AMERICA

The consumption of UPF is growing exponentially in Latin America countries (2). In a joint effort, the World Health Organization (WHO) and the Pan American Health Organization (PAHO) conducted an epidemiological study in 13 countries throughout Latin America with the goal of determining how the increasing prevalence of UPF in Latin American markets was affecting the chronic disease burden of these countries (2). The following countries were included in this study: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, Mexico, Peru, Uruguay, Venezuela, and Guatemala. Between 2000 and 2013, the retail sales of ultra-processed products, which encompasses both foods and beverages, from fast-food outlets increased in almost all 13 countries, with Argentina and Venezuela being the exception due to financial crises (**Figure 1**).

Overall, there is a positive association between annual retail sales of UPF and the prevalence of obesity in Latin America (2). **Figures 2**, **3** depict this correlation. In Brazil, the increasing intake of processed foods, sugar-sweetened beverages (SSBs), and refined carbohydrates has occurred in tandem with the rising prevalence of overweight and obesity in that country (3). These concurrent trends have been identified as major causes of death from cardio-metabolic diseases in Brazil. Between 2002 and 2009, intake of UPF in Brazilian households increased from 20.8% of total calories to 25.4% (33). As intake of UPF increased, intake of minimally processed foods also decreased.

As retail sales for fast foods have risen in Latin America, so has the prevalence of diabetes (34).

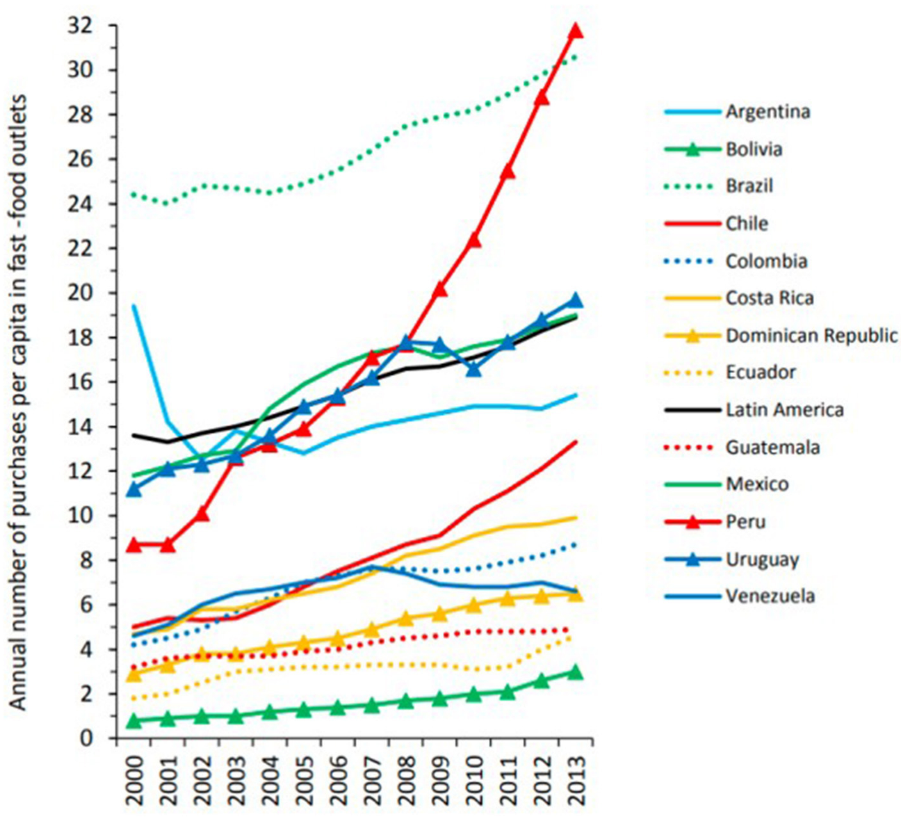


**FIGURE 1 |** Annual number of purchases per capita in fast-food outlets in 13 Latin American countries, 2000–2013. Purchases refers to single, completed purchases (which may include more than one meal). Fast-food outlets are defined as establishments offering limited menus prepared quickly where customers order, pay, and pick up from a counter. Data are from the Euromonitor Passport Database (2014). Source (2).

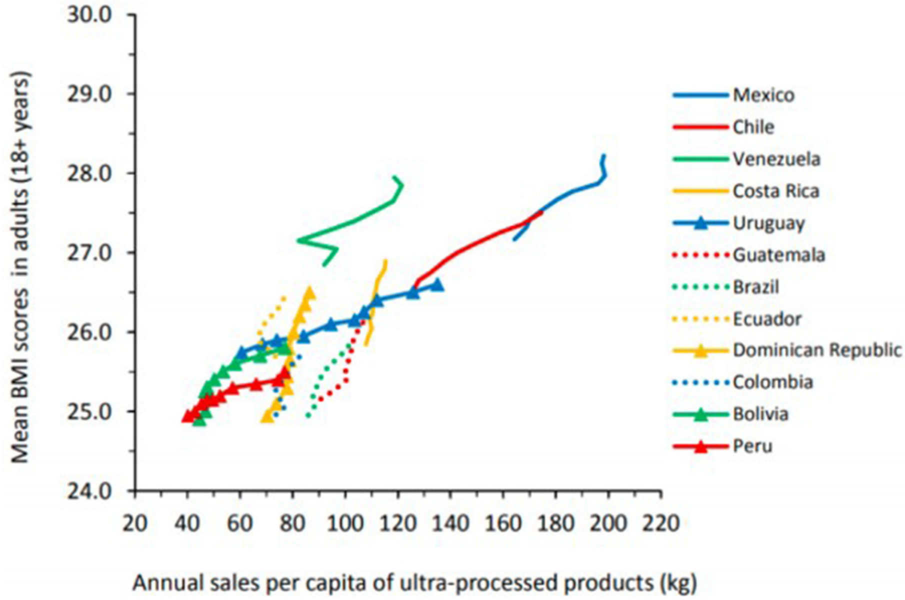


**FIGURE 2 |** Annual sales per capita of ultra-processed food and drink products and mean body mass index (BMI) scores in 12 Latin American coutries, 2000-2009. Ultra-processed products here include carbonated soft drinks, sweet and savory snacks, breakfast cereals, confectionary (candy), ice cream, biscuits (cookies), fruit and vegetable juices, sports and energy drinks, ready-to-drink tea or coffee, spreads, sauces, and ready-meals. Source (2).

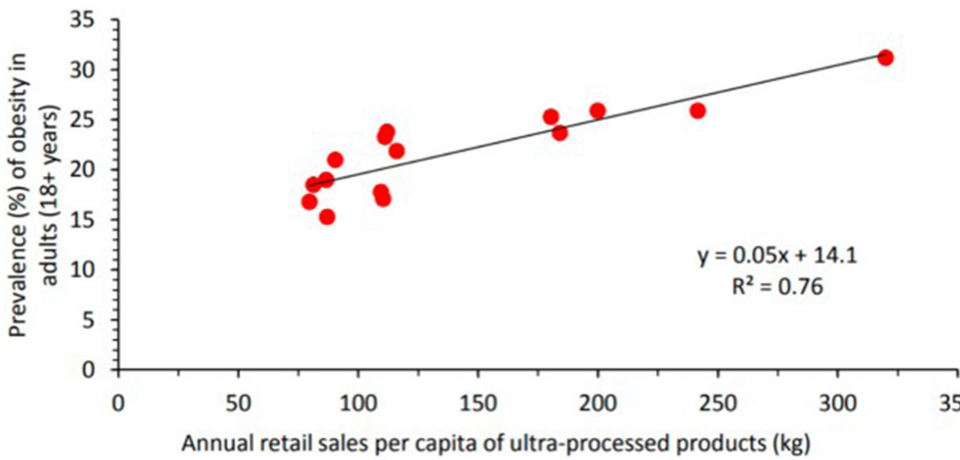


**FIGURE 3 |** Annual retail sales per capita of ultra-processed food and drink products and prevalence of obesity (%) in adults in 14 countries (Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, Guatemala, Mexico, Peru, Uruguay, Venezuela, Canada, and the United States) in the Americas, 2013. Ultra-processed products here include carbonated soft drinks, sweet and savory snacks, breakfast cereals, confectionary (candy), ice cream, biscuits (cookies), fruit and vegetable juices, sports and energy drinks, ready-to-drink tea or coffee, spreads, sauces, and ready-meals. Source (2).

Within the span of the last decade, the prevalence of diabetes rose from 10.8 to 13.5% in Mexico, 6.4 to 10.4% in Brazil, and 5.7 to 8.6% in Chile (**Figure 4**). Argentina and Venezuela also experienced moderate (<1%) increases in diabetes prevalence. The only country to experience a notable decline in diabetes prevalence was the Dominican Republic, where there was a 2.6% reduction in diabetes prevalence. This ecological correlation between UPF sales per capita and diabetes prevalence invites discussion about a potential causal relationship between these two factors.

An assessment of diet quality conducted among children in the Bogotá School Children Cohort provides evidence that the nutrient profiles of UPF consumed in this region tend to be incongruent with good health (35). Specifically, these foods are lower in omega-3 polyunsaturated fatty acids, calcium, zinc, and vitamins A, C, E, and B12 when compared to unprocessed or minimally processed foods consumed in the same population.

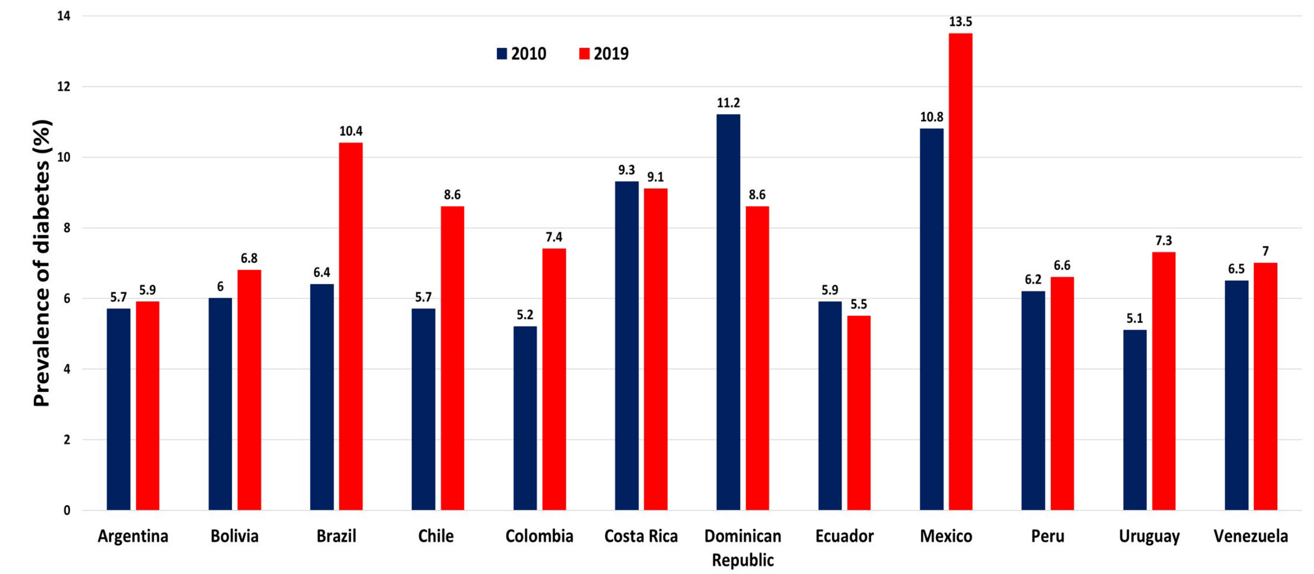


**FIGURE 4 |** Prevalence of diabetes per country, 2010 and 2019. Data are from World Bank Database. International Diabetes Federation, Diabetes Atlas (2021). Source (34).

In Chile, UPF have been shown to contribute 58.6% (standard error 0.9%) of all added sugars consumed in the diet in a national sample (36). Soft drinks, fruit juices and flavored beverages, and cookies, cakes, and pies were the most commonly consumed high-sugar UPF among Chileans. Excessive consumption of added sugars has been correlated with increased cardiovascular disease risk (37).

This is concerning, particularly in the context of the latest data on food intake in Latin America which was collected as part of the Latin American Study of Nutrition and Health (ELANS) study (38). In this cross-sectional study, 24-h recall data from 9,218 adolescents and adults living in Argentina, Brazil, Chile, Colombia, Costa Rica, Ecuador, Peru, and Venezuela was assessed for intake of foods associated with non-communicable disease (NCD) risk. It was determined that <3.5% of respondents were meeting the WHO recommendations for intake of vegetables, whole grains, nuts, yogurt, and fish. A mere 7.2% of participants reported that they were consuming sufficient quantities of fruits and vegetables. If the trend in UPF intake continues, the number of Latin Americans who are eating a diet that is protective against NCDs will decline, and the prevalence of NCDs will continue to escalate.

While Venezuelans do not appear to be spending much on ultra-processed foods in the retail sector, it is worth noting that the typical Venezuelan diet still contains significant amounts of ultra-processed foods. Goodman and colleagues (39) collected data from a nationally representative sample of Venezuelans between 2014 and 2017 and found that traditional foods such as arepas and yucca remain staples in the Venezuelan diet and have not been replaced by more Western foods. In this country, Western fare like French fries and burgers are consumed once a month or less by three quarters of the population. Nevertheless, with a median consumption of one per day (interquartile range: IQR: 0.43–3 portions per day), the traditional foods that were most consumed in Venezuela—arepas and cheese—could still be classified as ultra-processed foods according to the NOVA classification system. Interestingly, there was a negative correlation between the prevalence of hypertension and type 2 diabetes and intake of arepas. This may be attributable to post-diagnostic changes in behavior.

## SOCIAL DETERMINANTS IN THE SALES INCREASE OF ULTRA-PROCESSED FOODS IN LATIN AMERICA

The following factors all contribute to the observed increase in the sale of ultra-processed foods in Latin-American countries: urbanization, foreign investment, and market deregulation. While the *volume* of sales of ultra-processed foods is higher in high-income countries like the United States, the *rate* of sales growth is higher in lower-income countries. It is evident that middle- and low-income countries are becoming increasingly attractive markets for the producers of ultra-processed drinks and foods.

The growing presence of UPF in grocery stores in Latin America places consumers in an environment that is challenging to navigate for several reasons (40). Firstly, relative to fresh foods, UPF tend to be sold at lower prices, an important factor for the millions of Latin Americans who are living in precarious financial situations. Secondly, the processed food labels often contain misleading health claims which may sway consumers to purchase a particular product with the aim of improving their health when in reality that product may be affecting their health negatively. And finally, food advertisers often aim their marketing tactics at children who are particularly susceptible to the effects of media (41). While television advertisements for ultra-processed foods and beverages abound on Latin American television, advertisements of minimally or unprocessed foods are difficult to come by (42).

Of note, the trends in intake of UPF vary country to country. As previously mentioned, economic crises have stymied the growth of the UPF market in Argentina and Venezuela (2). Meanwhile, daily per capita sales of SSBs is approximately 200 milliliters (ml) per capita per day in Colombia, while in Mexico that number is closer to 450 ml per capita per day (4). Per capita daily junk food sales is also twice as high in Mexico as it is for all of Latin America, while Chile is experiencing the fastest increase in sales of both SSB and junk food (4). While the overall sales volume varies widely between countries, the trend of reducing intake of traditional foods in favor of ultra-processed foods transcends nations.

## THE LINK BETWEEN THE INTAKE OF ULTRA-PROCESSED FOODS AND CHRONIC DISEASES

The displacement of whole foods in the diet by UPF is becoming increasingly associated with all forms of disease risk.

### Overweight/Obesity

The association between the intake of UPF and the risk of being overweight or obese was assessed in numerous studies (**Table 2**), one of which is the NutriNet-Santé cohort study (5). After following 110,260 adults (mean age 43.1±14.6 years, 78.2% female) living in France for 10 years (2009–2019), researchers were able to conclude that intake of UPF is positively associated with risk of overweight (hazard ration (HR) for 10% absolute increase: 1.11, 95% confidence interval (CI): 1.08–1.14) and obesity (HR for 10% absolute increase: 1.09, 95% CI:1.05–1.13) after adjusting for energy intake, age, sex, education, physical activity, tobacco and alcohol use, marital status, and number of 24-h diet records. These findings are consistent with the findings of the Seguimiento Universidad de Navarra (SUN) Project, a Spanish prospective study wherein consumption of ultra-processed foods was also found to be associated with an increased risk of overweight and obesity (6). In another Spanish cohort, the Seniors Study on Nutrition and Cardiovascular Risk in Spain: Seniors-ENRICA-1 cohort (mean age 67.1±5.8 years, 44% female), it was found that consuming UPF increased participants' likelihood of having abdominal obesity, a risk factor for cardio-metabolic dysfunction (7).

Similar results were obtained from a longitudinal study conducted in Latin America by Canhada and colleagues (43). This cohort consisted of 11,827 participants living in Brazil (mean age 51.3±8.7 years 55.0% female). Mean follow up time was 3.8 years, and diet was assessed via food frequency questionnaire. After adjusting for a variety and social and lifestyle factors, a significant positive association between intake of UPF and being at an unhealthy weight [relative risk (RR): 1.27, 95% CI: 1.07–1.50] as well as risk of gaining weight (RR:1.33, 95% CI: 1.12–1.58) was detected in this cohort.

In a cross-sectional Brazilian study ($n = 30{,}243$), researchers found that adolescents and adults with the highest intake of UPF according to the Brazilian Dietary Survey had significantly greater odds of being obese [odds ratio (OR): 1.98, 95% CI: 1.26–3.12] (46). The validity of this association is further supported by a cross-sectional study of NHANES data collected from 15,977 American adults, wherein UPF intake was found to be associated with greater adiposity, especially for females (45). The same association has been reported in a Canadian study as well (44).

There has been only one randomized controlled trial assessing the effects of UPF on health to date (21). Twenty adults (mean age 31.2 ± 1.6 years, 50% female) were randomly assigned to consume an ultra-processed diet or an unprocessed diet for a period of 2 weeks. Following a 2-week wash out period, participants were assigned to the alternate diet for an additional 2 weeks. The meals provided to participants were matched for energy, macronutrients, fiber, sodium, and sugar content and participants were instructed to eat *ad libitum*. While following the ultra-processed diet, participants consumed more calories ($p < 0.0001$), carbohydrates ($p < 0.0001$), and fat ($p = 0.0004$) and experienced significant weight gain (0.9±0.3 kg, $p = 0.009$). While on the unprocessed diet, participants experienced significant weight loss (0.9±0.3 kg, $p = 0.007$).

### Hypertension and Cardiovascular Disease

In a prospective study of 14,790 Spanish adults with a mean follow-up period of 9.1 years, participants with the highest intake of UPF had the greatest risk of developing hypertension (HR: 1.21, 95% CI: 1.06–1.37) (8). The findings of this study, the SUN project, are especially robust considering that data collection commenced in 1999, bringing the total person-years for this cohort to 134,784. In a similar vein, results from the NutriNet-Santé French cohort also indicate that higher consumption of UPF is associated with increased risk for coronary heart disease (HR for absolute 10% increase: 1.13, 95% CI: 1.02–1.24), cardiovascular disease (HR for absolute 10% increase: 1.12, 95% CI: 1.05–1.20), and cerebrovascular diseases (HR for absolute 10% increase: 1.11, 95% CI: 1.01–1.21), even with adjustment for diet quality (9).

### Type-2 Diabetes Mellitus

Srour and colleagues of the NutriNet-Santé French prospective cohort also assessed the association between UPF intake and type-2 diabetes (T2D) incidence (10). Consumption of UPF was shown to positively correlate with incident type-2 diabetes, and this association persisted after adjustment for metabolic comorbidities and diet quality.

### Cancer

Consumption of UPF has also been tied to increased cancer incidence. Overall cancer risk and breast cancer risk were both found to increase in proportion to the amount of UPF in subjects' diets within the NutriNet-Santé French cohort (HR per 10% increase: 1.12, 95% CI: 1.06–1.18 and HR per 10% increase: 1.11, 95% CI: 1.02–1.22, respectively) (11).

**TABLE 2 |** Studies assessing the association between UPF intake and excess adiposity.

| Authors | Year | Study Design | Population | Median follow up period (years) | Main Findings |
|---|---|---|---|---|---|
| Beslay et al. (5) | 2020 | Prospective | NutriNet-Santé cohort: 110,260 French adults (age 43.1±14.6 years, 78.2% ♀) | 10 | UPF intake is associated with risk of overweight ($HR_{10\%}$: : 1.11, 95% CI: 1.08–1.14) and obesity ($HR_{10\%}$: 1.09, 95% CI:1.05–1.13) |
| Sandoval-Insausti et al. (7) | 2020 | Prospective | Seniors Study on Nutrition and Cardiovascular Risk in Spain Seniors (ENRICA-1) cohort: 652 Spanish elderly adults (age 67.1±5.8 years, 44% ♀) | 6 | UPF intake is associated with greater odds of developing abdominal obesity (OR: 1.62, 95% CI: 1.04–2.54) |
| Canhada et al. (43) | 2020 | Prospective | Brazilian Longitudinal Study of Adult Health (ELSA-Brasil) cohort: 11,827 Brazilian adults (age 51.3±8.7 years, 55.0% ♀) | 3.8 | UPF intake is associated with being at an unhealthy weight (RR: 1.27, 95% CI: 1.07–1.50) as well as weight gain (RR:1.33, 95% CI: 1.12–1.58) |
| Nardocci et al. (44) | 2020 | Cross-sectional | Canadian Community Health Survey, cycle 2.2 respondents: 19,363 Canadian adults (age 45.99±18.1 years, 49.1% ♀) | n/a | UPF intake is associated with greater odds of being obese (predicted OR: 1.32; 95% CI: 1.05–1.57) |
| Hall et al. (21) | 2019 | RCT | 20 adults (age 31.2±1.6 years, 50% ♀) randomly assigned to consume an ultra-processed diet or an unprocessed diet for a period of two weeks | n/a | Following an ultra-processed diet led to greater intake of calories ($p<0.0001$), carbohydrates ($p<0.0001$), and fat ($p = 0.0004$), as well as weight gain (0.9±0.3 kg, $p = 0.009$) |
| Juul et al. (45) | 2018 | Cross-sectional | National Health and Nutrition Examination Survey (NHANES) respondents: a nationally representative sample of 15,977 American adults (age 41.9±0.2 years, 50.6% ♀) | n/a | UPF intake is associated with significantly higher BMI and WC and increased odds of overweight (OR: 1.48, 95% CI: 1.25–1.76), obesity (OR: 1.53, 95% CI: 1.29–1.81), and abdominal obesity (OR: 1.62, 95% CI: 1.39–1.89) |
| Mendonça et al. (6) | 2016 | Prospective | Seguimiento Universidad de Navarra (SUN) Project cohort: 8,451 Spanish adults (age 37.6±11.0 years, 64.9% ♀) | 8.9 | UPF intake is associated with increased risk of overweight/obesity (adjusted HR: 1.26; 95% CI: 1.10–1.45) |
| Louzada et al. (46) | 2015 | Cross-sectional | Brazilian Dietary Survey respondents: a nationally representative sample of 30,243 Brazilians; age in years, range (%): 10–19 (24.2%), 20–39 (41.3%), 40–59 (26.0%), and ≥60 (8.5%); 50.2% ♀ | n/a | UPF intake is associated with greater odds of being obese (OR: 1.98, 95% CI: 1.26–3.12) |

*RCT, randomized controlled trial; $HR_{10\%}$, hazard ratio per 10% increment; 95% CI, 95% confidence interval; OR, odds ratio; RR, relative risk; WC, waist circumference; Age reported as Mean ± SD unless indicated otherwise; ♀, female.*

## Mortality

UPF also appear to adversely impact mortality risk. Using data from a sub-set ($n$ = 44,551, mean age 56.7±7.5 years, 73.1% female) of the NutriNet-Santé French cohort, researchers discovered that after adjusting for common socioeconomic and lifestyle confounders, higher intake of UPF was associated with an elevated risk of death from all causes (HR per 10% increase: 1.14, 95% CI: 1.04–1.27) after a median follow up time of 7.1 years (12). In the SUN Spanish cohort study, participants who reported the highest consumption of UPF had the highest risk of all-cause mortality (HR: 1.62, 95% CI: 1.13–2.33). This relationship was also dose-dependent ($p$ for trend: 0.005) (13). The same association has been found among US adults (14).

# POTENTIAL MECHANISMS WHICH MAY EXPLAIN THE LINK BETWEEN THE INTAKE OF ULTRA-PROCESSED FOODS AND CHRONIC DISEASES

## Decreased Nutritional Quality: Energy Density, Sodium, Sugar, and Fiber

The high energy density of UPF may partially explain the association between UPF intake and excess adiposity. This is because the energy density of foods in one's diet is predictive of overall energy intake (47). Studies show that as people incorporate more energy dense foods into their diets, they typically do a poor job of adjusting their overall energy intake. This leads to what has been termed as "passive over-consumption (47)."

As intake of UPF foods increases, intake of saturated fat, free sugars, and sodium all rise while fiber, protein, and potassium intake fall (48). UPF also tend to be high in sodium relative to minimally processed foods. Independent of other dietary factors, high sodium intake has been identified as a contributor to death due to cardio-metabolic dysfunction (49, 50). The same holds true for SSBs, which are ultra-processed (49). SSB consumption may also increase one's risk of developing hypertension (51) and CVD (52). Furthermore, the consumption of added sugars is significantly associated with CVD mortality risk (37). It has been estimated that 89.7% of energy provided by added sugars in a typical American diet comes from UPF (53).

The low fiber content of UPF may also play a role in the link between UPF intake and cardio-metabolic disease. Based on data compiled in an umbrella review of 18 meta-analyses, Veronese and colleagues found that high fiber intake was protective against cardiovascular disease incidence and mortality, coronary artery disease, and cancers associated with the gastrointestinal system (54). Ultra-processing typically removes the protective fiber layer of grains.

### Contaminants and Neoformed Compounds

Acrylamide, acrolein, polycyclic aromatic hydrocarbons (PAH), and furan are some common compounds associated with the preparation of UPF. Acrylamide is an organic compound that is formed when starchy foods are cooked at high temperatures. Potato chips and breakfast cereals are two examples of foods that may contain high amounts of acrylamide (55). Acrylamide may have adverse effects on hormone regulation, signal propagation across nerve fibers, reproductive health, and cancer formation, however this evidence comes primarily from animal studies (55). Dietary exposure to acrylamide as assessed by hemoglobin biomarkers was shown to be significantly associated with death from all causes in the NHANES 2003–2006 cohort ($p$ for trend =0.0124) (56).

Acrolein is an unsaturated aldehyde that is produced as a result of cooking fats at high temperatures. In the Louisville Healthy Heart Study, acrolein exposure measured via a urinary biomarker was associated with increased CVD risk (57). PAH are produced during dry, high-heat cooking. When solid fuels such as wood or coal are used to prepare food, PAH from the burning of those fuels can contaminate the food. According to data from the NHANES 2005–2014 cohort, PAH exposure positively correlates with diabetes prevalence (58). Similarly, Ranjbar and colleagues determined that dyslipidemia, hypertension, excess adiposity, and type-2 diabetes may all be related to PAH exposure (59). Furan is an organic compound that is also produced during high heat cooking as a consequence of thermal degradation. The European Food Safety Authority has stated publicly that while there are a plethora of uncertainties in the risk assessment of furan, this compound has been shown to induce oxidative stress in animal models and has the potential to be hepatotoxic (60).

### Alteration of the Food Matrix

Processing foods alters the food matrix and often involves the removal of protective food structures. For instance, refined grains and their products are very low in fiber due to the removal of the bran layer. In animal studies, fiber intake has been shown to be protective against obesity in the context of a high fat diet (61). Likewise, dietary polyphenols, which are also greatly reduced during ultra-processing, have been demonstrated to fortify the gut microbiome against inflammation associated with a high fat diet (62).

Ultra-processing also breaks down cellular structures and frees nutrients in food from the compartments in which they are normally contained, producing acellular nutrients (63). Destruction of the cell wall facilitates rapid digestion and may also spur bacterial overgrowth in the small intestine and alter gut microbiome composition (64). A high proliferation of gut bacteria can precipitate low grade inflammation in the host, which can affect not only local tissues but also the entire organism, as bacteria associated with inflammation and metabolic disease can translocate and enter the systemic circulation (65, 66). The composition of the gut microbiome is largely reflective of the host diet, and high intake of simple sugars favors the growth of microorganisms that can metabolize this substrate. As a consequence, microbial diversity may shift to favor leptin resistance, hyperphagia, and the development of chronic diseases (64, 67).

## CONCLUSIONS

The rising popularity of ultra-processed foods in Latin America is significantly associated with the prevalence of non-communicable diseases in this region of the world. This association is graded and reflects increasing urbanicity and interplay with foreign markets in the Latin American economy. While countries like Mexico and Chile appear to be consuming the most UPF per capita, these findings represent a major public health concern for all of Latin America. It would be prudent of policy makers to design measures that facilitate production, promotion, and access to healthy foods in order to reverse this trend. Promoting good health practices enhances quality of life not only at the individual level, but ultimately at the global level.

## AUTHOR CONTRIBUTIONS

RM, MA, and JS all contributed to this manuscript through conceptualization, acquisition and interpretation of relevant data, and preparation of the final approved paper. RM and MA contributed equally to the writing of this manuscript. All authors contributed to the article and approved the submitted version.

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# Ultra-Processed Food Consumption Among Chilean Preschoolers Is Associated With Diets Promoting Non-communicable Diseases

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**Introduction:** In adults, intake of ultra-processed foods (UPF) has been linked with poor diets and adverse health outcomes. In young children, evidence is scarcer but suggests a higher dietary share of UPF.

**Objective:** To quantify the intake of UPF and its association with the nutrient composition of the diet in a sample of preschoolers in Santiago, Chile.

**Methods:** Cross-sectional analysis of dietary data (24-h recall survey) from 960 preschoolers. Foods were categorized according to the extent and purpose of processing (NOVA classification) and participants were classified in quintiles of UPF intake. We explored the associations between UPF intake (% of the total energy) and intake of nutrients of concern for non-communicable disease development (carbohydrates, total sugars, fats, and sodium), and nutrients for promotion (proteins, polyunsaturated fats, iron, calcium, zinc, vitamins A, D, C, and $B_{12}$, folate, and fiber) using multivariate regression after controlling for covariates.

**Results:** UPF constituted 49% of the total energy intake. Preschoolers with higher intake consumed more energy, saturated and monounsaturated fats, carbohydrates, total sugars, and vitamin D, compared to preschoolers in the lowest quintile of UPF intake. In contrast, UPF intake was negatively associated with the consumption of proteins, polyunsaturated fats, fiber, zinc, vitamin A, and sodium ($p < 0.05$).

**Conclusion:** In Chilean preschoolers, UPF was the primary source of energy intake. The dietary share of UPF was associated with the nutrient composition of the diet. Improving children's diet should consider not only promoting healthy food consumption but also limiting UPF consumption.

**Keywords: ultra-processed foods, children, preschooler, diet, Chile**

## INTRODUCTION

Unhealthy diets—characterized by a low intake of whole grains, fruits, nuts and seeds, seafood, and legumes together with a high intake of sodium, trans fats, processed meats, and sugar-sweetened beverages, among other factors—account for 22% of deaths and 15% of disability-adjusted life years (DALYs) (1, 2).

Over the last few decades, in several countries, traditional foods have been replaced by ultra-processed foods (UPF); products manufactured industrially using processes and ingredients not commonly used in culinary preparations (3, 4). UPF consumption has been associated with a variety of markers of poor nutritional quality. A greater dietary share of UPF has been linked to diets promoting non-communicable diseases (NCD), characterized by a high content of energy and nutrients of concern such as sugars, saturated fats, trans fats, and sodium, as well as poor content of micronutrients and fiber among different populations (5–9). Different longitudinal studies among adults have shown an association between UPF consumption and the development of NCDs such as overweight/obesity, high blood pressure, and cancer (10–12). These conditions, in turn, are associated with greater risks of mortality (13).

Conversely, evidence of the link between UPF consumption and the nutrient composition of the diet or health impact among children is scarce (14–18). Studies on UPF consumption in children indicate that the intake of these products is higher than that in the general population (19, 20). Chile, a post-nutrition transitional country where approximately 75% of the adults and 50% of children aged 6–7 years are either overweight or obese (21–23), is no exception. In 2010, the National Dietary Survey showed a UPF consumption of 29% among the general population and 38% among children and adolescents (i.e., 2–19 years old) (20). In June 2016, the Chilean government implemented a set of regulations aimed at improving diets and preventing obesity, particularly in children (24, 25). Although the regulations were not directed to decrease UPF intake, the foods targeted were those with added sugars, fats, or sodium as part of their processing (25) and, therefore, encompassed most UPF. Understanding UPF intake among young children and its association with the intake of nutrients of concern for NCD development and nutrients for promotion prior to the implementation of the regulation is important for evaluating whether this set of policies may reduce UPF intake and lead to improvements in health. To address these objectives, we analyzed detailed dietary information collected from preschool children of middle to low socioeconomic status who participated in a longitudinal study in Santiago, Chile.

## MATERIALS AND METHODS

### Participants and Setting

During the first semester of 2016, the mothers of preschoolers attending public schools of the Chilean National School Board Program (JUNAEB) were invited to participate in the study. These counties are primarily of middle to low socioeconomic status (26). The inclusion criteria for the children were as follows: an age of 4–6 years, born from a single pregnancy, without any gastrointestinal condition that could affect food intake or growth, and with a mother responsible for food purchases and childcare in the home. The participants were recruited via written and verbal announcements to the guardians of students enrolled in kindergarten and preschool. We evaluated 962 mother-child pairs who met the inclusion criteria, two of which were excluded due to lack of plausible anthropometric data or incomplete dietary survey data. Thus, the analyses included 960 mother-child pairs, with approximately 190 participants per group when the sample was divided into quintiles according to the distribution of UPF intake. This sample size allowed the detection of differences between the 1st and 5th quintiles of a 1/3 of the standard deviation (SD) of the outcome, which is in line with the differences detected in a secondary analysis of the National Dietary Survey from 2010, were a quintile of 20% of children and adolescents (aged 2–19 years) with the lowest UPF intake had an average added sugars intake of 8 $\pm$ 6% of the energy intake, compared to 16 $\pm$ 13% among children and adolescents in the highest quintile of UPF consumption (20). This study was approved by the Ethics Committee of the Institute of Nutrition and Food Technology (INTA) of the Universidad de Chile and by the Institutional Review Board of the University of North Carolina at Chapel Hill. All procedures complied with the principles of the Declaration of Helsinki. Informed consent was obtained from the mothers of all participants.

### Study Description

Between April and August 2016, the participants were evaluated by trained dietitians at either INTA's outpatient clinic or the participants' homes. Anthropometric assessments were performed for preschoolers. Weight and height were collected following standardized procedures and standardized dietitians (intraclass correlation coefficient [ICC] > 0.75 for all measurements). The participants were measured while barefoot and wearing light clothing. Weight was collected using portable electronic scales (Seca 770 or 803, precision of 0.1 kg) and height with portable stadiometers (Seca 217, to the nearest 0.1 cm). The mothers were asked for the duration of their formal education.

### Evaluation of Food and Nutrient Intakes

The mothers of the preschoolers completed a 24-h recall (24 h) survey to estimate all of the foods and beverages consumed by the child the previous day (weekday or weekend), including food consumed at the school or nursery. This survey was conducted according to the United States Department of Agriculture (USDA) Automated Multiple-Pass Method (27). To more accurately estimate the proportions of consumed foods, the photographic atlas of food proportions used in the National Dietary Survey was employed (28). The mothers were specifically asked about the use of table salt. All data were recorded and analyzed using the 24 h survey software which considered 4,644 foods and 873 recipes commonly consumed by the Chilean population (including those provided by the school feeding program), with standardized ingredients and quantities (29–31).

## Energy and Nutritional Contents of the Foods

Given that a local database for the chemical and nutritional compositions of foods and beverages is not available for Chile, the energy and nutrient contents were assigned based on the USDA Food Composition Database, Release 28 (32). Foods from the USDA database were selected based on information provided by the *Guide on the Nutritional Composition of Natural Foods and Common Chilean Preparations* (33) as well as data declared as part of the nutritional information on packaged products (collected during 2015–2016 for packaged products available at supermarkets) (34). Most similar food (20% maximum variation) was selected based on the content of energy, macronutrient (i.e., proteins, carbohydrates, total fats), saturated fats, total sugars, and sodium. Information on other nutrients (i.e., other subtypes of fats, fiber, vitamins, and minerals) was not considered when selecting the most similar food from the USDA database.

## Classification of Foods by the Degree of Processing

The 4,644 reported foods, including preparations (e.g., natural milk with sugar, cooked rice, and lentil stew, among others), were categorized into one of four groups and then into subgroups according to the NOVA classification system (35, 36) as follows:

- Group 1, Unprocessed or minimally processed food: natural foods altered by processes such as drying, freezing, pasteurization, among others that do not add substances such as salt, sugar, oil, or fats to the original food; comprising 13 subgroups (e.g., milk and plain yogurt; fruits; legumes; meat).
- Group 2, Processed culinary ingredients: substances obtained directly from group 1 foods or from nature by processes such as pressing, refining, and milling, among others; comprising five subgroups (e.g., plant oils, table sugar, table salt).
- Group 3, Processed foods: relatively simple products made by adding sugars, oil, salt, or other group 2 substances to group 1 foods, with the main purpose of increasing the durability of group 1 foods or to modify their sensory qualities; comprising five subgroups (e.g., breads [fresh, unpackaged]; cheese; vegetables, fruits, and other plant foods preserved in brine or syrup).
- Group 4, Ultra-processed foods: industrial formulations typically with five or more ingredients, including the formulations used in group 3 and additives as anti-oxidants, stabilizers, preservatives, as well as substances not commonly used in culinary preparations whose purpose is to imitate the sensory qualities of group 1 foods or of culinary preparations of these foods or to disguise the undesirable sensory qualities of the final products; comprising 21 subgroups (e.g., milk-based drinks; sandwiches and hamburgers on a bun [ready-to-eat/heat]; cakes, cookies, and pies).

Detailed descriptions of each subgroup are provided as **Supplementary Material**.

## Nutritional Outcomes

The nutrient composition of the diet was assessed by the daily intake of energy, total carbohydrates, total sugars, fiber, total fats, fat subtypes (i.e., saturated, monounsaturated, polyunsaturated, and trans), proteins, iron, calcium, zinc, vitamins A, D, C, and $B_{12}$, and folate. The contribution of every NOVA food group was also estimated. The intake was reported (mean and SD) in absolute terms [i.e., grams, milligrams, micrograms, or international units (IU)], considering energy intake (per 100 or 1,000 kcal) and relative to the total daily intake of the specific participant.

## Covariates

Preschoolers' sex (male vs. female) and age were considered as covariates. Body mass index (BMI, weight [kg]/height [$m^2$]) and age- and sex-specific z scores were calculated based on the World Health Organization's (WHO) 2006 growth standards for preschoolers <5 years and 2007 references for older preschoolers. The weight status categories were defined according to BMI z score as normal weight (−1 to <1), overweight (+1 to <2), and obese (≥2). Formal education of the mother was categorized as low (<8 years of schooling), medium (8–12 years), and high (>12 years). Finally, the day of the 24 h survey was also included (weekday vs. weekend) as a covariate.

## Statistical Analysis

The participants were grouped into quintiles based on the amount of energy consumed from UPF. The general and anthropometric characteristics of children across quintiles of UPF intake were compared using chi-squared tests and one-way analysis of variance (ANOVA), with Bonferroni *post-hoc* correction. The associations between UPF consumption and the intake of energy and different nutrients were studied using linear regression models, considering quintiles of dietary share of UPF (set of indicator variables) as the predictor, and covariates relevant to the association (i.e., variation of the predictor's beta coefficient >10% when removed). Adjusted means and standard errors derived from the models are presented. The final models met all expected assumptions. *P*-values <0.05 were considered statistically different. All data were analyzed using Stata v13 (StataCorp, TX, USA).

# RESULTS

The sociodemographic characteristics of the sample are summarized in **Table 1**. Participants were on average 5 years of age and nearly half of the participants were overweight or obese, with an average BMI z score of 1. Most mothers had completed high school (52%) and <10% had a low level of education.

**Table 2** displays the intake of energy, macronutrients, micronutrients, and fiber by NOVA food groups. UPF accounted for 49% of the daily energy intake, whereas 32% of energy came from unprocessed or minimally processed foods, 10% from processed foods, and 8% from culinary ingredients. UPF was also the main dietary source of carbohydrates (53%), total sugars (76%), total fats (48%), saturated fats (55%), trans fats (49%), and sodium (39%). In contrast, the groups of minimally

**TABLE 1** | Sociodemographic variables, weight status, and energy intake among the participants (*n* = 960).

| Variables | Descriptive |
|---|---|
| Female, *n* (%) | 498 (51.9) |
| Age [years], mean ± SD | 4.8 ± 0.5 |
| BMI [z score], mean ± SD* | 1.0 ± 1.2 |
| **Weight status, *n* (%)*** | |
| Normal weight (< −1 to 0.9 SD) | 508 (52.9) |
| Overweight (1 to 1.9 SD) | 276 (28.8) |
| Obese (≥2 SD) | 175 (18.3) |
| **Mother's education level, *n* (%)** | |
| Low (<8 years of schooling) | 69 (7.3) |
| Medium (8–12 years of schooling) | 499 (52.0) |
| High (>12 years of schooling) | 392 (40.7) |

*Values represent either the total number and (percentage) or mean ± standard deviation.*
**n = 959 with anthropometric data.*

processed foods and culinary ingredients were the main sources of proteins (47% from group 1), fiber (51% from group 1), and polyunsaturated fats (43% from group 2).

The details of the dietary share of energy, total sugars, saturated fats, and sodium of the different food subgroups within the UPF group are available in **Figure 1** and **Supplementary Tables 1–4**. Within UPF, milk-based drinks were the primary source of energy (18%), total sugars (30%), saturated fats (24%), and sodium (13%). Cakes, cookies, and pies also contributed importantly to the UPF consumption of NCD-related nutrients: energy (7%), total sugars (7%), saturated fats (11%), and sodium (4%); as well as sweet snacks (energy (3%), total sugars (5%), saturated fats (5%), except in the case of sodium). Primary food sources of energy and total sugars also included nectar (4 and 10%, respectively) and desserts (3 and 6%, respectively), while sodium reconstituted meats (6%), sauces, dressing, and gravies (2%), and breakfast cereals (2%) also played a role. The details of the dietary shares of energy, total sugars, saturated fats, and sodium among subgroups of NOVA groups 1–3 are also displayed in **Supplementary Tables 1–4**.

Preschoolers were classified into five groups according to UPF intake: the mean dietary share of UPF increased in every quintile, at 24% in quintile 1, 40% in quintile 2, 50% in quintile 3, 60% in quintile 4, and 74% in quintile 5. **Table 3** shows the sociodemographic characteristics, weight status, and energy intake according to NOVA food groups across the quintiles of UPF consumption. No difference in sociodemographic or anthropometric characteristic was observed by UPF quintile ($p > 0.05$); however, as expected, the dietary shares of every NOVA group differed significantly. Children in the first quintile consumed an average of 61% of their energy from minimally processed foods and culinary ingredients, whereas, only 21% of energy intake among children in the fifth quintile came from groups 1 and 2.

The adjusted intakes of energy and different nutrients by quintiles of UPF intake are presented in **Table 4**. Compared to the quintile with the lowest UPF intake, participants from other quintiles had significantly greater intakes of energy, saturated fats, monounsaturated fats, total carbohydrates, total sugars, and vitamin D. However, participants with a greater UPF dietary share had significantly lower intakes of proteins, polyunsaturated fats, fiber, sodium, zinc, vitamin A, and folate than the reference group (i.e., the first quintile). The intakes of total fats, iron, calcium, vitamin C, and vitamin $B_{12}$ were not associated with UPF intake in this sample.

## DISCUSSION

The results of this study showed that UPF accounted for an important proportion of energy (∼50%), total sugars (76%), saturated fats (55%), and sodium (∼40%) intake among preschoolers from a longitudinal study in Santiago, Chile. UPF consumption was independently associated with the nutrient composition of the diet (i.e., greater intake of energy and nutrient of concern such as carbohydrates, total sugars, saturated and trans fats, and lower intake of nutrients for promotion, such as proteins, zinc, vitamin A, folate, and fiber.

Previous reports on the consumption of UPF in children are limited but in general, have shown a high dietary share of these products. In Belgium, the reported intake was 33% of daily energy for children and 29% for adolescents (2014–2015) (15); in Chile it was 38% for children aged 2–19 years (dietary data from 2010) (20), in Australia 53% (dietary data from 2011–2012) (9), 55% in Canada (dietary data from 2004) (6), and 65% in the United States of America (USA) (2009–2014) (14). Data from two Brazilian preschooler samples (the Pelotas cohort) showed a 36% energy intake from UPF among children between 2 and 6 years of age (dietary data from 2008) (37), reaching 40% among 6-year-old children (dietary data from 2004) (38). The age of participants, year of dietary collection, and the type of culinary culture may explain the differences in the dietary shares of UPF but overall, the data reflect the relevance that these type of foods have on the diet of children from countries facing advance stages of the nutrition transition.

Other studies in the general population have also reported an association between UPF intake and an unhealthier nutrient composition of diet. According to the 2010 Chilean National Dietary Survey, UPF consumption was positively associated with the intake of nutrients of concern, specifically energy density, free sugars, total fats, saturated fats, and trans fats, and negatively associated with the intake of potassium and fiber (8). Data derived from the 2004 Canadian dietary survey showed that UPF intake was associated with diets with greater energy density, carbohydrates, free sugars, total and saturated fats but lower contents of proteins, fiber, vitamins A, C, D, B6, and $B_{12}$, niacin, thiamine, and riboflavin as well as zinc, iron, magnesium, calcium, phosphorus, and potassium (6). According to nationally representative surveys, children from the USA, Australia, and Chile reporting higher UPF intake showed greater intakes of free or added sugars (9, 14, 20), while those from Belgium not meeting the dietary goals for fruits and vegetables, sodium, saturated, and trans fats had higher UPF intake (15). Other studies in specific pediatric populations have reported the impact of UPF intake

**TABLE 2 |** Intake of energy and nutrients of concern by the participants ($n = 960$).

| | Total | Unprocessed or minimally processed foods | Processed culinary ingredients | Processed foods | Ultra-processed foods | *p*-value* |
|---|---|---|---|---|---|---|
| **Energy intake** | | | | | | |
| Absolute [kcal] | 1,240.0 ± 392.4 | 398.9 ± 208.0[a] | 98.8 ± 80.3[b] | 126.5 ± 125.0[c] | 617.5 ± 318.3[d] | <0.01 |
| Relative [% daily energy intake] | 100 | 32.4 ± 14.9[a] | 7.9 ± 5.9[b] | 10.4 ± 9.9[c] | 49.2 ± 18.0[d] | <0.01 |
| **Protein intake** | | | | | | |
| Absolute [g] | 43.1 ± 15.4 | 20.9 ± 12.9[a] | 0.0 ± 0.1[b] | 5.6 ± 6.3[c] | 16.6 ± 9.7[d] | <0.01 |
| Absolute [% daily energy intake] | 14.1 ± 3.3 | 6.9 ± 4.0[a] | 0.0 ± 0.0[b] | 1.8 ± 2.0[c] | 5.4 ± 2.7[d] | <0.01 |
| Relative [% daily protein intake] | 100 | 47.3 ± 20.7[a] | 0.0 ± 0.1[b] | 12.9 ± 13.1[c] | 39.8 ± 19.8[d] | <0.01 |
| **Carbohydrate intake** | | | | | | |
| Absolute [g] | 178.2 ± 58.4 | 60.2 ± 33.9[a] | 3.3 ± 7.7[b] | 19.1 ± 19.4[c] | 95.7 ± 49.4[d] | <0.01 |
| Absolute [% daily energy intake] | 57.8 ± 7.2 | 19.7 ± 10.0[a] | 1.1 ± 2.5[b] | 6.4 ± 6.4[c] | 30.6 ± 11.8[d] | <0.01 |
| Relative [% daily carbohydrates intake] | 100 | 34.2 ± 17.1[a] | 1.8 ± 4.2[b] | 11.1 ± 11.0[c] | 52.8 ± 18.7[d] | <0.01 |
| **Total sugars intake** | | | | | | |
| Absolute [g] | 88.2 ± 35.9 | 15.0 ± 14.0[a] | 3.2 ± 7.6[b] | 1.6 ± 3.2[b] | 68.3 ± 35.5[c] | <0.01 |
| Absolute [% daily energy intake] | 28.7 ± 8.4 | 5.0 ± 4.7[a] | 1.1 ± 2.5[b] | 0.5 ± 1.0[b] | 22.1 ± 9.3[c] | <0.01 |
| Relative [% daily total sugars intake] | 100 | 18.6 ± 17.6[a] | 3.7 ± 8.4[b] | 2.2 ± 4.5[b] | 75.5 ± 19.9[c] | <0.01 |
| **Fiber intake** | | | | | | |
| Absolute [g] | 11.5 ± 6.6 | 6.4 ± 5.7[a] | 0.0 ± 0.0[b] | 1.7 ± 1.4[c] | 3.8 ± 2.9[d] | <0.01 |
| Absolute [g/1,000 kcal intake] | 9.2 ± 4.3 | 5.2 ± 4.3[a] | 0.0 ± 0.0[b] | 1.4 ± 1.1[c] | 3.0 ± 2.0[d] | <0.01 |
| Relative [% daily total fiber intake] | 100 | 51.4 ± 23.2[a] | 0.0 ± 0.1[b] | 17.4 ± 14.6[c] | 36.0 ± 21.8[d] | <0.01 |
| **Total fats intake** | | | | | | |
| Absolute [g] | 40.7 ± 17.3 | 8.4 ± 7.4[a] | 9.6 ± 8.1[b] | 3.0 ± 4.5[c] | 19.7 ± 13.6[d] | <0.01 |
| Absolute [% daily energy intake] | 29.1 ± 6.5 | 6.2 ± 5.1[a] | 6.9 ± 5.4[b] | 2.2 ± 2.9[c] | 13.9 ± 7.5[d] | <0.01 |
| Relative [% daily total fats intake] | 100 | 21.3 ± 16.6[a] | 23.4 ± 16.8[b] | 7.6 ± 10.2[c] | 47.7 ± 22.7[d] | <0.01 |
| **Saturated fats intake** | | | | | | |
| Absolute [g] | 13.9 ± 6.8 | 3.2 ± 3.6[a] | 1.7 ± 1.8[b] | 1.2 ± 2.1[c] | 7.8 ± 5.7[d] | <0.01 |
| Absolute [% daily energy intake] | 9.9 ± 3.3 | 2.3 ± 2.5[a] | 1.3 ± 1.2[b] | 0.8 ± 1.4[c] | 5.5 ± 3.2[d] | <0.01 |
| Relative [% daily saturated fats intake] | 100 | 22.9 ± 20.4[a] | 13.7 ± 13.2[b] | 8.2 ± 12.9[c] | 55.1 ± 25.1[d] | <0.01 |
| **Trans fats intake** | | | | | | |
| Absolute [g] | 0.3 ± 0.4 | 0.1 ± 0.2 [a] | 0.0 ± 0.1 [b] | 0.0 ± 0.0 [c] | 0.2 ± 0.3 [d] | <0.01 |
| Absolute [% daily energy intake] | 0.2 ± 0.3 | 0.1 ± 0.1 [a] | 0.0 ± 0.1 [b] | 0.0 ± 0.0 [c] | 0.1 ± 0.2 [d] | <0.01 |
| Relative [% daily trans fats intake] | 100 | 34.5 ± 36.5[a] | 12.3 ± 24.9[b] | 10.9 ± 19.3[c] | 49.3 ± 37.7[d] | <0.01 |
| **Monounsaturated fats intake** | | | | | | |
| Absolute [g] | 13.1 ± 6.3 | 3.0 ± 2.9[a] | 2.8 ± 2.5[a] | 1.1 ± 1.7[b] | 6.6 ± 5.2[c] | <0.01 |
| Absolute [% daily energy intake] | 9.3 ± 2.8 | 2.2 ± 1.9[a] | 2.0 ± 1.7[a] | 0.8 ± 1.1[b] | 4.6 ± 3.0[c] | <0.01 |
| Relative [% daily monounsaturated fats intake] | 100 | 23.7 ± 19.0[a] | 22.1 ± 16.9[a] | 8.5 ± 10.6[b] | 48.6 ± 24.4[c] | <0.01 |
| **Polyunsaturated fats intake** | | | | | | |
| Absolute [g] | 10.0 ± 5.5 | 1.2 ± 1.2[a] | 4.8 ± 4.1[b] | 1.0 ± 1.0[c] | 3.4 ± 3.2[d] | <0.01 |
| Absolute [% daily energy intake] | 7.1 ± 3.0 | 0.9 ± 0.9[a] | 3.4 ± 2.7[b] | 0.7 ± 0.6[c] | 2.4 ± 2.0[d] | <0.01 |
| Relative [% daily polyunsaturated fats intake] | 100 | 14.0 ± 13.0[a] | 42.9 ± 24.7[b] | 12.2 ± 10.6[c] | 35.2 ± 24.0[d] | <0.01 |
| **Total sodium intake** | | | | | | |
| Absolute [mg] | 1,484.0 ± 670.4 | 191.5 ± 207.8[a] | 489.7 ± 378.0[b] | 223.6 ± 221.6 [a] | 579.3 ± 454.1[c] | <0.01 |
| Absolute [mg/1,000 kcal intake] | 1,216.6 ± 474.5 | 156.3 ± 156.0[a] | 406.6 ± 317.2[b] | 184.1 ± 177.3[a] | 469.5 ± 386.2[c] | <0.01 |
| Relative [% total sodium intake] | 100 | 13.2 ± 12.1[a] | 32.5 ± 18.3[b] | 15.6 ± 14.6[c] | 38.7 ± 20.2[d] | <0.01 |

*Quintiles were classified according to NOVA food groups among the Food Environment Chilean Cohort.*
*Values represent the mean ± standard deviation.*
**One-way ANOVA across NOVA food groups; different letters indicate significant differences between groups. P-values < 0.05 were considered statistically significant.*

on the nutrient composition of their diet. Among adolescents from the Pelotas cohort, a greater UPF intake was associated with lower inadequacy of selenium and vitamin B1 (39), whereas the combined intake of processed and UPF was associated with lower intakes of vitamins A and E, zinc, proteins, polyunsaturated and trans fats, and fiber along with greater intake of total

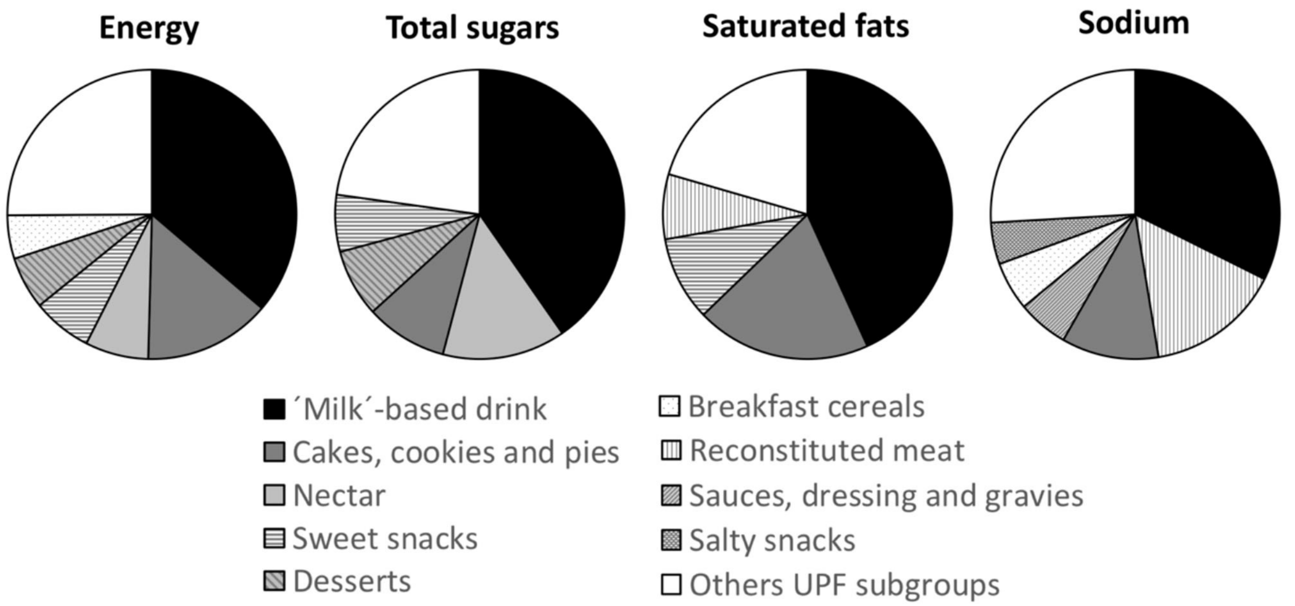


**FIGURE 1 |** Main food groups contributing to the intake of energy, total sugars, saturated fats, and sodium among ultra-processed food (UPF). Only UPF subgroups contributing to 75% of the intake of energy, total sugars, saturated fats, and sodium are specified.

and saturated fats, cholesterol, sugars, calcium, and sodium in children aged 5–12 years from Colombia (40).

While most reports are consistent regarding the impact of UPF consumption on a greater intake of nutrients of concern (except for sodium) and lower consumption of fiber, the available information regarding micronutrient intake remains controversial. The latter could be explained by country-to-country differences in micronutrient fortification policies and the quality (e.g., dietary diversity) of diets based on food groups with a lower degree of processing (i.e., NOVA groups 1–3). We did observe a positive association between UPF and vitamin D, likely due to the fact that several of the main UPF food groups are fortified with vitamin D in the USA. Several authors have highlighted the risks associated with promoting the intake of vitamins in UPF foods and whether this should be a matter of concern and have more active monitoring (41). In the case of sodium intake, the discrepancies can be explained by the difficulty of assessing sodium intake (42) and by differences between countries on the other relevant dietary sources of sodium. For instance, in the current study, UPF was the main NOVA group contributor to sodium intake (39% daily intake); however, table salt and fresh bread accounted for 45% of daily sodium intake.

Given that the first years of life, including the preschool period, are relevant in establishing future food preferences (43, 44), high UPF consumption could translate into a notable future increase in UPF intake in the adult population. In turn, greater UPF intake could lead to overeating and weight gain (45) as well as the development of NCDs (10–12) and greater mortality (13). One method to shift this trend is to modify aspects of the food environment that facilitate the consumption of these products, such as availability, marketing, and price. The recent implementation of the Food Labeling and Marketing Law in Chile (24), in addition to other initiatives (25), may mark an important shift in these tendencies (46, 47). Newly implemented measures include increasing the price of sugar-sweetened beverages, the required use of warning labels when the content of nutrients of concern exceeds established values, the prohibition of selling or freely offering foods that exceed established cutoffs in schools, and restrictions on marketing directed toward children. While these measures are not specifically directed at UPF intake, there is an important overlap between these products and those subject to the new regulations (i.e., foods that, as part of processing, have added sodium, sugars, or saturated fats, which exceed established values) (24). This study serves as the basis for evaluating changes in UPF consumption by preschool-aged children and for assessing the nutrients of concern derived from UPF.

The present study has several limitations that are important to mention. The sample was limited to children from nurseries in low-middle-income neighborhoods in Southeast Santiago and may not represent preschool children from other socioeconomic backgrounds in Santiago or across Chile. Only one 24 h survey was used for the analysis, which does not represent usual dietary intake. Furthermore, given the lack of a Chilean database for the chemical composition of foods and beverages, the USDA database for chemical compositions was used. The foods recorded in the USDA database may present important differences in the contents of some nutrients as compared to foods available in Chile, particularly for packaged products (i.e.,

**TABLE 3 |** Sociodemographic characteristics, weight status, and dietary share of NOVA food groups, by quintiles of UPF in the diet of the Food Environment Chilean Cohort ($n = 960$).

| | Q1: 1st quintile $n = 192$ | Q2: 2nd quintile $n = 192$ | Q3: 3rd quintile $n = 192$ | Q4: 4th quintile $n = 192$ | Q5: 5th quintile $n = 192$ | *p*-value |
|---|---|---|---|---|---|---|
| Female, *n* (%) | 101 (52.6) | 101 (52.6) | 96 (50.0) | 99 (51.6) | 101 (52.6) | 0.98[†] |
| Age [years], mean ± SD | 4.8 ± 0.5 | 4.7 ± 0.5 | 4.7 ± 0.6 | 4.8 ± 0.5 | 4.7 ± 0.5 | 0.66[¥] |
| BMI [z score], mean ± SD* | 1.0 ± 1.3 | 1.0 ± 1.3 | 1.1 ± 1.1 | 1.0 ± 1.2 | 1.0 ± 1.1 | 0.99[¥] |
| Weight status, *n* (%)* | | | | | | |
| Normal weight (< −1 to 1 SD) | 100 (52.1) | 108 (56.3) | 99 (51.6) | 101 (52.6) | 100 (52.4) | |
| Overweight (1 to 1.9 SD) | 56 (29.2) | 50 (26.0) | 59 (30.7) | 55 (28.7) | 56 (29.3) | 0.99[†] |
| Obese (≥2 SD) | 36 (18.8) | 34 (17.7) | 34 (17.7) | 36 (18.8) | 35 (18.3) | |
| Mother's education level, *n* (%) | | | | | | |
| Low (<8 years of schooling) | 16 (8.3) | 15 (7.8) | 12 (6.3) | 14 (7.3) | 13 (6.8) | |
| Medium (8–12 years of schooling) | 96 (50.0) | 107 (55.7) | 98 (51.0) | 106 (55.2) | 92 (47.9) | 0.76[†] |
| High (>12 years of schooling) | 80 (41.7) | 70 (36.5) | 82 (42.7) | 72 (37.5) | 87 (45.3) | |
| Total energy intake according to NOVA food groups, mean ± SD | | | | | | |
| Unprocessed or minimally processed foods [% of energy] | 49.4 ± 14.3[a] | 38.0 ± 10.1[b] | 32.3 ± 9.2[c] | 25.6 ± 8.0[d] | 16.9 ± 7.5[e] | <0.01[¥] |
| Processed culinary ingredients [% of energy] | 11.9 ± 6.9[a] | 9.7 ± 6.3[b] | 7.8 ± 4.6[c] | 6.4 ± 4.2[c] | 3.9 ± 3.1[d] | <0.01[¥] |
| Processed foods [% of energy] | 15.1 ± 12.9[a] | 12.9 ± 9.9[a,b] | 10.4 ± 8.6[b,c] | 8.4 ± 8.0[c] | 5.3 ± 6.1[d] | <0.01[¥] |
| Ultra-processed foods [% of energy] | 23.6 ± 8.1[a] | 39.5 ± 3.0[b] | 49.5 ± 2.8[c] | 59.5 ± 3.2[d] | 73.9 ± 7.8[e] | <0.01[¥] |

*UPF, Ultra-processed foods.*
**N = 191 in the fifth quintile with anthropometric data.*
*[†]Chi-squared test across UPF intake quintiles (i.e., 1st quintile, 2nd quintile, 3rd quintile, 4th quintile, and 5th quintile); different letters indicate significant differences between quintiles.*
*[¥]One-way ANOVA across intake UPF quintiles (i.e., 1st quintile, 2nd quintile, 3rd quintile, 4th quintile, and 5th quintile); different letters indicate significant differences between quintiles.*
*P-values <0.05 were considered statistically different.*

**TABLE 4 |** Intake of energy, nutrients of concern, and nutrients for promotion by dietary contribution of UPF in the diet of the Food Environment Chilean Cohort ($n = 959$).

| | Q1: 1st quintile $n = 192$ | Q2: 2nd quintile $n = 192$ | Q3: 3rd quintile $n = 192$ | Q4: 4th quintile $n = 192$ | Q5: 5th quintile $n = 191$ |
|---|---|---|---|---|---|
| Energy [kcal] | 1,088.9 ± 29.9 | 1,214.1 ± 29.9* | 1,249.9 ± 29.9* | 1,248.2 ± 29.9* | 1,253.9 ± 30.0* |
| Protein [% of energy] | 15.9 ± 0.2 | 14.3 ± 0.2* | 13.9 ± 0.2* | 12.9 ± 0.2* | 12.1 ± 0.2* |
| Total fats [% of energy] | 28.8 ± 0.6 | 28.4 ± 0.6 | 28.9 ± 0.6 | 28.4 ± 0.6 | 30.2 ± 0.6 |
| Saturated fats [% of energy] | 9.1 ± 0.3 | 9.0 ± 0.3 | 9.3 ± 0.3 | 9.5 ± 0.3 | 10.7 ± 0.3* |
| Trans fats [% of energy] | 0.2 ± 0.0 | 0.2 ± 0.0 | 0.2 ± 0.0 | 0.2 ± 0.0 | 0.2 ± 0.0 |
| Monounsaturated fats [% of energy] | 8.8 ± 0.2 | 8.7 ± 0.2 | 9.1 ± 0.2 | 9.2 ± 0.2 | 9.6 ± 0.2* |
| Polyunsaturated fats [% of energy] | 7.4 ± 0.2 | 7.0 ± 0.2 | 7.1 ± 0.2 | 6.7 ± 0.2* | 6.4 ± 0.2* |
| Carbohydrates [% of energy] | 55.4 ± 0.6 | 58.7 ± 0.6* | 57.4 ± 0.6* | 59.5 ± 0.6* | 57.8 ± 0.6* |
| Total sugars [% of energy] | 22.1 ± 0.6 | 27.3 ± 0.6* | 28.6 ± 0.6* | 30.4 ± 0.6* | 33.0 ± 0.6* |
| Fiber (g/1,000 kcal intake) | 9.3 ± 0.3 | 9.0 ± 0.3 | 8.2 ± 0.3* | 7.9 ± 0.3* | 7.5 ± 0.3* |
| Sodium [mg/1,000 kcal intake] | 1,299.3 ± 33.1 | 1,145.7 ± 33.2* | 1,178.2 ± 33.2* | 1,083.9 ± 33.1* | 1,030.7 ± 33.3* |
| Iron [mg/1,000 kcal intake] | 6.7 ± 0.2 | 7.0 ± 0.2 | 7.2 ± 0.2 | 7.2 ± 0.2 | 7.2 ± 0.2 |
| Calcium [mg/1,000 kcal intake] | 621.0 ± 20.3 | 595.9 ± 20.3 | 645.0 ± 20.3 | 630.5 ± 20.3 | 628.8 ± 20.4 |
| Zinc [mg/1,000 kcal intake] | 5.4 ± 0.2 | 5.2 ± 0.2 | 5.2 ± 0.2 | 5.0 ± 0.2* | 5.0 ± 0.2* |
| Vitamin A [IU/1,000 kcal intake] | 3,321.1 ± 208.5 | 3,571.3 ± 208.7 | 3,252.2 ± 208.6 | 2,851.6 ± 208.5 | 2,074.6 ± 209.5* |
| Vitamin D [IU/1,000 kcal intake] | 40.2 ± 7.7 | 56.2 ± 7.7 | 80.4 ± 7.7* | 76.6 ± 7.7* | 90.3 ± 7.7* |
| Vitamin C [mg/1,000 kcal intake] | 40.8 ± 2.8 | 45.3 ± 2.8 | 41.2 ± 2.8 | 42.2 ± 2.8 | 42.1 ± 2.8 |
| Folate [μg/1,000 kcal intake] | 200.6 ± 7.8 | 184.2 ± 7.8 | 168.4 ± 7.8* | 143.6 ± 7.8* | 141.7 ± 7.8* |
| Vitamin $B_{12}$ [μg/1,000 kcal intake] | 2.3 ± 0.1 | 2.2 ± 0.1 | 2.3 ± 0.1 | 2.3 ± 0.1 | 2.2 ± 0.1 |

*UPF, Ultra-processed food.*
*Values represent the adjusted mean ± standard error from predictive margin multivariate regression models.*
*Multivariate regression models considered quintiles of UPF intake as independent variables (reference group: 1st quintile) and sex, age, and weight status of preschoolers (three categories), mother's education (three categories), and day of the dietary recall (i.e., weekday vs. weekend) as covariates.*
**P-values <0.05 from multivariate regression models, compared to 1st quintile of UPF intake (reference group).*

with some degree of processing). To minimize this limitation, foods listed by the USDA were selected according to the similarity of nutritional information (i.e., energy/calories, macronutrients, and nutrients of concern) provided by the Chilean table of food compositions and, in the case of packaged products, by the nutritional contents reported by manufacturers. As the selection of foods did not consider other nutrients or factors, the results regarding micronutrients and fiber should be interpreted based on this important limitation. This may be especially relevant for vitamin D, which is fortified among dairy products in the USA but not in Chile. Finally, we did not have any biomarker to more accurately assess the diet, which could be especially important for sodium intake. A strength of this study was that all information was collected by a team of trained professionals using standardized methods and supplemented by an atlas to estimate portions, with photographs of foods, and with locally relevant recipes, which supports the precision of the reported results; moreover, we also had access to the recipes used by the school feeding program.

In conclusion, in 4–6-year-old preschoolers from Santiago, Chile, UPF were an important source of energy and nutrients of concern such as total sugars, saturated fats, and sodium. Children with a greater dietary share of UPF had diets characterized by greater content of energy, saturated fats, carbohydrates, and total sugars, and a lower content of fiber, zinc, vitamin A, and folate. Early dietary behaviors might influence long-term dietary behaviors and health status and therefore, improving children's diet should be prioritized on the nutrition agenda. Our results highlight the need of implementing actions to decrease UPF consumption while promoting the consumption of minimally processed and traditionally prepared foods; specific actions targeting sodium might also be required for achieving healthier diets.

## DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because of funder's restrictions. Requests to access the datasets should be directed to mreyes@inta.uchile.cl.

## ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethics Committee of the Institute of Nutrition and Food Technology (INTA), University of Chile, and the Institutional Review Board of the University of North Carolina at Chapel Hill. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

## AUTHOR CONTRIBUTIONS

MR, CC, and LT contributed to the overall study conception and design, contributed to funding acquisition, study execution, and coordination. CA and GC classified the food and beverages according to the NOVA groups and subgroups. CA analyzed and interpreted the data with assistance from MR and CC and wrote the original draft of the manuscript, which the other co-authors reviewed and edited. MR has full access to all the data in the study and has final responsibility for the decision to submit for publication. All authors approved the final version of the manuscript before submission.

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## SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fnut.2021.601526/full#supplementary-material

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# Food Consumption and Characteristics Associated in a Brazilian Older Adult Population: A Cluster Analysis

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Epidemiological studies support diet as a factor in the prevention and treatment of non-communicable chronic diseases, whose occurrence increases with age due to the poor choices or the adoption of a monotonous diet. The aim of this study was to construct the food consumption profiles of older adults of a Brazilian city to identify the main food groups and eating habits that contribute to these profiles and to estimate its association with socioeconomic characteristics, health and use of health services, lifestyle, and anthropometric indicators. This is a population-based cross-sectional study conducted with a representative sample of 621 community-dwelling older adults (≥60 years) in Viçosa, Minas Gerais, Brazil. The food consumption profile was the dependent variable obtained from a Food Frequency Questionnaire, utilizing the two-step cluster method. The multiple multinomial logistic regression model was used to estimate the independent associations, obtaining the odds ratios and 95% confidence intervals. Three clusters were generated, namely, (1) "unhealthy" (2) "less unhealthy," and (3) "fairly healthy." The cluster "unhealthy" was characterized by a regular consumption of beans, fats, fatty/processed meats, and whole milk. The factors independently associated with this cluster were lower education level, lower individual income, history of at least one doctor's appointment in the year preceding this study, and being a former smoker. The cluster "less unhealthy" was characterized by a regular consumption of beans, green vegetables, vegetables and fruits, as well as fats, fatty/processed meats, and whole milk. The factors independently associated with the "less unhealthy" cluster were lower education level and history of at least six doctor's appointments in the prior year. The cluster "fairly healthy" was characterized by the same pattern of "less unhealthy," except for skim milk and low-fat dairy products. The evidence of the associations indicates the profile of older adults who require greater attention and care related to improved nutrition. The illiterate or semi-literate aged individuals, those with low income, and those who neglect to seek medical advice must be the focus of healthy eating actions and programs.

**Keywords: food consumption, nutritional epidemiology, eating habits, aging, older adults, cluster analysis**

# INTRODUCTION

Maintenance of the independence of older adults as well as their effective participation in society is directly linked to the preservation of their health, which is influenced by various factors, including lifestyle (1). In this context, the epidemiological and review studies offer evidence to support the importance of diet as a factor in the prevention and treatment of various non-communicable chronic diseases like diabetes, dyslipidemia, hypertension, and obesity (2–4), which pose challenges to the health professionals given that their occurrence increases dramatically with advancing age (5). Due to the poor choices or the adoption of a monotonous diet, the aged individuals may experience deficiencies of essential nutrients necessary to maintain health and appropriate disease control (4, 6).

Studies available in the literature also deepen the understanding of the determinants of eating habits in various populations. Within the scope of the older adult population, international studies have demonstrated that higher income, greater education level, and less cognitive impairment are associated with better nutrition (3, 7–9), while diet deficiencies and unhealthy eating habits are associated with male gender, obesity treatment (10), history of myocardial infarction, ischemic heart disease, and heart failure (11). In Brazil, nutritional epidemiology focused on aging is still a relatively new field of study, and only a few studies have investigated the determinants of eating habits of older adults. From these studies, a positive association has been identified between adequate eating habits and female gender, higher education (12–14), advancing age, a greater number of comorbidities (15), non-smoking (13, 14) overweight, and a history of consultation with a nutritionist (13, 14). On the other hand, low diet quality was associated with male gender, age <80 years, lower education, problems in affording food (16), smoking habit, underweight, mouth or teeth problems, and having <4 meals a day (17, 18).

Although there is an increase in the number of studies on food consumption among older adults in Brazil, little is known about this phenomenon in smaller cities. Social, economic, and cultural differences are significant among the Brazilian subpopulations, and the effectiveness of the promotion of healthy eating habits is influenced by these distinctions. In addition, grouping aged individuals according to their eating habits allows the identification of more vulnerable profiles that need more attention from public policies. This approach is still scarce in Brazil.

Thus, the aim of this study is to construct and describe the food consumption profiles of the older adult population of a medium-sized Brazilian city, by identifying the main food groups and eating habits that contribute to these profiles, and to estimate the association of the social and demographic characteristics, health and use of health services, lifestyle, and anthropometric indicators with these profiles.

# MATERIALS AND METHODS

## Study Design and Participants

This was a population-based, cross-sectional study—part of the project "Health conditions, nutrition, and use of medication by older adults in Viçosa (Minas Gerais): a population-based survey." Viçosa is a medium-sized Brazilian city located in the region of Zona da Mata in the state of Minas Gerais.

The study population consisted of older adults, aged 60 years or more, who are non-institutionalized residents in the municipality, including rural and urban areas. The target population was 7,980 individuals. The sample size was calculated with a confidence level of 95%, with an estimated prevalence of 50% for different outcomes of interest in the larger project, a tolerated error of 4%, and 20% to cover losses. Based on the calculation, the total number obtained was 670 individuals. There were losses by refusal ($n = 24$, 3.6%) due to death, address not found, and emigration from the city ($n = 25$, 3.7%). Losses did not differ by gender and age group. The participants were selected and interviewed according to the description of Nascimento et al. (19). The final sample consisted of 621 participants.

The interviews were pre-scheduled and conducted in the participants' houses by previously trained nutritionists paired with final-year undergraduate nutrition students. The present study was conducted according to the Declaration of Helsinki. The research project was approved by the Research Ethics Committee of the Federal University of Viçosa (ref. 27/2008). All the participants signed the informed consent form.

## Study Variables

### Social, Demographic, and Economic Variables, Health Conditions, and Lifestyle

The social and demographic variables of interest included sex (male, female), age range (60–69, 70–79, and 80 years or more), education level (never studied, <8 years of study, 8 years of study or more), income (quartiles), and cohabitation (lived alone, resided with someone else).

The variables of health conditions were self-perception of health (very good/good, regular, poor/very poor), hospital admissions (none, one, or more), and number of doctor's appointments (none, one to five, six or more) in the year preceding the interview as an indicator of healthcare or need for medical care. The functional ability was assessed using the questions regarding the ability to perform 14 basic and instrumental daily life activities, and the answer options included no difficulty, little difficulty, great difficulty, unable to do, and do not do (19). Besides the variable functional ability, the variables of instrumental daily life activities such as difficulty in eating and difficulty in preparing food were considered. The functional ability was defined as inadequate when the participant reported difficulty with the performance of seven or more activities or when they evaluated themselves as unable to perform three or more activities. Otherwise, the functional ability was defined as adequate (20). Polypharmacy, which was considered in this study, is defined as the use of five or more drugs (21). The 15-day recall period was defined in line with the literature to minimize memory bias (21, 22). Regarding the history of chronic disease, the following question was posed: "Even once in your life, has a doctor or any other health professional ever mentioned that you have or have had any of these diseases?" For the analysis, a history of diabetes, high blood pressure, dyslipidemia, and depression were used. The development of the instrument used to obtain information on health conditions was based on validated

**TABLE 1 |** Classification of foods in groups of healthy and unhealthy eating indicators.

| Food Groups | | Foods |
|---|---|---|
| Healthy Eating Indicators | Beans[a] and Green vegetables[a] | Black, brown, and red beans |
| | Other vegetables[a] | |
| | Fruits[a] | |
| | Skim milk and low-fat dairy products[a] | Skim milk |
| | | White cheese (Minas cheese[d]) |
| | | Ricotta |
| Unhealthy eating indicators | Whole milk[b] | |
| | Soda[c] | |
| | Processed foods in general[c] | Cracker |
| | | Cornstarch cookie |
| | | Pound cake |
| | | Lasagna |
| | | Fried “pastel”[e] |
| | | Pizza |
| | Sweets[c] | Sweets in general (desserts) |
| | | Frosted cake |
| | | Chocolate |
| | Fatty/processed meats[b] | Fried chicken |
| | | Sausage |
| | | Wiener |
| | | Pork rinds |
| | | Ham/salami |
| | Fats[b] | Margarine |
| | | Butter |
| | | Lard |

*Source: Adapted from Ministério da Saúde do Brasil (Vigitel 2016) (28).*
*[a]Healthy eating indicators, if they were consumed five times/week or more. For the group of “other vegetables,” yam, cassava, and potatoes were excluded.*
*[b]Unhealthy eating indicators, if they were consumed at least once a week.*
*[c]Unhealthy eating indicators, if they were consumed five times/week or more.*
*[d]A kind of cheese very popular in the state of Minas Gerais, Brazil.*
*[e]Traditional Brazilian food prepared with wheat flour dough and various fillings.*

questionnaires as used by large national health surveys and prospective health studies with older adult populations (23–25).

Regarding their lifestyle, the seniors were questioned about their consumption of alcoholic beverages (yes; no, but used to drink formerly; never drank at all) and smoking (yes; no, but used to smoke formerly; never smoked at all). Besides that, they were questioned about a decrease in food intake due to loss of appetite, digestive problems, and chewing or swallowing difficulties within 3 months prior to the interview (26).

### Anthropometric Variables

Concerning nutritional status, we calculated the body mass index (kg/m²), the waist-to-hip ratio, and the waist-to-height ratio. All these rates were used in the analysis as continuous variables besides waist circumference (27).

### Food Consumption Variables

Regarding food consumption variables, the data collection instrument was a Food Frequency Questionnaire (FFQ) consisting of a long list of foods and consumption frequency options: once a day, two or more times a day,2–4 times a week, 5–6 times a week, once a week, twice a week, monthly, and never or rarely. The foods presented in the FFQ were grouped and classified as “healthy” and “unhealthy” eating indicators. Food groups classified as healthy eating indicators included beans, green vegetables, other vegetables, fruits, skim milk, and low-fat dairy products. Food groups classified as unhealthy eating indicators were whole milk, soda, processed foods in general, sweets, fatty /processed meats, and fats (saturated and trans-fat) (**Table 1**). According to the methodology of a national study in Brazil, entitled Protective and Risk Factors for Chronic Diseases by Telephone Survey (VIGITEL) of the year 2016, the consumption of each group was considered “regular” when some foods of the group were consumed at least five times a week and was considered “non-regular” when it was consumed up to four times a week. The exceptions were the consumption of whole milk, fats, and fatty/processed meats, which were considered unhealthy eating indicators with a regular consumption even when they were consumed once a week (28).

## Statistical Analysis

The profile of food consumption was obtained from categorizing the individuals based on the frequency of consumption of the food groups listed in the FFQ. To obtain this variable, we used the two-step cluster analysis (TSC), which is a consistent method used for grouping the subjects and aggregate units based on the characteristics that they possess (29). In the cluster analysis, the idea is to explore the homogeneity in each cluster and the heterogeneity among the clusters to define a data structure. When the probability of the presence of a given characteristic in a cluster is above 50%, this characteristic determines the cluster format (29). In this study, the main characteristic was the categorical variables of the regular consumption of each food group, that is, the presence or absence of food groups. The unit of analysis was the individual, and in the pre-agglomeration step, TSC checked each data; in this case, each senior pointing out whether the individual could be added to a previously formed cluster or a new cluster needed to be created for him/her (30).

The descriptive analysis includes the estimates of medians and interquartile ranges for the quantitative variables and the frequency distribution for the categorical variables. Multinomial logistic regression was used to identify the association between the independent variables of interest in this study and the dependent variable, the clusters of food consumption. Crude and adjusted odds ratios (OR) were estimated as well as their 95% confidence intervals (CI). In this study, the independent variables that were associated with the dependent variable with $p < 0.20$ in the univariate stage were included in the multiple multinomial logistic regression model according to Hosmer and Lemeshow (31). Data analysis was performed using the IBM SPSS software, version 20.0. The level of significance for rejecting the null hypothesis was $\alpha = 0.05$.

**TABLE 2 |** Socioeconomic characteristics, health and use of health services, lifestyle, and anthropometric indicators in the older adult sample, Viçosa, State of Minas Gerais, Brazil, 2009 ($n = 621$).

| Variable | *n* | % | Median | Interquartile range |
|---|---|---|---|---|
| **Sex female** | 331 | 53.3 | | |
| Age range | | | | |
| 60–69 | 311 | 50.1 | | |
| 70–79 | 216 | 34.8 | | |
| ≥80 | 94 | 15.1 | | |
| Education level | | | | |
| Never studied | 95 | 15.3 | | |
| Less than eight years of study | 397 | 63.9 | | |
| Eight years of study or more | 129 | 20.8 | | |
| Individual income/month (quartiles) | | | | |
| Q1 (US$ 0–210.99) | 72 | 11.6 | | |
| Q2 (US$ 211.00–273.49) | 234 | 37.7 | | |
| Q3 (US$ 237.50–670.99) | 153 | 24.6 | | |
| Q4 (≥ US$ 671.00) | 153 | 24.6 | | |
| Lived alone | 66 | 10.6 | | |
| Self-perception of health[a] | | | | |
| Very good/good | 272 | 43.8 | | |
| Regular | 289 | 46.5 | | |
| Poor/very poor | 38 | 6.1 | | |
| Number of doctor's appointments (in the preceding year)[a] | | | | |
| None | 45 | 7.2 | | |
| 1–5 | 449 | 72.3 | | |
| ≥6 | 126 | 20.3 | | |
| **History of at least one hospitalization (in the preceding year)** | 94 | 15.1 | | |
| **Functional disability** | 100 | 16.1 | | |
| **Difficulty with eating** | 53 | 8.5 | | |
| **Difficulty with food preparation** | 66 | 10.6 | | |
| **Polypharmacy (in the preceding 15 days)** | 224 | 36.1 | | |
| **History of diabetes** | 139 | 22.4 | | |
| **History of dyslipidemia** | 353 | 56.8 | | |
| **History of high blood pressure** | 475 | 76.5 | | |
| **History of depression** | 117 | 18.8 | | |
| Consumption of alcoholic beverages[a] | | | | |
| Yes | 209 | 33.7 | | |
| No, but used to drink formerly | 205 | 33.0 | | |
| Never drank at all | 206 | 33.2 | | |
| Smoking habit[a] | | | | |
| Yes | 67 | 10.8 | | |
| No, but used to smoke formerly | 207 | 33.3 | | |
| Never smoked at all | 345 | 55.6 | | |
| Decrease in the food intake (in the preceding 3 months) | 78 | 12.6 | | |
| Anthropometric variables[b] | | | | |
| BMI (kg/m$^2$) | | | 26.37 | 23.49–29.53 |
| WC (cm) | | | 95.30 | 87.60–103.10 |
| WHR | | | 0.96 | 0.91–1.00 |
| WHtR | | | 0.60 | 0.55–0.65 |

*BMI, body mass index; WC, waist circumference; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio.*
*[a]Not informed by a part of the sample.*
*[b]Not measured/calculated in a part of the sample.*

**TABLE 3 |** Frequency of regular consumption of food groups, listed under healthy and unhealthy eating indicators, Viçosa, State of Minas Gerais, Brazil, 2009 ($n = 621$).

| Food groups | Consumption | |
|---|---|---|
| | *n* | % |
| **Healthy eating indicators** | | |
| Beans | 581 | 93.6 |
| Vegetables | 443 | 71.3 |
| Green vegetables | 440 | 70.9 |
| Fruits | 443 | 71.3 |
| Skim milk and low-fat dairy products | 170 | 27.4 |
| **Unhealthy eating indicators** | | |
| Fatty/processed meat | 553 | 89.0 |
| Fat | 385 | 62.0 |
| Whole milk | 359 | 57.8 |
| Processed foods in general | 183 | 29.5 |
| Sweets | 54 | 8.7 |
| Soda | 13 | 2.1 |

## RESULTS

Regarding the socioeconomic characteristics of the participants, the majority were female, between 60 and 69 years old, had <8 years of study, and resided with someone else (**Table 2**). Regarding income, most seniors fell under the second quartile (individual income between US$ 211.00 and US$ 237.49 per month). The lower limit corresponded to the minimum wage converted into American dollars according to the rates at the time of the study. Most of the seniors perceived their health to be regular and had a history of one to five doctor's appointments, with 15.1% reporting a history of hospitalization in the year preceding the survey. Functional ability was considered inadequate for about 16% of the individuals, and a minority reported difficulty with eating, difficulty with food preparation, and some decrease in food intake over the 3 months prior to the survey. Polypharmacy was identified in a third of the participants as well as the consumption of alcoholic beverages; however, the majority had never smoked. Regarding the diagnosis of non-communicable diseases, high blood pressure was the most prevalent, followed by a history of dyslipidemia, a history of diabetes, and depression. Anthropometric variables are presented as median and interquartile range (**Table 2**).

Most of the individuals used to consume foods that were listed under "healthy eating indicators," except for skim milk and low-fat dairy products. Of note is the regular consumption (five times or more per week) of beans by nearly the entire sample. In relation to "unhealthy eating indicators," we identified a low frequency of consumption of sweets and soda. On the other hand, the consumption of fatty/processed meat at least once a week was reported by the majority of the seniors (**Table 3**).

The analysis generated three clusters using the information regarding the individual's food consumption, which were named according to the behavior of the seniors that they included. The first was "unhealthy," the second "less unhealthy," and the

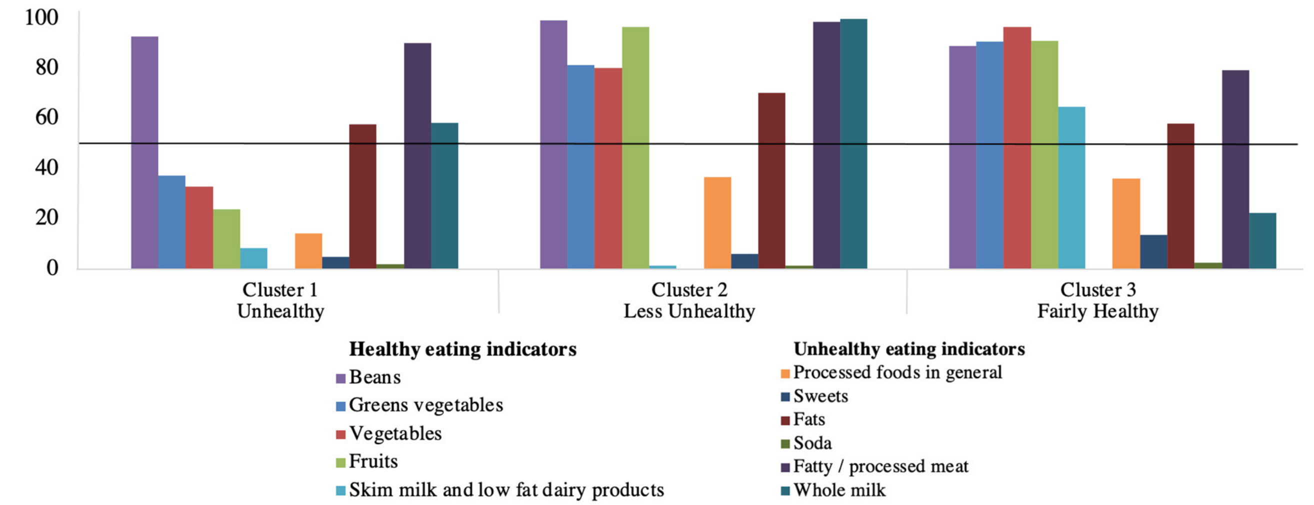


**FIGURE 1 |** Consumption frequency of the groups of healthy and unhealthy eating indicators, according to the clusters of older adults, Viçosa, State of Minas Gerais, Brazil, 2009 ($n = 621$). When the probability of regular consumption of an indicator is above 50% (y-axis), this food group is a characteristic that determines the cluster format.

third "fairly healthy" (**Figure 1**). The cluster "unhealthy" (32.2% of the sample) was characterized by older adults who regularly consumed beans, fats, fatty/processed meats, and whole milk. The cluster "less unhealthy" was formed by 30.6% of the participants who regularly consumed beans, green vegetables, vegetables, and fruits as well as consumed fats, fatty/processed meats, and whole milk. The cluster "fairly healthy" was represented by 37.2% of the individuals who regularly consumed beans, green vegetables, vegetables, fruits, fats, fatty/processed meats, skim milk, and low-fat dairy products. Among the healthy eating indicators, we highlight the consumption of beans, as in the three clusters almost all the participants consumed this food regularly (five or more times per week). Similar behavior was observed in relation to the consumption of fats and fatty/processed meats, characterizing them as unhealthy eating indicators that were present in all clusters. Some food groups had a low frequency of consumption in all clusters, such as processed foods in general, sweets, and soda. Processed foods in general had an even lower consumption frequency in cluster 1, and the sweets were slightly more frequent in cluster 3.

In the univariate analysis, the variables associated with the clusters "unhealthy" and "less unhealthy" were education level, individual income, number of doctor's appointments, history of diabetes, history of dislipidemia, polypharmacy, consumption of alcoolic beverages, smoking habbit, reduction in food ingestion, and waist circumference (data not shown). The OR and the respective confidence intervals (95% CI) of the multiple analyses between the socioeconomic and health conditions and clusters of food consumption in this older adult population are presented in **Table 4**. Individuals who never studied or with <8 years of study and those who reported at least six doctor's appointment in the prior year were more likely to belong to the clusters "unhealthy" and "less unhealthy." The seniors in quartiles 1 and 2 of individual income, those who reported one to five doctor's appointment in the prior year, and the former smokers had a greater chance to belong to the cluster "unhealthy." There was a borderline association of the cluster "unhealthy" with a history of diabetes (OR 0.6; 95% CI 0.3,1.0; $p = 0.051$), and there was also a borderline association of the cluster "less unhealthy" with a history of dyslipidemia (OR 0.6; 95% CI 0.4,1.0; $p = 0.054$).

## DISCUSSION

This is the first Brazilian population-based study that obtained and described three profiles of older adults from the two-step cluster analysis concerning food consumption. We identified the food groups and eating habits that contributed to characterize these profiles, and we estimated the association of social and demographic variables, health and use of health services, lifestyle, and anthropometric indicators with these profiles.

The first cluster was identified as "unhealthy." Despite being characterized by the regular consumption of beans, a healthy eating indicator, their other three food groups were unhealthy eating indicators (whole milk, fatty/processed meats, and fats). Moreover, most of the seniors in the cluster "unhealthy" were not used to consuming fruits and vegetables regularly. The second cluster was classified as "less unhealthy" because, although it was characterized by the presence of fruits, green vegetables, and beans, it also included whole milk, fatty/processed meats, and fats. The third cluster was classified as "fairly healthy" because it differed from cluster 2, as it included skim milk and low-fat dairy products, and from cluster 1 by the consumption of all healthy eating indicators. Thus, this cluster represents individuals with a healthier food profile, as compared to the other two clusters, but is not completely healthy because it was also characterized by the consumption of fats and fatty/processed meats.

Changes in food consumption caused by modernization are of concern in all population groups, as they are characterized by

**TABLE 4 |** Final results of the multiple analysis of the association among the sociodemographic and health conditions and the food consumption clusters[a], Viçosa, State of Minas Gerais, Brazil, 2009 ($n = 621$).

| Variable | Cluster 1 | Cluster 2 |
|---|---|---|
| | Unhealthy | Less unhealthy |
| | OR (CI 95%) | OR (CI 95%) |
| **Education level** | | |
| Eight years of study or more | 1.0 | 1.0 |
| Less than 8 years of study | **3.8 (1.9–7.5)** | **2.8 (1.6–4.9)** |
| Never studied | **10.7 (4.2–27.7)** | **5.4 (2.2–13.2)** |
| **Individual income/month (quartiles)** | | |
| Q4 (≥US$ 671.00) | 1.0 | 1.0 |
| Q3 (US$ 237.50–670.99) | 1.5 (0.8–3.1) | 1.1 (0.6–2.0) |
| Q2 (US$ 211.00–273.49) | **2.3 (1.2–4.6)** | 1.1 (0.6–2.0) |
| Q1 (US$ 0–210.99) | **2.4 (1.1–5.5)** | 1.1 (0.5–2.3) |
| **Number of doctor's appointments** | | |
| None | 1.0 | 1.0 |
| 1–5 | **0.3 (0.1–0.8)** | 0.6 (0.2–1.6) |
| ≥6 | **0.3 (0.1–0.9)** | **0.3 (0.1–0.9)** |
| **History of diabetes** | | |
| No | 1.0 | 1.0 |
| Yes | 0.6 (0.3–1.0) | 0.8 (0.4–1.3) |
| **History of dyslipidemia** | | |
| No | 1.0 | 1.0 |
| Yes | 0.7 (0.5–1.2) | 0.6 (0.4–1.0) |
| **Polypharmacy** | | |
| No | 1.0 | 1.0 |
| Yes | 0.7 (0.4–1.1) | 0.8 (0.5–1.2) |
| **Consumption of alcoholic beverages** | | |
| Never drank at all | 1.0 | 1.0 |
| No, but used to drink formerly | 1.4 (0.8–2.5) | 1.1 (0.6–1.9) |
| Yes | 0.8 (0.4–1.5) | 0.9 (0.5–1.6) |
| **Smoking habit** | | |
| Never smoked at all | 1.0 | 1.0 |
| No, but used to smoke formerly | **1.8 (1.1–3.1)** | 1.6 (0.9–2.6) |
| Yes | 2.0 (0.9–4.2) | 0.9 (0.4–1.9) |
| **Reduction in food ingestion** | | |
| No | 1.0 | 1.0 |
| Yes | 1.6 (0.8–3.4) | 1.7 (0.8–3.5) |
| **WC (median = 95.3cm)** | | |
| Lesser than the median | 1.0 | 1.0 |
| Larger than or equal to the median | 0.9 (0.9–1.0) | 1.0 (0.9–1.0) |

*[a]For this analysis, the cluster "fairly healthy" was the reference category.*
*CI95%, 95% confidence interval; OR, odds ratio; WC, waist circumference.*
*Values in bold indicate factors independently associated with the "unhealthy" and "less unhealthy" clusters.*

the replacement of fresh foods rich in nutrients with processed foods rich in sugar, fat, and additives (32). When it turns to older adults, monotonous food choices with low nutritional quality are the greatest risk (33, 34). Nevertheless, in this study, we observed a mix of high consumption of healthy eating indicators, such as fruits and vegetables, and unhealthy eating indicators, such as whole milk, fatty/processed meats, and fats. The consumption of processed foods, sweets, and soda did not characterize any cluster, which shows that the older adults in this sample still remained on a traditional diet despite that the cluster "unhealthy" had shown little variety.

Lower education level was found to be directly associated with the clusters "unhealthy" and "less unhealthy." Low education level is often a factor that negatively impacts the eating habits and leads to a greater risk of malnutrition as reported by previous epidemiological studies (3, 16, 17, 32, 35, 36). Giuli et al. (3), in an Italian study, identified that seniors with a higher education level consumed more beans, cereals, fruits, fish, red meat, and dairy products. In Brazil, another study observed a lower education level among aged individuals whose families revealed food insecurity (35), and Gadenz and Benvegnú (13) identified a positive association between more years of study and the consumption of fruits and vegetables by aged individuals. In the present study, the cluster "unhealthy" is an example of worse nutrition associated with low education. With more years of study, there may be greater access to information about the quality of food and the contribution of each food group to health. In addition, more often, higher education is also related to higher income, which will be discussed later. The only difference between the clusters "fairly healthy" and "less unhealthy" was the regular consumption of skim milk and low-fat dairy products in the first category and the consumption of whole milk in the second. Considering this, the results of the current study suggest that a higher education level (8 years of study or more) promotes access to information on healthy eating, making it reasonable to assume that it influences the habit of replacing whole milk with skim products when necessary. A review from Netherlands about dietary guidances confirms that dairy products are part of these food-based dietary guidelines because of their nutrient richness and emphasizes that low-fat or skimmed versions must be generally advocated (37). This result may also indicate that nutrition will be better with the tendency of increase in the education of older adults, a hypothesis that requires further investigation in the future. For now, this result evidences the need to promote nutrition education suitable for the low-educated older adult population with appropriate communication.

Lower income was also found to be directly associated with the cluster "unhealthy," that is, the seniors included in this cluster were more likely to possess an individual income less than US$ 237.50 per month, marginally higher than the minimum wage of the time, when compared with the cluster "fairly healthy." Assumpção and colleagues also reported results in which seniors earning higher incomes revealed higher healthy eating scores (15). Total household income was significantly and positively associated with fruits and vegetables intake among older adults in the Canadian study of Riediger and Moghadasian (32). Despite the great offer and diversity of fruits and vegetables in Brazil, even at lower costs, it is still expected that the aged individuals with higher personal incomes enjoy greater purchasing power, which may encourage food choices with more quality and variety. The association observed between the lower socioeconomic level and low quality of diet suggests unequal access to food among the older adults, which is supported by the evidence that the cluster "unhealthy" was characterized by people with a more monotonous food consumption, lacking the important variety and quality provided by fruits, vegetables, skim milk, and low-fat dairy products. In this sense, policies must be developed to reduce income inequality and guarantee access to adequate food for older adult populations.

The variable "number of doctor's appointments" was inversely associated with the clusters "unhealthy" and "less unhealthy." The individuals assigned to the cluster "fairly healthy" had a higher number of consultations in the year preceding the survey. Gadenz and Benvegnú identified a similar behavior with aged individuals, revealing the direct association between adequate diet and a history of consultation with a nutritionist (13). An inference that can be drawn is that, because these seniors had sought more healthcare, they enjoyed greater access to information related to wise eating choices and therefore consumed more food considered as healthy eating indicators, such as fruits, vegetables, skim milk, and low-fat dairy products.

From the univariate analysis, the history of diabetes was inversely associated with the cluster "unhealthy," and the history of dyslipidemia was inversely associated with both clusters "unhealthy" and "less unhealthy." Both did not remain in the final model, but they were in the significance threshold ($p = 0.051$ for diabetes and $p = 0.054$ for dyslipidemia). It is possible that these morbidities resulted in greater demand/utilization of health services by the seniors and, consequently, provided greater access to information, culminating in better eating habits. This possible behavioral change, called reverse causality, was also reported by Assumpção and colleagues, who observed a better quality of diet among older adults with a reported diagnosis of diabetes (15). Thus, it is possible that the best diet quality can be due to the diagnosis of non-communicable chronic diseases, which demands the adoption of a healthy diet for accurate treatment.

Another condition directly associated with the cluster "unhealthy" was having been a former smoker. The individuals in this profile were more likely to have smoked and stopped this habit at some point in their lives. Due to the lack of information regarding the time of smoking exposure and the time that had lapsed between the interview and smoking cessation, this data can be extremely variable, and the relationship between this old habit and the present diet is not precise. Smoking is known to change the palatability of some foods, such as fruits, vegetables, dairy products, and even water (38), and the cessation of this habit can reawaken the ability to experience the taste of these foods (38, 39). Besides that, the adoption of a healthier behavior, such as smoking cessation, should be accompanied by an improvement in other aspects, like eating habits. Perhaps these changes are motivated by different reasons, which explains the results observed. The association between the current smoking habit and the cluster "unhealthy" in multiple analysis showed a trend toward significance ($p = 0.066$). Studies show the association between smoking and poor eating habits (15, 38, 40, 41). It is possible that the small number of smokers in this study ($n = 67$; 10.8%) has restricted the ability to identify this association in the sample under study.

It is worth emphasizing that all methods of evaluation of food intake have limitations, such as the possibility of memory bias, especially in aged individuals. The FFQ is considered an efficient tool for identifying the usual food consumption, speccially when conducted by trained interviewers, besides having a low cost and simple application (42). In addition, we believe that the monotony of the diet of the Brazilian older adults (33, 34) minimizes the limitations of the FFQ and the possible distortions in the results of the food profile of this population. The qualitative characteristic of the instrument used has not enabled the evaluation of the food portions consumed by the seniors. This fact impairs the comparison with some recommendations and a deeper evaluation of the diet.

A limitation inherent in the cross-sectional design is the inability to establish the temporal relationship of some of the associations observed. Nevertheless, they are consistent with the literature and generate hypotheses that need to be explored in longitudinal studies in order to recognize the determinants of the eating habits of older adults, and despite the limitations, they are important as a nutritional advice for these invididuals.

A possible limitation of the study is the fact that the health conditions and drug utilization information are self-reported. However, the way to obtain this information was based on instruments adopted by large national surveys that have already reported its satisfactory validity.

In conclusion, we identified three clusters called "unhealthy," "less unhealthy," and "fairly healthy" based on data from the food consumption of older adults in Brazil. Although all clusters have been characterized by the consumption of some unhealthy foods, the subjects presented traditional eating habits in this study, especially showing a low consumption of soda, sweets, and processed foods in general and a high consumption of beans. However, the cluster "unhealthy" was composed of individuals without the habit of regular consumption of fruits and vegetables. We observed an association between low education level, low income, few doctor's appointments, and the fact of being a former smoker with poor diet quality. The evidence indicates the profile of seniors who require greater attention and care related to improved nutrition. Nutrition education public policies and health actions must be focused on and appropriate for the illiterate or semi-literate aged individuals with lower income and those who do not seek guidance. In light of the obtained results, efforts should be made to encourage older adults to keep the traditional and healthy eating habits, with greater access to consumption of fruits, vegetables, and beans and low consumption of soda, sweets, and processed foods.

## DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## ETHICS STATEMENT

This study was reviewed and approved by Research Ethics Committee of the Federal University of Viçosa (ref. 27/2008).

The participants provided their written informed consent to participate in this study.

## AUTHOR CONTRIBUTIONS

LL, MP, and AR contributed to the conception and design of the study. AR contributed to the acquisition of data. LL and AR wrote the first draft with contributions from MP, LA, and CM. All the authors reviewed and commented on the subsequent drafts of the manuscript.

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# Diet and Lifestyle Changes During the COVID-19 Pandemic in Ibero-American Countries: Argentina, Brazil, Mexico, Peru, and Spain

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This study aimed to evaluate changes in dietary and lifestyle habits during the period of confinement due to the first wave of the COVID-19 pandemic in Ibero-American countries. A cross-sectional investigation was conducted with 6,325 participants of both genders (68% women), over 18 years of age and from five countries: Brazil ($N = 2{,}171$), Argentina ($N = 1{,}111$), Peru ($N = 1{,}174$), Mexico ($N = 686$), and Spain ($N = 1{,}183$). Data were collected during the year 2020, between April 01 and June 30 in Spain and between July 13 and September 26, in the other countries studied using a self-administered online survey designed for the assessment of sociodemographic, employment, physical activity, health status, and dietary habits changes. Most participants (61.6%), mainly those from Spain, remained constant, without improving or worsening their pattern of food consumption. Among those who changed, a pattern of better eating choices prevailed (22.7%) in comparison with those who changed toward less healthy choices (15.7%). Argentina and Brazil showed the highest proportion of changes toward a healthier pattern of food consumption. Peruvians and Mexicans were less likely to make healthy changes in food consumption (OR: 0.51; 95% CI: 0.4–0.6 and OR: 0.69; 95% CI: 0.4–0.8, respectively), when compared to Argentinians. Most respondents did not change their pattern of meal consumption, but those who did reduced their consumption of main meals and increased intake of small meals and snacks. Although most participants affirmed to be doing physical activity at home, about one-half reported perception of weight gain. Individuals with alterations in sleep pattern (either by increasing or decreasing sleep time) were more likely to change their diets to a healthier pattern. In contrast, individuals with confirmed diagnosis of COVID-19 and those who reported feeling anxious were more likely to perform changes to a less healthy eating pattern (OR: 1.72; 95% CI: 1.2–2.3 and OR: 1.21; 95% CI: 1.1–1.4, respectively). In conclusion, although most participants remained constant in their eating habits, lifestyle changes and anxiety feelings were reported. Among those who changed patterns of food consumption, healthier choices prevailed, with differences between countries. However, there were alterations in the distribution of meals, with higher consumption of snacks and small meals. These results can be used to guide policies to prevent deleterious consequences that may affect the incidence of chronic diseases.

**Keywords: COVID-19, diet, lifestyle, confinement, pandemic, E-survey**

## INTRODUCTION

Despite global efforts, the rapid spread of the coronavirus disease 2019 (COVID-19) has strongly affected Ibero-American countries. Since the declaration of a world health emergency by the World Health Organization (1) in March 2020, followed by the declaration of the pandemic (2), each government has managed the situation using different strategies. The most common measures adopted varied from radical quarantine or total confinement; selective quarantine, meaning flexible confinement for part of the population and total confinement for vulnerable people (elderly and/or individuals with underlying diseases); to the maintenance of normality, aiming to obtain the so-called "herd immunity."

While social physical distance practices are important to prevent the collapse of the health system, they also affect interpersonal relationships and many aspects of everyday life, including dietary and lifestyle habits of individuals, families, and populations. The pandemic now is far from being controlled and according to experts from the WHO and other institutions, we will not avoid future ones. As a result of this scenario, it is expected that physical and psychological consequences will last for a long time after the COVID-19 pandemics crisis. It can be expected that slowly evolving diet and lifestyle changes will affect the incidence of chronic diseases. Hence, it is difficult to estimate the extent of the consequences of lifestyle changes on the health system (3).

The impact of isolation, confinement, and social distancing in large populations has led to numerous statistical, educational, psychological, sociological, and historical studies, among others. Some have investigated how confinement affected people in their homes, the change in their routines and the consequent adaptations regarding eating habits, physical activity, use of screens, sleep patterns, among others (4–15). Many studies evaluated dietary changes (11, 12, 16). Some have focused on Chinese children and adolescents (7), Croatian adolescents and medical students (15), adults from Israel (17). Brazilian adults (11), single European countries (10, 18, 19) and children or adults with comorbidities (5, 6, 8). One study compared dietary changes among adolescents from different Ibero-American countries during the pandemic (9). Thus far, there are no comparative studies among adults from Ibero-American countries.

Understanding the effects of the pandemic on lifestyle habits can guide behavioral and psychological measures, directed at individuals and communities, improving resilience, preventing diseases, and increasing the effectiveness of health approaches to mitigate the effects during this contingency and in others that could potentially occur. Therefore, we aimed to assess changes in dietary and lifestyle habits due to COVID-19-induced confinement in different Ibero-American countries.

## MATERIALS AND METHODS

### Study Design and Population

This study was a cross-sectional, online Ibero-American survey of adult men and women aged $\geq$ 18 years, from four Latin American countries (Argentina, Brazil, Mexico, and Peru) and one European country (Spain). Data were collected in the year 2020, between April 01 and June 30 in Spain and between July 13 and September 26, in Latin American countries, during the period of confinement due to the COVID-19 pandemic. This was a period of self-isolation, remote work, and restrictions of access to indoor and outdoor places. Participants were invited mainly through the research team and university social networks (e-mail, Facebook, Instagram, and WhatsApp) and completed an online structured questionnaire using the Google Forms web survey platform. A total of 6,525 answers were received. After excluding, aged $<$ 18 years ($N = 26$) and respondents from other countries ($N = 174$), the final data set includedr 6,325 participants.

### Ethical Aspects

A brief description of the study and its aim as well as an informed consent were provided on the first electronic page containing the invitation to participate in the survey. All subjects consented to join in the study after clicking the "accept" icon, meaning that they have agreed with the terms of the informed consent.

This study follows the international ethical standards found in the Declaration of Helsinki (2000). All procedures involving human subjects were approved by the Research and Ethics Committee of each country as follows: Research and Ethics Committee of the Adventist University of River Plate School of Medicine in Argentina (Resolution # 1.7/2020); Ethics Committee of the Federal University of Espírito Santo in Brazil (approval #: 33948820.7.0000.5060); Ethics Committee of the University of the Americas Puebla in Mexico (approval # 019/2020); Ethics in Research Committee of the Peruvian Union University (approval # 2020-CEUPeU-00013); and Ethics Committee of the Autonomous University of Madrid, Spain (Projet: Cohorte UAM/AUF COVID-19 (CEI 106- 2082).

**TABLE 1 |** Socio-demographic, confinement, diagnosis of COVID 19 and nutritional status characteristics, according to direction of changes in eating patterns during the confinement due to COVID-19 pandemic.

| | Total 6,325 | Changes in eating pattern | | | *p* |
|---|---|---|---|---|---|
| | | Healthier *n* (%) 1,435 (22.7) | No change *n* (%) 3,894 (61.6) | Less healthy *n* (%) 996 (15.7) | |
| **Sex** | | | | | |
| Male | 2,019 (31.9) | 385 (19.1) | 1,329 (65.8) | 305 (15.1) | <0.001 |
| Female | 4,306 (68.1) | 1,050 (24.4) | 2,566 (59.6) | 690 (16.0) | |
| **Country** | | | | | |
| Argentina | 1,111 (17.5) | 320 (28.8) | 637 (57.3) | 154 (13.9) | <0.001 |
| Brazil | 2,171 (34.3) | 573 (26.4) | 1,278 (58.9) | 320 (14.7) | |
| Mexico | 686 (10.8) | 154 (22.4) | 384 (56.0) | 148 (21.6) | |
| Peru | 1,174 (18.5) | 193 (16.4) | 753 (64.1) | 228 (19.4) | |
| Spain | 1,183 (18.7) | 195 (16.5) | 843 (71.3) | 145 (12.3) | |
| **Age (years)** | | | | | |
| 18–29 | 3,059 (48.4) | 751 (24.6) | 1,761 (57.6) | 547 (17.9) | <0.001 |
| 30–49 | 2,310 (36.5) | 529 (22.9) | 1,429 (61.9) | 352 (15.2) | |
| ≥50 | 956 (15.1) | 155 (16.2) | 705 (73.7) | 96 (10.0) | |
| **Marital status** | | | | | |
| Single | 3,599 (56.9) | 865 (24.0) | 2,113 (58.7) | 621 (17.3) | <0.001 |
| Married | 2,360 (37.3) | 495 (21.0) | 1,541 (65.3) | 324 (13.7) | |
| Separated/divorced/widowed | 366 (5.7) | 75 (20.5) | 241 (65.8) | 50 (13.7) | |
| **Educational level** | | | | | |
| High school or less | 1,683 (26.6) | 377 (22.9) | 1,048 (62.3) | 257 (15.6) | 0.064 |
| College | 2,712 (42.9) | 579 (21.3) | 1,704 (62.8) | 429 (15.8) | |
| Graduate | 1,930 (30.5) | 479 (24.8) | 1,143 (59.2) | 308 (16.0) | |
| **Employment status** | | | | | |
| Unemployed/retired | 502 (7.9) | 94 (18.7) | 337 (67.1) | 71 (14.1) | <0.001 |
| Housewife | 170 (2.7) | 39 (22.9) | 108 (63.5) | 23 (13.5) | |
| Student | 2,230 (35.3) | 552 (24.8) | 1,288 (57.8) | 390 (17.5) | |
| Worker and student | 1,000 (15.8) | 248 (24.8) | 594 (59.4) | 158 (15.8) | |
| Worker | 2,391 (37.8) | 496 (20.7) | 1,547 (64.7) | 348 (14.6) | |
| **Confinement*** | | | | | |
| No | 452 (8.8) | 95 (21.0) | 309 (68.4) | 48 (10.6) | <0.001 |
| Yes, I am still | 1,152 (22.4) | 269 (23.4) | 691 (60.0) | 48 (10.6) | |
| Yes, but I am back to my activities | 3,541(68.8) | 877 (24.8) | 2,054 (58.0) | 610 (17.2) | |
| **Confirmed diagnosis of COVID-19*** | | | | | |
| No | 5,891(93.5) | 1,355 (23.0) | 3,619 (61.4) | 917 (15.6) | 0.039 |
| Yes | 405 (6.4) | 73 (18.0) | 257 (63.5) | 75 (18.5) | |
| **Perception of weight change during lockdown*** | | | | | |
| Yes, weight gain | 2,794 (48.6) | 809 (29.0) | 1,512 (54.1) | 473 (16.9) | <0.001 |
| Yes, weight loss | 1,331 (23.1) | 198 (14.9) | 912 (68.5) | 221 (16.6) | |
| No, weight maintenance | 1,619 (28.1) | 306 (18.9) | 1,117 (69.0) | 196 (12.1) | |
| **Nutritional status*** | | | | | |
| Underweight | 2,017 (32.3) | 451 (22.4) | 1,253 (62.1) | 313 (15.5) | 0.941 |
| Normal | 3,380 (54.1) | 775 (22.9) | 2,062 (61.0) | 543 (16.1) | |
| Overweight/obesity | 844 (13.6) | 196 (23.2) | 515 (61.0) | 133 (15.8) | |

*n, number; Chi-square test, * different sample size.*

## Assessment of Socio-Demographic, Diet, Health and Well-Being, and Lifestyle Exposures

Data collection was carried out through a single structured digital self-administered questionnaire elaborated by the authors using the Google Forms tool. The instrument was designed and culturally adapted by a team of nutrition and lifestyle research experts to be applied in the studied countries and included questions on sociodemographic, confinement, diet, health and well-being, and lifestyle exposures. The following socio-demographic variables were evaluated: age in years; sex (male or female); marital status (single, married, separated/divorced, or widowed); educational level (elementary, middle school, high school, college, or graduate); current occupation (student, worker, housewife, unemployed, or retired); labor condition (formal worker with contract, self-employed, or public service employee). The instrument included the following questions on confinement during the pandemic: (1) *Were you part of the confinement?* The answer options were: *yes, I am still confined, yes but I have returned to work, or no;* (2) *For how many days were you in confinement/are you still in confinement?* The possible answers were: *<15, 15–30, 31–45, 45–60 days,* or *more than 61 days*; (3) *How many people lived in your home before confinement?* (4) *How many people lived in your home during confinement?*

Two questions were used to evaluate consumption of meals: (1) *Meals usually consumed before confinement: breakfast, small morning snack, lunch, small afternoon snack, dinner, and snacking between meals* and (2) *Meals usually consumed during confinement: breakfast, small morning snack, lunch, small afternoon snack, dinner, and snacking between meals.* The answer options were *yes* or *no,* for each meal. Thus, the following responses were obtained: unchanged consumption of the meal, increased consumption of the meal and decreased consumption of the meal due to COVID-19-induced confinement.

Previous and current consumption of food groups (vegetables, fruits, legumes, nuts, fish, red meat and poultry, eggs, milk, yogurt, bakery products, salty chips, soft drinks, beer, wine, distilled alcoholic beverages, and fast food) were evaluated with two questions, respectively: (1) *Choose the option that describes your consumption before confinement* and (2) *Choose the option that describes your consumption during confinement.* For each food group there were six options of frequency of consumption: never /seldom, 1–2 times a week, 3–4 times a week, 5–6 times a week, and 1 time per day, and 2+ times per day. Frequencies of intake were converted to weekly equivalents, as follows: never/seldom = zero/week, 1–2 times a week = 1.5/week, 3–4 times a week = 3.5/week, 5–6 times a week = 5.5/week. Answers of 1 time per day and 2+ times per day were collapsed for analyses and converted into weekly equivalents: 1+ times per day = 7+/week. Weekly equivalents were used to calculate the difference between consumption before confinement and during the confinement of each food group, thus generating the variable "difference in the consumption."

For the lifestyle variables, we evaluated sleep hours/night, sleep changes (no change, sleeping more or less) and the practice of physical activity during confinement. The first question used to assess the practice of physical activity was: *During the period of confinement do you practice some type of physical activity?* The answer options were *yes* or *no.* Those who answered affirmatively were asked two more questions: (1) *How many days per week?*, with answer options ranging from 1 to 7 and (2) *What is the duration of physical activity?,* with the following answer options: *<30 min, 30 min—1 h, 1–2 h, or Other* (open answer).

Two questions were used to explore feelings of anxiety among participants. We asked if confinement generated feelings of anxiety (yes or no) and if feelings of anxiety were generated by other situations, such as: unemployment, illness (own or in the family), worries about pandemic information, or other cause (to be completed by the participant as an open question). Changes in lifestyle habits and eating patterns during confinement were assessed retrospectively using the same instrument which included questions about the habit before the confinement and during the confinement, separately. Self-reported height and current weight were used to calculate body mass index (BMI) in $kg/m^2$. Participants were asked if there was any weight change during confinement reported either as weight gain, loss, maintenance, or ignored. Self-reported data on COVID-19 diagnostic and hospitalization were also collected.

## Data Analysis

In the present study, the percentage of individuals consuming or not consuming each meal before and during confinement due to COVID-19 in different countries was compared using the McNemar test. K-means cluster analysis was used to determine patterns of dietary changes during confinement. Variables used to create patterns were "difference in consumption" of food groups (vegetables, fruits, legumes, nuts, fish, red meat and poultry, eggs, milk, yogurt, bakery products, salty chips, soft drinks, beer, wine, distilled alcoholic beverages, and fast food). Three best interpretable patterns were created: (1) Healthier, characterized by increased consumption of fruits, vegetables, and legumes and less consumption of bakery products, and snacks, (2) No change, characterized by relatively stable (Constant) dietary patterns during the confinement compared to previous time; and (3) Less healthy, characterized by decreased consumption of vegetables, fruits, legumes, nuts, eggs, milk and yogurt during the confinement.

The chi-square test was used to analyze associations of socio-demographic, lifestyle and anxiety variables among patterns of dietary changes (healthier, no change, and less healthy) and among individuals with/without a confirmed diagnosis of COVID-19. Moreover, stepwise multivariate logistic regression analyses were performed to analyze the factors that influenced the odds of assignment to the (1) healthier, (2) no change/constant, and (3) less healthy patterns of dietary changes. The created models included socio-demographics (sex, age, educational level, employment status, and country, confinement status, confirmed diagnosis of COVID-19, and BMI category) and lifestyle factors (physical activity, sleep changes, and feelings of anxiety during confinement). The results of logistic regression analyses were expressed as odds ratio (OR) and 95% confidence intervals (95% CI). For all analyses, $p \leq 0.05$ was considered significant. All statistical analyses were performed using the SPSS 23.0.

# RESULTS

The studied sample consisted of 6,325 respondents with women predominating significantly (**Table 1**). The largest group was from Brazil and the smallest group was from Mexico. About half of the population aged 18–29 years and 73.4% of respondents had a higher educational level or more. Nearly 90% of participants were either students, workers, or both. During the period of the pandemic, the largest percentage was confined and had no confirmed diagnosis of COVID-19.

Most participants reported no change in their eating habits during the pandemic (61.6%), however, most of those who changed, did so in the direction of healthier dietary choices (22.7%). The same pattern was mainly found among women, Argentinians, Brazilians, among youngest participants (<30 years), students, workers and students, among those who did confinement, and those who gained weight. No statistical significance was found between dietary changes and educational levels or nutritional status (**Table 1**).

When analyzing eating behavior changes in individuals from different countries, it was evident that higher proportions of Argentinians (28.8%) and Brazilians (26.4%) adopted healthier patterns of food choices during the pandemic. Spaniards followed the same trend with 16.5% individuals shifting diet patterns toward healthier options and 2.3% individuals moving in the opposite direction. Similar proportions of Mexicans adopted healthier (22.4%) and less healthy (21.6%) eating patterns, while higher proportions of Peruvians adopted less healthy eating patterns (19.4%) than those who made healthier choices (16.4%) (**Table 1**).

Most participants remained constant in their pattern of meal consumption, neither introducing nor omitting meals during confinement. Respondents who reported changes are described in **Figure 1**. There was a trend in reducing the consumption of main meals (breakfast, lunch, and dinner) during the confinement. In contrast, participants were more likely to increase their consumption of small morning and afternoon meals. Except for Peru, they also tended to snack more between meals. The *p*-values for comparisons using the McNemar test were significant for all meals ($p < 0.001$ for breakfast, dinner, morning and afternoon meals, and snacks and $p < 0.005$ for lunch).

**Table 2** shows that most participants reported doing physical activities (57.1%) 1–6 days/week (51.3%) with a duration of 30 min−1 h (62%). Changes in sleeping habits and feelings of anxiety during the pandemic were also frequently reported (72.1 and 63.0%, respectively). Interestingly, participants who reported not having changed sleeping hours during confinement slept on average 7.3 ± 1.1 h. Those who reported sleeping more had an average of 8.5 ± 1.5 h of sleep and those who reported sleeping less had an average of 6.0 ± 1.1 h of sleep ($p < 0.001$). Healthier eating choices were mainly observed among those who reported not doing physical activity or practiced fewer days/week (1–3 days/week), those who had sleep duration changes, and those who reported feeling anxious during confinement (specially feelings of anxiety from illness of family members and due to COVID-19 statistics). The sensitivity analysis for participants with COVID is reported in **Supplementary Table 1**.

**Table 3** presents selected variables among participants who changed their eating pattern toward healthier choices during the COVID-19 pandemic using three multiple logistic regression models with progressive adjustments. It was found a positive association with the adoption of healthier dietary changes among those who were younger (<30 years, OR: 1.61; 95% CI: 1.2–2.1; 30–49 years, OR: 1.41; 95% CI: 1.1–1.7) and those who changed their sleep pattern, either sleeping more (OR: 1.40; 95% CI: 1.2–1.7) or less (OR: 1.46; 95% CI: 1.2–1.7). On the contrary, individuals with lower educational levels, Peruvians and Mexicans were less likely to adopt healthier diet changes (OR: 0.70 95% CI: 0.5–0.8; OR: 0.51; 95% CI: 0.4–0.6; and 0.59; 95% CI: 0.4–0.8, respectively).

**Table 4** shows a comparison of the studied variables among participants who during the COVID-19 pandemic remained constant on their eating pattern. After adjustments, positive associations were found for educational level, lockdown and physical activity, and negative associations were observed for gender, age, diagnosis of COVID-19, sleep pattern and feelings of anxiety. Indeed, individuals with low educational levels were more likely to maintain their eating patterns than participants with graduate educational level (high school or less, OR: 1.33; 95% CI: 1.1–1.5; college, OR: 1.36; 95% CI 1.1–1.6). The absence of lockdown was also associated with no changes in eating patterns (1.43; 95% CI 1.1–1.8). The same pattern was observed among those who were physically active during the pandemic confinement (1.29; 95% CI 1.1–1.4). In contrast, women (OR = 0.88; 95% CI: 0.6–0.9), individuals with <30 years (OR: 0.55; 95% CI: 0.4–0.7), and 30–49 years (OR: 0.72; 95% CI: 0.5–0.9), with diagnosis of COVID-19 (OR: 0.77; 95% CI: 0.5–0.9), with change in sleep pattern (increased sleep time, OR: 0.68; 95% CI: 0.5–0.8 and decreased sleep time, OR: 0.67; 95% CI: 0.5–0.8), and who reported feelings of anxiety (OR: 0.72; 95% CI: 0.6–0.8) were less likely to keep eating patterns constant.

A comparison of chosen variables among participants who changed their eating patterns toward a less healthy profile during the COVID-19 pandemic is presented in **Table 5**. Positive associations were only found for age group, country of residence, diagnosis of COVID-19, and feelings of anxiety. Individuals below 30 years old (OR: 1.60, 95% CI:1.1–2.3), Peruvians (OR: 1.38; 95% CI: 1.1–1.7), Mexicans (OR: 1.61; 95% CI: 1.2–2.1), individuals with a diagnosis of COVID-19 (OR: 1.72; 95% CI 1.2–2.3), and those who reported feelings of anxiety during confinement (OR = 1.21; 95% CI: 1.1–1.4) were more likely to make dietary changes to a less healthy pattern.

## DISCUSSION

During confinement due to the first wave of COVID-19 pandemic, most participants from the five Ibero-American studied countries remained constant. This trend was greater in Spain. Among those who changed, the change toward a healthier dietary pattern prevailed, especially in Argentina and Brazil, with an increase in the frequency of consumption of fruits, vegetables, legumes and a decrease in snacks and bakery products. Peruvians and Mexicans were less likely to make healthy changes in food consumption when compared to Argentinians. The pandemic situation also resulted in a constant pattern of meal consumption, neither introducing nor omitting meals during confinement. Nevertheless, among those who changed meal patterns, there was a trend in reducing the consumption of main meals (breakfast, lunch, and dinner) and in increasing the consumption of small meals and snacks in all studied countries More than half of

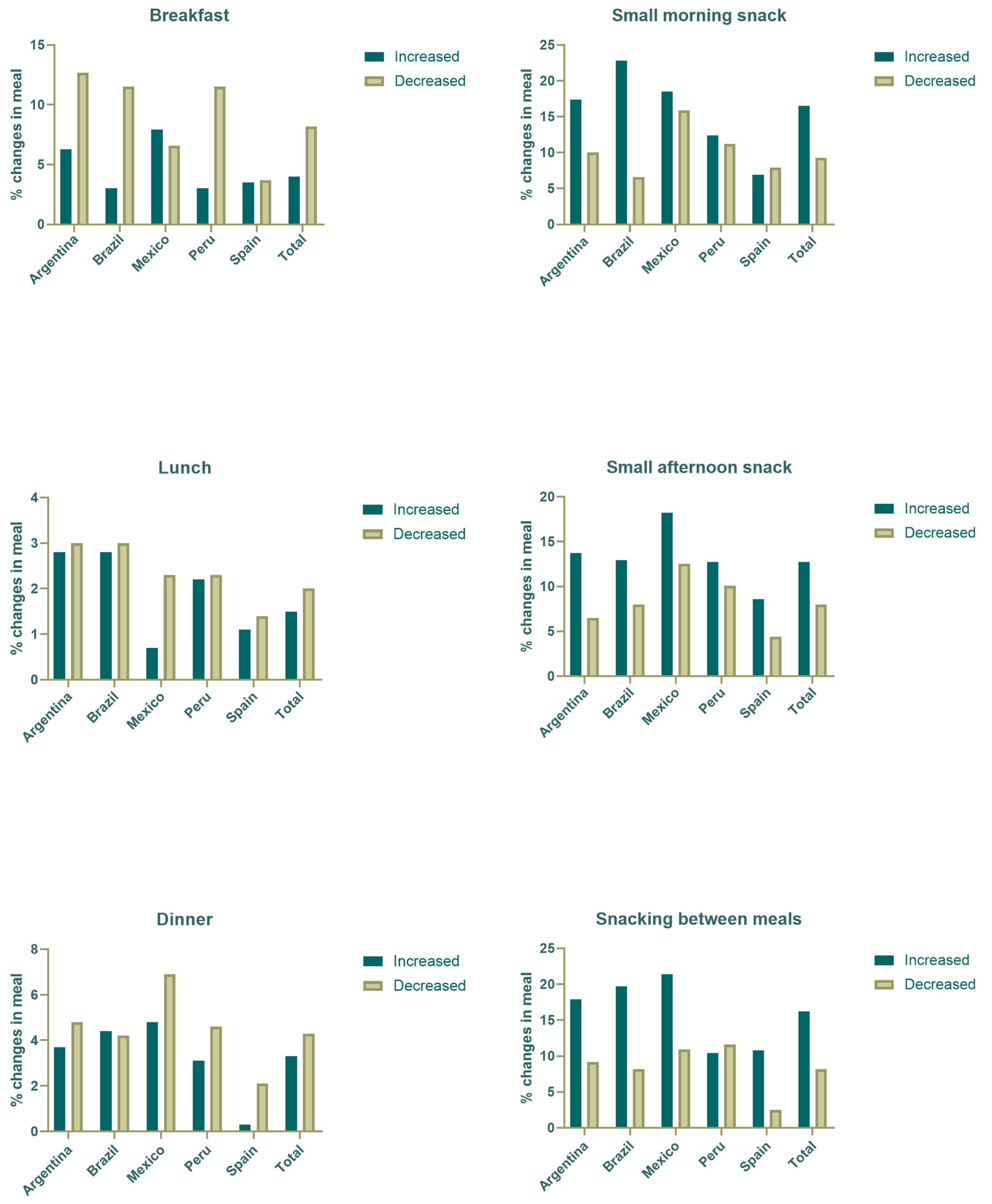


**FIGURE 1 |** Percentages of change in meal in Iberoamerican countries.

**TABLE 2 |** Physical activity, sleep changes and anxiety, according to direction of changes in eating patterns during the confinement due to COVID-19 pandemic.

| | Total 6,325 | Changes in eating pattern | | | *p* |
|---|---|---|---|---|---|
| | | **Healthier** *n* (%) **1,435 (22.7)** | **No change** *n* (%) **3,894 (61.6)** | **Less healthy** *n* (%) **996 (15.7)** | |
| **Physical activity during confinement** | | | | | |
| No | 2,714 (42.9) | 740 (27.3) | 1,555 (57.3) | 419 (15.4) | <0.001 |
| Yes | 3,611 (57.1) | 695 (19.2) | 2,340 (64.8) | 576 (16.0) | |
| **Physical activity during confinement (days/week)*** | | | | | |
| 1–3 | 1,710 (27.0) | 365 (21.3) | 1,089 (63.6) | 256 (14.9) | |
| 3–6 | 1,539 (24.3) | 280 (18.1) | 989 (64.2) | 270 (17.5) | |
| 7 | 362 (5.7) | 50 (13.8) | 262 (72.3) | 50 (13.8) | |
| **Physical activity confinement (time/week)*** | | | | | |
| <30 min | 623 (22.1) | 135 (21.7) | 379 (60.8) | 109 (17.5) | <0.001 |
| 30 min−1 h | 1,746 (62.0) | 358 (20.5) | 1,082 (62.0) | 306 (17.5) | |
| 1–2 h | 446 (15.8) | 96 (21.5) | 286 (64.1) | 64 (14.3) | |
| **Sleep changes during confinement*** | | | | | |
| No | 1,754 (27.8) | 305 (17.4) | 1,227 (70.0) | 222 (12.7) | <0.001 |
| Yes, sleep more | 2,629 (41.7) | 662 (25.2) | 1,521 (57.9) | 446 (17.0) | |
| Yes, sleep less | 1,918 (30.4) | 462 (24.1) | 1,132 (59.0) | 324 (16.9) | |
| **Feelings of anxiety during confinement** | | | | | |
| No | 2,327 (37.0) | 416 (17.9) | 1,589 (68.3) | 322 (13.8) | <0.001 |
| Yes | 3,969 (63.0) | 1,012 (25.5) | 2,287 (57.6) | 670 (16.9) | |
| Feelings of anxiety about work and economics | 370 (9.1) | 80 (20.5) | 221 (59.8) | 69 (19,7) | 0.363 |
| Feelings of anxiety for own or family members' disease | 1,361 (34.3) | 360 (26.5) | 759 (55.8) | 242 (17.7) | <0.001 |
| Feelings of anxiety due to COVID-19 statistics | 2,276 (57.3) | 616 (27.1) | 1,296 (56.9) | 364 (16.0) | <0.001 |
| Feelings of anxiety about studies | 367 (9.2) | 77 (21.0) | 224 (61.0) | 66 (18.0) | 0.486 |
| Feelings of anxiety about living together | 321 (8.1) | 75 (23.4) | 203 (63.2) | 43 (13.4) | 0.514 |
| Other sources of anxiety feelings (pregnancy, breastfeeding, addictions) | 574 (14.5) | 134 (23.3) | 349 (60.8) | 91 (15.9) | 0.733 |

*n, number; Chi-square test, *different sample size.*

the participants affirmed to be doing physical activity at home. Changes in sleep pattern, feelings of anxiety and perception of weight gain were also reported. Individuals who showed sleep changes were less likely to remain constant and more likely to modify their diets to a healthier pattern. In contrast, individuals with a confirmed diagnosis of COVID-19, and those who reported feeling anxious during confinement were more likely to perform changes to a less healthy eating pattern.

Other studies have also found a no change pattern in eating habits during the first wave of the COVID-19 pandemic, among older persons from the general Finnish population (20) and Polish adults (10). Scientific reports carried out before the pandemic revealed that diet quality in the studied Ibero-American countries deserves attention and surveillance. Therefore, our results showing maintenance of dietary patterns in most participants during the pandemic can be worrying. The Latin American region is facing an ongoing epidemiological nutritional transition. Data from the ELANS study (Latin American Study of Nutrition and Health) carried out just before the pandemic with an urban sample of 9,218 individuals between 15 and 65 years old from eight Latin American countries (Argentina, Brazil, Chile, Colombia, Costa Rica, Ecuador, Peru, and Venezuela) has shown that diet quality is deficient and with low diversity (21, 22). Only 7.2% of the overall sample reached the WHO's recommendation for fruits and vegetable consumption (400 g/day). Less than 3.5% of the sample met the optimal consumption levels of vegetables, nuts, whole grains, fish and yogurt.

In Mexico poor diets were the third leading risk factor for disability-adjusted life Years (DALYs) among adults (10.6%), followed by high BMI (11.7%) and high blood fasting glucose (11.1%), both of which are also partially linked with dietary habits (23). The intakes of sugar-sweetened beverages and energy-dense nutrient-poor foods are also especially problematic in Mexico (24).

Likewise, a Spanish national survey on the trends and evolution of patterns of food consumption showed changes in energy and nutrient intake from 1964, 1981, 1991, to 2000–2012, differing from the traditional and healthy *Mediterranean Diet*. Meat and derived product consumption was higher than the recommendations, whereas for cereals and their derivatives, vegetables and greens, fruits, and legumes and pulses, consumption was below recommendations for the Spanish population. Some staple Mediterranean foods (e.g., bread and olive oil) showed a dramatic decline (25).

**TABLE 3 |** Comparison of socio-demographic and selected variables among participants who changed their eating patterns toward healthier choices during the COVID-19 pandemic ($n = 1,435$).[a].

| | Model 1 OR (95% CI) | Model 2 OR (95% CI) | Model 3 OR (95% CI) |
|---|---|---|---|
| **Sex** | | | |
| Male | 1 | 1 | 1 |
| Female | 1.28 (1.1–1.4) | 1.19 (1.0–1.3) | 1.23 (1.0–1.4) |
| **Age (years)** | | | |
| 18–29 | 1.66 (1.2–2.1) | 1.61 (1.2–2.2) | 1.61 (1.2–2.1) |
| 30–49 | 1.50 (1.1–1.8) | 1.43 (1.1–1.8) | 1.41 (1.1–1.7) |
| ≥50 | 1 | 1 | 1 |
| **Marital status** | | | |
| Single | 1 | 1 | 1 |
| Married | 0.94 (0.7–1.1) | 0.95 (0.7–1.1) | 0.95 (0.7–1.1) |
| Separated/divorced/widowed | 0.97 (0.7–1.3) | 0.97 (0.6–1.4) | 0.92 (0.6–1.2) |
| **Educational level** | | | |
| High school or less | 0.72 (0.6–0.8) | 0.72 (0.6–0.8) | 0.70 (0.5–0.8) |
| College | 0.71 (0.6–0.8) | 0.73 (0.6–0.8) | 0.69 (0.5–0.8) |
| Graduate | 1 | 1 | 1 |
| **Employment status** | | | |
| Unemployed/retired | 0.95 (0.7–1.2) | 1.04 (0.7–1.4) | 0.96 (0.7–1.3) |
| Housewife | 0.97 (0.6–1.4) | 1.01 (0.6–1.5) | 0.97 (0.6–1.4) |
| Student | 1.09 (0.8–1.3) | 1.07 (0.8–1.3) | 1.10 (0.9–1.3) |
| Worker and student | 1 | 1 | 1 |
| Worker | 0.90 (0.7–1.1) | 0.86 (0.7–1.0) | 0.89 (0.7–1.0) |
| **Country** | | | |
| Brazil | 1.13 (0.8–1.3) | 1.13 (0.8–1.4) | 1.14 (0.9–1.3) |
| Peru | 0.59 (0.4–0.7) | 0.59 (0.4–0.7) | 0.51 (0.4–0.6) |
| Mexico | 0.64 (0.5–0.8) | 0.63 (0.4–0.8) | 0.59 (0.4–0.8) |
| Argentina | 1 | 1 | 1 |
| Spain | 0.60 (0.1–1.5) | 1.31 (0.1–1.5) | 1.55 (0.1–1.6) |
| **Confinement** | | | |
| No | | 0.82 (0.6–1.0) | 0.85 (0.6–1.1) |
| Yes, still confined | | 1 | 1 |
| Yes, back to activities | | 0.99 (0.8–1.1) | 1.02 (0.8–1.1) |
| **Confirmed diagnosis of COVID- 19** | | | |
| No | | 1 | 1 |
| Yes | | 0.93 (0.6–1.2) | 0.89 (0.6–1.2) |
| **Nutritional status** | | | |
| Underweight | | | 0.91 (0.7–1.0) |
| Normal | | | 1 |
| Overweight/obesity | | | 0.97 (0.7–1.2) |
| **Physical activity during confinement** | | | |
| No | | | 1 |
| Yes | | | 0.68 (0.5–1.1) |
| **Sleep changes during confinement** | | | |
| No | | | 1 |
| Yes, I sleep more | | | 1.40 (1.2–1.7) |
| Yes, I sleep less | | | 1.46 (1.2–1.7) |
| **Feelings of anxiety during confinement** | | | |
| Not | | | 1 |
| Yes | | | 1.7 (1.1–1.4) |

*95% CI, 95% confidence interval; OR, Odds Ratio.*

[a]*Estimated by stepwise multiple logistic regression. Model 1 adjusted for socio-demographic variables (sex, age, marital status, educational level, and country); Model 2 adjusted for socio-demographic variables, confinement, and diagnosis of COVID-19; Model 3 adjusted for sociodemographic variables, confinement, diagnosis of COVID-19, nutritional status, and lifestyle (physical activity, sleep changes and anxiety during confinement) variables.*

**TABLE 4 |** Comparison of selected variables among participants who remained constant on their eating pattern during the COVID-19 pandemic ($n$ = 3,849).[a].

| | Model 1 OR (95% CI) | Model 2 OR (95% CI) | Model 3 OR (95% CI) |
|---|---|---|---|
| **Sex** | | | |
| Male | 1 | 1 | 1 |
| Female | 0.77 (0.6–0.8) | 0.77 (0.6–0.8) | 0.88 (0.6–0.9) |
| **Age (years)** | | | |
| 18–29 | 0.50 (0.4–0.6) | 0.53 (0.4–0.6) | 0.55 (0.4–0.7) |
| 30–49 | 0.62 (0.5–0.7) | 0.69 (0.5–0.8) | 0.72 (0.5–0.9) |
| ≥50 | 1 | 1 | 1 |
| **Marital status** | | | |
| Single | 1 | 1 | 1 |
| Married | 1.07 (0.9–1.2) | 1.2 (1.0–1.5) | 1.01 (0.8–1.1) |
| Separated/divorced/widowed | 0.95 (0.7–1.2) | 1.3 (1.1–1.5) | 1.05 (0.7–1.4) |
| **Educational level** | | | |
| High school or less | 1.33 (1.1–1.5) | 1.29 (1.0–1.5) | 1.33 (1.1–1.5) |
| College | 1.38 (1.1–1.6) | 1.32 (1.1–1.5) | 1.36 (1.1–1.6) |
| Graduate | 1 | 1 | 1 |
| **Employment status** | | | |
| Unemployed/retired | 0.97 (0.7–1.2) | 0.93 (0.6–1.2) | 0.92 (0.6–1.2) |
| Housewife | 1.10 (0.7–1.2) | 1.12 (0.7–1.6) | 1.11 (0.7–1.6) |
| Student | 0.93 (0.7–1.1) | 0.98 (0.8–1.1) | 0.96 (0.8–1.1) |
| Worker and student | 1 | 1 | 1 |
| Worker | 1.05 (0.8–1.2) | 1.11 (0.9–1.3) | 1.09 (0.9–1.3) |
| **Country** | | | |
| Brazil | 0.95 (0.8–1.1) | 0.95 (0.8–1.1) | 0.91 (0.7–1.1) |
| Peru | 1.24 (1.0–1.4) | 1.22 (1.0–1.4) | 1.19 (1.0–1.4) |
| Mexico | 1.03 (0.8–1.2) | 1.03 (0.8–1.2) | 1.01 (0.8–1.2) |
| Argentina | 1 | 1 | 1 |
| Spain | 1.58 (1.3–1.8) | 0.87 (0.5–14.0) | 0.71 (0.4–11.0) |
| **Confinement** | | | |
| No | | | 1.43 (1.1–1.8) |
| Yes, still confined | | | 1 |
| Yes, back to activities | | | 0.98 (0.8–1.1) |
| **Confirmed diagnosis of COVID-19** | | | |
| No | | 1 | 1 |
| Yes | | 0.72 (0.5–0.9) | 0.77 (0.5–0.9) |
| **Nutritional status** | | | |
| Underweight | | | 1.10 (0.9–1.2) |
| Normal | | | 1 |
| Overweight/obesity | | | 0.94 (0.7–1.1) |
| **Physical activity during confinement** | | | |
| No | | | 1 |
| Yes | | | 1.29 (1.1–1.4) |
| **Sleep changes during confinement** | | | |
| No | | | 1 |
| Yes, sleep more | | | 0.68 (0.5–0.8) |
| Yes, sleep less | | | 0.67 (0.5–0.7) |
| **Feelings of anxiety during confinement** | | | |
| No | | | 1 |
| Yes | | | 0.72 (0.6–0.8) |

*95% CI, 95% Confidence interval; OR, Odds Ratio.*

*[a]Estimated by stepwise multiple logistic regression. Model 1 adjusted for sociodemographic variables (sex, country, age, marital status, educational level, and employment status); Model 2 adjusted for sociodemographic variables, confinement and confirmed diagnosis of COVID-19; Model 3 adjusted for sociodemographic, confinement, COVID-19 diagnosis, lifestyles variables (nutritional status, physical activity, and sleep changes during confinement), and anxiety during confinement.*

**TABLE 5 |** Comparison of selected variables among participants who changed their eating patterns toward less healthy choices during the COVID-19 pandemic ($n = 996$).[a].

| | Model 1 OR (95% CI) | Model 2 OR (95% CI) | Model 3 OR (95% CI) |
|---|---|---|---|
| **Sex** | | | |
| Male | 1 | 1 | 1 |
| Female | 1.14 (0.9–1.3) | 1.24 (1.0–1.4) | 1.22 (1.0–1.4) |
| **Age (years)** | | | |
| 18–29 | 1.8 (1.3–2.4) | 1.61 (1.1–2.3) | 1.60 (1.1–2.3) |
| 30–49 | 1.4 (1.1–1.9) | 1.25 (0.9–1.7) | 1.24 (0.9–1.7) |
| ≥50 | 1 | 1 | 1 |
| **Marital status** | | | |
| Single | 1 | 1 | 1 |
| Married | 0.95 (0.7–1.1) | 1.01 (0.8–1.2) | 1.01 (0.8–1.2) |
| Separated/divorced/widowed | 1.13 (0.7–1.6) | 1.00 (0.6–1.5) | 0.98 (0.6–1.5) |
| **Educational level** | | | |
| High school or less | 0.90 (0.7–1.1) | 0.97 (0.7–1.2) | 0.97 (0.7–1.2) |
| College | 0.86 (0.7–1.0) | 0.92 (0.7–1.1) | 0.91 (0.7–1.1) |
| Graduate | 1 | 1 | 1 |
| **Employment status** | | | |
| Unemployed/retired | 1.09 (0.7–1.5) | 1.07 (0.7–1.5) | 1.08 (0.7–1.5) |
| Housewife | 0.86 (0.5–1.4) | 0.80 (0.4–1.3) | 0.83 (0.4–1.4) |
| Student | 0.99 (0.7–1.2) | 0.92 (0.7–1.1) | 0.93 (0.7–1.2) |
| Worker and student | 1 | 1 | 1 |
| Worker | 1.03 (0.8–1.3) | 0.99 (0.7–1.2) | 1.01 (0.7–1.2) |
| **Country** | | | |
| Brazil | 0.89 (0.7–1.1) | 0.93 (0.7–1.1) | 0.93 (0.7–1.1) |
| Peru | 1.30 (1.1–1.5) | 1.35 (1.1–1.6) | 1.38 (1.1–1.7) |
| Mexico | 1.57 (1.2–2.0) | 1.60 (1.2–2.1) | 1.61 (1.2–2.1) |
| Argentina | 1 | 1 | 1 |
| Spain | 0.84 (0.6–1.0) | 0.90 (0.6–1.1) | 0.90 (0.6–1.1) |
| **Lockdown** | | | |
| No | | 0.57 (0.4–0.8) | 0.59 (0.4–0.8) |
| Yes, still confined | | 1 | 1 |
| Yes, back to activities | | 0.97 (0.8–1.1) | 0.98 (0.8–1.1) |
| **Confirmed diagnosis of COVID-19** | | | |
| No | | 1 | 1 |
| Yes | | 1.75 (1.2–2.4) | 1.72 (1.2–2.3) |
| **Nutritional status** | | | |
| Low weight | | | 0.94 (0.7–1.1) |
| Normal | | | 1 |
| Overweight/obesity | | | 1.14 (0.8–1.4) |
| **Physical activity during confinement** | | | |
| No | | | 1 |
| Yes | | | 1.04 (0.8–1.2) |
| **Sleep changes during confinement** | | | |
| No | | | 1 |
| Yes, sleep more | | | 1.18 (0.9–1.4) |
| Yes, sleep less | | | 1.23 (0.9–1.5) |
| **Feelings of anxiety during confinement** | | | |
| No | | | 1 |
| Yes | | | 1.21 (1.1–1.4) |

*95% CI, 95% Confidence interval; OR, Odds Ratio.*

*[a]Estimated by stepwise multiple logistic regression. Model 1 adjusted for sociodemographic variables (sex, country, age, marital status, educational level, and employment status); Model 2 adjusted for sociodemographic variables, confinement and confirmed diagnosis of COVID-19; Model 3 adjusted for sociodemographic, confinement, COVID-19 diagnosis, lifestyles variables (nutritional status, physical activity, and sleep changes during confinement), and anxiety during confinement.*

Therefore, changes toward a higher quality of dietary habits would be important for Ibero-American countries, especially considering the context of the current pandemic. It is well-known that the regular intake of foods with high nutritional values is associated with fewer ailments and better health conditions. Studies show that consistent eating of whole food plant-based diets may assist the immune system in fighting human pathogens by improving the intestinal microbiota and providing minerals, vitamins, and several other phytochemicals essential for the proper functioning of human metabolism (26, 27). Fruits and vegetables are rich in fibers supporting a healthy gut microbiome, and antioxidant phytochemicals such as alkaloids and flavonoids. Investigations have shown that certain types of vegetables may exert anti-inflammatory, antioxidant, cytoprotective, and antiviral properties due to elements found in garlic, onions, ginger, Curcuma, and berries (28). The promotion of changes in this direction could potentially prevent the future onset of chronic diseases and strengthen the organism to fight against infections.

Among participants who changed their food choices most went toward a healthier pattern. This result was also reported in studies performed in Poland (10), Italy (18), and Finland (20), during the COVID-19 pandemic. Indeed, spending more time at home may increase cooking time and promote better adaptation to healthier nutritional standards (29). Busy routines that made it difficult to consume homemade meals and led to the consumption of high-calorie fast foods, might have been replaced by homemade healthier preparations for those participants, during confinement. This behavior may also be related to COVID-19 driven stay-at-home guidelines. To support healthy food intakes during self-quarantine and isolation, the WHO published a document that recommends prioritizing legumes, fresh fruits, and vegetables and for cooking their recipes at home (30). The COVID-19 pandemic fostered the search for new foods and nutritional supplements which are safe and suitable to mitigate the infection and the subsequent state of hyper-inflammation, oxidation, and cytokines storms caused by the SARS-CoV-2 on humans, which is associated in some cases with higher health complications, multiorgan injury and worse prognosis (31).

Mexicans and Peruvians showed an inverse association for adherence to a healthier eating pattern in the present study. Data from the ELANS study showed that although Peruvians had the highest intake of fruits and whole grains and lower consumption of red and processed meat when compared with other Latin American countries, they had the highest intake of homemade sugar-sweetened beverages. Indeed, almost the entire sample of participants from Peru (97%) consumed such beverages. Moreover, Peruvians showed the highest prevalence of sedentary behavior (18, 32). Mexicans also face nutritional transition. In a study to evaluate diet changes in the Mexican population during confinement due to COVID-19, 37.2% of the participants reported changes to less healthy diet habits, with an increase in the consumption of sweets and desserts in 39% of men and 51.6% of women (33).

In our study, we observed that younger people were more likely to be classified in the group reporting changes consistent with a healthier diet. This was also observed among young Italians (18) who increased their compliance to the Mediterranean diet with higher consumption of olive oil, vegetables and legumes during confinement. This behavior shows the ability to adapt to drastic changes typical of this age. We also identified an inverse association between a healthier pattern and educational level, as seen in the USA. In this research, low-income and educated adults suffered direct effects caused by the pandemic, represented by the presence of food insecurity at all levels (34).

All countries showed a reduction in the main daily meals, particularly breakfast. This was more common in Argentina, Peru, and Brazil. There was also an increase in the consumption of intermediate meals in all countries. There is evidence that skipping breakfast increases the likelihood of obesity, which is related to the quality of life and health outcomes (35). The omission of main meals can lead to a higher energy intake in intermediate meals, and snacks throughout the day. These poor dietary habits associated with a shorter time spent in physical activity can impact the development of obesity and other chronic diseases (36).

Increased consumption of snacks was observed in all countries of our study, except for Peru. This behavior can be associated with ready-to-eat, high-calorie quick foods. Consumption of these foods is commonly associated with environmental, cognitive, and affective variables (e.g., boredom and stressful situations) which encourage their consumption outside the main meals (32, 37), such as reported during confinement by COVID-19.

Adopting and maintaining healthy lifestyle habits is recommended as a fundamental physical and mental health principle, especially during COVID-19 confinement. In our study, more than half of the participants confirmed the practice of physical activity during confinement, especially those younger than 30 years and older than 50 years of age (60% of both groups declared to do some type of physical activity at home). Similar results were observed in an Italian survey of 3,533 people with 10% of the participants reporting increased exercise training during the confinement (18). Likewise, in a Mexican population ($n = 1{,}084$), 53.2% of the participants practiced physical activity during confinement (33).

Our study also showed that half of the participants reported weight gain. Although we have not measured energy intake or energy expenditure, we theorize that a possible energy imbalance between food consumption and energy expenditure could be contributing to weight gain, regardless of the quality of the diet. Lower energy expenditure during the pandemic can result from a reduction of outdoor physical activities due to the implementation of mobility restrictions. Moreover, greater daily energy intake could have occurred over the pandemic confinement as reported in some (38, 39). It was estimated that during the COVID-19 lockdown there was an increase of 6% in daily energy intake in Spain (39). Other potential contributors to weight gain perceived by the participants of this study could be the irregularity of meals and the mealtime, with increased consumption of food outside of main meals (snacks and intermediate morning and afternoon meals); and higher levels of anxiety (40). It is known that anxiety is associated with poorer diet quality (41), especially during the pandemic (17). Some studies have found that snacking was used as a mechanism to help cope with increased anxiety levels during self-quarantine (38, 40, 42).

Sleep is another lifestyle habit critical to overall health. Consistent sleep strengthens the immune system (43), while sleep deprivation is connected with the risk of chronic diseases (44, 45). We found some changes in the sleep pattern in Ibero-American countries associated with sleep duration. There was an increase in the number of sleeping hours. During confinement, changes in routines and fixed sleeping times may have influenced and altered physiological regulators of sleep. Besides, most individuals were either students, workers, or both and approximately half of the participants were under 30 years of age. During confinement, many workers and students changed their activities to a remote form. This could have favored flexible hours of work or study at home, ensuing in late sleeping which may have also been associated with the reduction of breakfast intake, an unhealthy habit associated with higher mortality from cardiovascular causes (46).

In our study, changing the eating pattern toward a less healthy profile was positively associated with a confirmed diagnosis of COVID-19 and feelings of anxiety. Recent investigations showed high scores of unhealthy eating behaviors and a high-frequency of depressive and anxiety symptoms in two Mediterranean countries during the COVID-19 outbreak (17, 47). A high prevalence of anxiety generated by confinement during the pandemic was also observed in Saudi Arabia (27.7%) (48) and China (28.8%) (49). Anxiety has been directly associated with poor eating habits and inversely associated with healthy eating habits. In Greece, greater anxiety was associated with an increase in the consumption of sweets and meat products in women (50). An Iranian study found an inverse association between anxiety and higher consumption of vegetables, fruits, and dairy products (51).

This is a cross-sectional study conducted in a convenience sample during a restricted time frame, which contributes to specific limitations. The lack of representativeness and the different sample number for each country are the main limitations of our study. Response rates were different among countries due to the intrinsic characteristics of each country, and strategies of recruitment. Therefore, it is not possible to expand the results to the population of each country. Although mean age and educational level are proportionally distributed among countries, there is an over-representation of younger individuals (<30 years) and of women, reflecting the known lower interest in health-related matters among men (52). Moreover, all data collected are self-reported and this could make them not completely reliable, especially when it comes to reporting behaviors for which there may be a social stigma (e.g., alcohol and tobacco consumption). Other limitations could be a sampling bias with university students and workers being the majority of the population and the lack of information about religious practices which could have influenced diet and lifestyle changes.

Due to the temporary, unique and relatively unpredictable character of the phenomenon under study (the SARS-CoV-2 pandemic), the instrument was designed to capture information in that context and was culturally adapted by a team of nutrition and lifestyle research experts to be applied in each of the countries under study. Diet information was not used to quantify food consumption, nutrients or other components. Instead, questions concerning eating or lifestyle habits were applied to collect both information on the period before the pandemic and during the period of confinement. Such information is subject to the individual's memory, which could have caused measurement errors inherent to this type of method.

This study has some strengths. To our knowledge, this is the first study that evaluated and compared dietary and lifestyle changes among adults from Ibero-American countries (Argentina, Brazil, Mexico, Peru, and Spain) including design and implementation during the social confinement phase of the pandemic in all countries. Nevertheless, we acknowledge some distinct factors among countries (e.g., data collection during spring and early summer in Spain, late summer in Mexico and late winter in South American countries), which may have affected our results. Government policies also differed between countries concerning confinement. While in Spain and Mexico stricter restrictions were relaxed during summertime, Argentina and Peru faced stronger restrictive health protocols. Despite the growth of the pandemic curve in Brazil at that time, there was no homogeneity in governmental policies. Social distancing policies were adopted in several states, including those of which were most of the participants in this study (Espírito Santo and Rio de Janeiro). Nevertheless, regardless of the season of the year or how restrictive governmental measures could be at any time point, many people had to remain confined, and participants of this study were asked whether they were confined.

Despite its limitations, this study was performed with robust data analysis and covers a very important public health question in countries that are already at high risk of chronic diseases which are strongly affected by lifestyle and eating choices. The pandemic situation can further aggravate health status by affecting lifestyle choices. Therefore, our study provides additional information that can be used to assist guide policies to prevent deleterious consequences that may affect the incidence of chronic diseases.

## DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Research and Ethics Committee of the Adventist University of River Plate School of Medicine in Argentina (Resolution # 1.7/2020); Ethics Committee of the Federal University of Espírito Santo in Brazil (approval #: 33948820.7.0000.5060); Ethics Committee of the University of the Americas Puebla in Mexico (approval # 019/2020); Ethics in Research Committee of the Peruvian Union University (approval # 2020-CEUPeU-00013); and Ethics Committee of the Autonomous University of Madrid, Spain (Project: Cohorte UAM/AUF COVID-19 (CEI 106- 2082). The patients/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

OE-M conceived the idea of this project, directed the statistical analyses, and wrote the initial draft of the paper. MCTM was an active collaborator with OE-M at each step and reviewed and edited the manuscript. MCTM, OE-M, DS, and MCBM were responsible for data collection in Brazil. TP and KL were responsible for data collection in Mexico. They conducted the statistical analyses and wrote the Methodology section with OE-M and DS. SP and FP were responsible for data collection in Argentina and reviewed the manuscript. SH-V and MR-V were responsible for data collection in Peru and SH-V reviewed the manuscript. MPM and AM-U designed the instrument and were responsible for data collection in Spain. MPM also conceived of the idea and design of this project with MCBM, reviewed the manuscript and provided funding for the publication. MCBM coordinated all steps of this project and worked closely with OE-M reviewing and editing the manuscript and the analysis. All authors participated in the project design and data collection in the different studied countries.

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## SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fnut.2021.671004/full#supplementary-material

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REVIEW
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# Introducing Plant-Based Mediterranean Diet as a Lifestyle Medicine Approach in Latin America: Opportunities Within the Chilean Context

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Latin America is experiencing a significant epidemiological and nutritional transition, with a trend toward higher incidence of food-related chronic diseases. In this context, Lifestyle Medicine (LM) is a growing field focused on assisting individuals in adopting healthy behaviors for the prevention and treatment of these chronic diseases, including, among other pillars, a great emphasis on healthy eating. There is also a growing interest worldwide in environmental sustainability of dietary patterns, with increasing concern about their effects on planetary health. In this context, whole-food, plant-based diets -such as the Mediterranean diet (MD)- have emerged as a solution for both healthier eating and lowering environmental impact. Yet in order to be effective at these goals and achieve a high adherence to any nutritional prescription, the sociocultural reality of the community or population where we aim to practice must also be taken into account. In this review, we specifically highlight the plant-based MD as a LM-contextualized dietary pattern that is adaptable, applicable, and sustainable within the Chilean context and has the potential to address the current trend of chronic diseases in our country.

**Keywords: Mediterranean diet, plant based diet, lifestyle medicine, planetary health, chronic diseases - prevention and control, Latin America, cultural adaptability**

## INTRODUCTION

During past decades, the patterns of health and disease have changed, explained mostly by a demographic shift and increasing urbanization and industrialization. This has led to an epidemiological transition characterized by a decrease in mortality from infectious diseases, a rise in life expectancy, and a sustained increase in non-communicable chronic diseases (NCDs) (1–4). Latin America and developing countries are not the exception to this trend, showing a double burden of infectious and chronic diseases (5). Even more, since the beginning of this century, countries such as Chile and Uruguay have already depicted age-adjusted mortality rates from cardiovascular diseases (CVD) and cancer similar to those found in developed countries, such as the United States and Canada (6). Correlation between certain lifestyle habits, such as unhealthy diet and low physical activity, and the risk of developing NCDs is already well-known (7). Reducing diet-related risk factors associated with these conditions is one of the most impactful ways to reduce NCD burden as well as lessening their detrimental influence on individuals and society as a whole (8, 9).

The largest study describing lifestyle patterns in Latin America is the *Estudio Latinoamericano de Nutrición y Salud* (ELANS) (10), which analyzed food and nutrient intake as well as nutritional status and physical activity in more than 9,000 subjects (age range 15–65 years) living in urban locations across eight Latin American countries (i.e., Argentina, Brazil, Chile, Colombia, Costa Rica, Ecuador, Peru, and Venezuela). Overall, there is a low adherence to a high-quality diet, with limited consumption of diverse food groups, particularly in vulnerable subpopulations, but also with a reduced intake of micronutrients-rich foods, such as fruits and vegetables, legumes, and nuts (11). Only 7.2% of the overall sample reached World Health Organization (WHO)'s recommendation for fruit and vegetable intake (12). High percentages of the daily energy consumption came from high sugar and fat food sources, whereas only 18% was provided by food sources rich in fiber and micronutrients (13). These deficient food and nutrient intake-related habits present in Latin America are closely related to the pathogenesis and development of NCDs, which are explained by a dietary pattern deficient in nutrient-dense food groups as well as low levels of physical activity and a sedentary lifestyle (14, 15).

With regard to Chile, data from the 2016–2017 National Health Survey (16) showed an increasingly high prevalence of risk factors/conditions and NCDs: obesity: 34%; metabolic syndrome: 40%; blood hypertension: 28%; diabetes: 13%, and high CVD risk: 26%. Indeed, 27 and 25% of total mortality occurred in 2011 were attributed to CVD and cancer, respectively. Among environmental factors, we have reported low adherence to an abbreviated healthy dietary score, the Alternate Healthy Eating Index 2010 (AHEI-2010) (17), and to a locally adapted Mediterranean diet (MD) index (18) in our population. Furthermore, an alarming 98% prevalence of high-salt intake has been described (16). Overall, ongoing epidemiological trends and deficient food intake patterns summon implementation of effective nutritional and other lifestyle-based interventions to attenuate the escalating burden of NCD risk in Chile.

In this worldwide context of NCDs affecting developing regions, lifestyle medicine (LM) is a growing field (19) focused on overall promotion of healthy behaviors and its important role in prevention as well as treatment of and rehabilitation from disease. The most consensual definition of LM is "*evidence-based practice of assisting individuals and their families to adopt and sustain behaviors that can improve health and quality of life* (20). It works on six main axes: healthy eating, regular physical activity, avoiding risky substance abuse, stress management, optimizing good quality sleep, and promoting healthy social relationships. It is worthy noticing that a solid support in scientific evidence is a core foundation of LM, including its Hierarchies of Evidence Applied to Lifestyle Medicine (HEALM) (21) aimed to a better quality of backing from observational and interventional studies on the effects of lifestyle choices in public health and their long-term impact. Thus, effectiveness at preventing, managing, and sometimes reversing many NCD is a main issue in LM (22).

The American College of Lifestyle Medicine (ACLM) was founded in 2004 as an independent medical professional association representing the diverse interests of its members in providing of LM education, practice support, and advocacy. Then, the Lifestyle Medicine Global Alliance (LMGA) was initiated by the ACLM in 2015 in response to the increasing need for LM solutions in low- and middle-income countries and for communication and coordination between LM medical professional organizations around the world. Now, more than 20 sister organizations exist and are present in every continent, including the Chilean Society of Lifestyle Medicine (SOCHIMEV).

This worldwide multilateral endeavor is relevant because LM particularly addresses lifestyle habits and many of them have unique geographical, psychosocial, and cultural characteristics which differ from one country or world region to another. As a consequence, it must be emphasized that eating habits not only obey to the fulfillment of caloric and nutritional needs in general, but also to food production and availability as well as deep psychological and cultural roots given by geographic and economic variables according to various realities in human groups. Indeed, native people from Latin America have various ethnic origins. In particular, Chile exhibits a combination between native Americans, mostly descended from Mapuche aboriginals, and immigrants from Europe, which has created unique nutritional habits, culinary traditions, and social frameworks. Thus, it is important to consider local adaptability and feasibility of prescriptions and recommendations in LM initiatives, especially when promoting healthy eating at population and individual levels.

In this review, we cover the topic of healthy eating as one of the pillars of lifestyle medicine in a particular Latin American context. More specifically, we highlight the plant-based Mediterranean diet as a dietary pattern adaptable, applicable, and sustainable within the Chilean food, social, and cultural framework to address the current transition toward chronic diseases in our country.

## PLANT-BASED FOOD INTAKE PATTERNS AS HEALTHY DIETS

Food patterns can be defined as quantity, proportion, variety, and/or combination of different foods and beverages in diets as well as the daily/weekly frequency in which they are habitually consumed (23). Usually, a healthy diet is labeled as such when this set of foods offers adequate amounts of energy and nutrients necessary to maintain body functions in a context of physical and mental health. Therefore, this conceptualization of a healthy diet is far from referring to its use as a restrictive nutritional pattern for short-medium term in order to achieve a goal (fad diet). Instead, food intake patterns capture multiple dietary factors and provide a comprehensive assessment of diets, which should account for the complex interactions between nutrients and foods and their wide-ranging impact on human body composition and physiology.

Multiple studies have tried to answer the question on which is the best or healthiest diet (24–30). Therefore, it is important to recognize there is no single diet that is universally recognized for achieving the best clinical results in all people. Nor it is possible to attribute health benefits or harm to specific nutrients or foods directly and unequivocally in a cause-effect relationship. This uncertainty is secondary to limitations given by methodological factors in nutritional epidemiology and interventions. Second, people eat complex diets made up of many interdependent components rather than individual nutrients or foods (9). There are synergies among nutrients and foods present in different dietary patterns (31, 32). The degree of food processing can also influence their physical and chemical characteristics and subsequent health impact (33). Thus, dietary patterns may be more predictive of diet–disease associations than analyses focused on single foods or nutrients (34, 35).

Among various dietary patterns, high intake of mostly plant-based foods (mainly fruits, vegetables, nuts, oils, legumes, and whole grains) as well as low intake of animal products and ultra-processed foods has shown the strongest support from scientific evidence to demonstrate their human health benefits (36–39). Although plant-based diets are frequently associated with vegan/vegetarian diets, they entail a variety of eating patterns. Indeed, the expression "plant-based" is not intrinsically restrictive, but it means food intake mostly derived from plants, thus it may embrace consumption of small amounts of foods from animal origin such as meat, fish, milks, and eggs. Thus, a plant-based diet may exchange animal items for vegetable choices, but it does not require absolute and permanent restriction of animal foods. Then, it is necessary to emphasize that the concept of plant-based diet is an eating spectrum that does not represent a single specific all-or-nothing pattern, but rather a general outline with the common elements already described above, which at the same time allows tailoring it to the reality of each individual with a unique cultural context.

Therefore, it becomes evident why professionals dedicated to LM in Chile and around the world promote mostly whole-food plant-based diets -a term introduced a few years ago and recently popularized in Chile- as a fundamental pillar of a healthy diet (40). Leading proponents in the LM field have varying opinions about what comprises the optimal whole-food plant-based diet: from allowing small amounts or completely avoiding all animal-based foods as well as holding back nuts and soybeans, especially for coronary patients, where total fat and oils are generally restricted (41–43). However, there is a broad consensus on aiming to maximize the consumption of nutrient-dense plant foods in their whole form, especially vegetables, fruits, legumes, and seeds and nuts (the latter in smaller amounts), whereas limiting processed and animal products for maximal health benefits. Moreover, consumers are increasingly adhering to this trend. In fact, retail market for plant-based foods has grown faster than the overall retail food market and plant-based alternatives are expected to increase significantly due to health and sustainability issues (44, 45).

Thus, even though the main focus in nutrition has traditionally been on the distribution and proportion of dietary macronutrients, this new emphasis converges on the quality and proportion of micronutrients, phytochemicals, and antioxidants as well as the amount of fiber, highlighting a lower degree of food processing as a priority, and ensuring its variety and an optimal micronutrient profile without excess calories. The latter is key since in general all eating patterns associated with health (i.e., prevention of chronic diseases, quality of life, and longevity) are almost by definition based on moderate food intake and calorie restriction (46). In fact, high adherence to mostly plant-based food dietary indexes have been correlated with decreased chronic disease risk (47–50). The benefits of predominantly plant-based diets are also currently emphasized in overall health outcomes rather than preventing or treating individual pathological conditions, with a special accent on quality of life and long-term well-being, therefore not exclusively focused on a disease-oriented point of view.

There is also a greater understanding about the (patho)physiological effects of various dietary patterns. Recent research has highlighted the multiple interacting pathways linking diet, microbiome, and health (51–54) as well as the role of low grade, but sustained, inflammation in the development of many chronic diseases, mainly related to food-triggered metabolic effects (55–58). Indeed, some dietary patterns have been associated with inflammation. The Western dietary pattern has been linked with increased concentrations of inflammatory markers, whereas higher scores in the Healthy Eating Index and the Mediterranean diet as well as in plant-based diets are associated with lower concentrations of inflammatory indicators (59, 60). In recent years, it has even been proposed a dietary inflammatory index based on food groups to assess diet quality based on the pro- vs. anti-inflammatory potential (61).

In addition, big data omics approaches are being applied in nutritional research on plant-based diets leading to high throughput and more integrative perspectives (62–64). For instance, a specific metabolomic signature has been identified for the MD, not only reflecting adherence and metabolic response to this diet, but also predicting future CVD risk independent of traditional risk factors (65).

More recently, it has become increasingly important to understand and assess human feed habits with regard to their consonance with the environment on which we interdepend, incorporating the variable of environmental sustainability as well as the concepts of planetary health and One Health (66). A sustainable diet may be defined as "a diet comprised of foods brought to the market with production processes that have little environmental impact, is protective and respectful of biodiversity and of ecosystems, and is nutritionally adequate, safe, healthy, culturally acceptable, and economically affordable" (67). When scientific evidence on different dietary patterns is analyzed in terms of their contribution to environmental sustainability, plant-based diets are the ones that have the greatest support in minimizing carbon and water footprints (68), contributing favorably to people's and environmental health. Many studies have shown that reducing meat consumption can attenuate greenhouse gases while remaining nutritionally adequate (69, 70). Based on detailed calculations and projections, the EAT Lancet report proposed a diet that is allegedly sustainable, nutritious, and healthy. This model diet fits with a mostly plant-based food pattern, consisting of mainly vegetables, fruit, whole grain, legumes, nuts and unsaturated fats, only moderate to small amounts of fish and poultry, and no or very little red meat, processed meat, added sugars, refined cereals, and starchy vegetables. Adhering to this plant-based dietary recommendation, it should be possible to meet the United Nations Sustainable Development Goals (United Nations (UN), 2019) (71).

## MEDITERRANEAN FOOD PATTERN: A PLANT-BASED DIET THAT PROMOTES HUMAN AND PLANETARY HEALTH

Using the broad definition analyzed above, the traditional Mediterranean dietary pattern has been considered a mostly plant-based diet because it is aimed to a high intake of olive oil, fruit, nuts, vegetables, cereals, herbs, and spices; a moderate consumption of fish and poultry as well as wine with meals; and a low intake of dairy products, red meat, processed meats, and sweets.

The positive health outcomes associated with the MD were identified in the early 1960s, when researchers showed the protective effects against coronary heart disease of diets eaten in Southern Europe compared to Northern Europe and US (72). Since then, an increasing body of research has suggested the beneficial effects of this dietary pattern with evidence supporting its value on different clinical outcomes (73–76). Currently, the MD is considered one of the healthiest dietary patterns. Cross-sectional and prospective observational studies in Europe, US, and Australia have associated higher adherence to Mediterranean-style food patterns with lower prevalence/incidence of NCD conditions including diabetes, CVD, cancer, neurodegenerative diseases, and overall mortality (77–80).

The evidence regarding the association between the MD and cancer comes predominantly from observational studies. Most of these studies found a protective effect of high adherence to the MD against the development of different types of neoplasms, with a reduction in the risk of developing cancer in general ranging from 5 to 21% (36, 81). By types of cancer, risk reductions of 33% for gastric cancer (82), 36% for prostate cancer (83), 49% for hepatocellular cancer (84), 50% for colorectal carcinoma (85), 58% for head and neck cancer (86), 81% for lung cancer (87), and 6% in postmenopausal breast cancer (88) have been reported. The main limitation of these studies is that recording of dietary practices was done by means of quantified consumption frequency surveys or 24-h recall, whose high probability of bias makes it an unreliable tool. The only clinical trial with regard to cancer prevention is the PREDIMED study, being, so far, the one that provides the best quality of evidence demonstrating the benefit of this dietary pattern on cancer incidence, reporting a 67% reduction in breast cancer risk in women at high cardiovascular risk, when adhering to MD supplemented with extra virgin olive oil (89).

Among longitudinal studies, MD patterns have been linked with lower incidence of mental conditions, such as depression in Spain, Italy, US and Australia (90–97). Two additional trials (SMILES and MEAL) are evaluating the impact of implementing a MD pattern on depression prevention and/or treatment (98, 99). Interestingly, adherence to MD correlated cross-sectionally with self-esteem and self-concept in children living in Santiago (100). MD has also been proposed as one of the dietary patterns of choice for patients with chronic kidney disease (101).

It must also be taken into account the sex/gender-driven differences in metabolic response to nutrients (102, 103). Some dietary patterns have been specifically studied in women related health issues, for example higher consumption of vegetable protein has been associated with less risk of early menopause (104), and lower glycemic index diets have shown less rates of insomnia in postmenopausal women (105). As for the MD, to our extent of knowledge, there are certain studies that emphasize their results specifically in women, showing some associations with less risk of osteoporosis (106), and in an uncontrolled calorie-restricted MD, decreased serum levels of end glycation products were found in premenopausal women who had overweight or obesity (107). Also, the lower risk of incident stroke, mediated by a higher adherence to MD, appears to be driven specifically by an association found in women (108), and higher MD intake was associated with one-fourth relative risk reduction in CVD events in women from the Women's Health Study (109). In another study, MD was associated with less risk of rheumatoid arthritis only in men (110). Therefore, there is still more research needed in this field in order to confirm these sex-specific associations with MD intake as well to define their underlying mechanisms.

Far fewer interventional studies have also evaluated the effect of MD on long-term and hard clinical outcomes. First, the secondary prevention Lyon Heart Study exhibited a significantly lower recurrence of MI and reduced CVD mortality (111). Despite randomization issues recently addressed (112), PREDIMED (Prevención con Dieta Mediterránea) trial, a Spanish primary prevention study involving high cardiovascular risk participants, demonstrated that MD - without caloric restriction or physical activity recommendation but supplemented with olive oil or nuts- reduced CVD events by 30% compared to a low-fat diet (112, 113). Further analyses in PREDIMED have shown that MD attenuates diabetes mellitus incidence (114), diabetic retinopathy (115), age-related cognitive decline (116) and invasive breast cancer occurren (89). Whether reported irregularities in the randomization process (112) have influenced these latter findings reported by PREDIMED remain to be established. Interestingly, RCT study design in non-Mediterranean countries have been recently reported in US (117) and Australia (118).

Also, growing evidence from the so-called blue zones (119–123) -including two locations within the Mediterranean basin (e.g., Sardinia in Italy and Icaria in Greece)- exhibits long-lived and high life quality populations. Even though this non-scientific concept has yet to be better defined and further validated, it is interesting how these world regions seem to share some common elements -including consuming a predominantly plant-based diet- that have wide beneficial evidence on different outcomes in health.

As mentioned, MD relies on minimization of animal products and high consumption of a variety of fruits and vegetables, with legumes being a crucial part of this pattern, contributing also to soil health. Furthermore, MD emphasizes the choice of foods from local origin and seasonal production. For all this, there is consensus that to a greater or lesser degree, plant-based MD food choices align with planetary health (124, 125). It has even been estimated that switching to a MD can reduce greenhouse gas emissions, land use, energy consumption, and water utilization by up to 72, 58, 52, and 33%, respectively (126). Therefore, MD can contribute to increase the sustainability of food production and consumption systems in addition to its well-known benefits in disease prevention and public health.

## MEDITERRANEAN DIET AS A MODEL OF A CULTURALLY ADAPTABLE FOOD CONSUMPTION PATTERN

As previously mentioned, diets are more than just the pattern of food consumption, representing also a way of life shaped by various economic, social, and cultural variables within the local context of each individual, including influences integrated through migration and globalization. Although they are closely linked to the biophysical resources (e.g., soils, microclimates, landscape) that characterizes agriculture, food patterns thus also take into account particular historical frameworks as well as sociocultural resources, including traditional knowledge, and practices (127).

Examples of regional/territorial diets are the Japanese Diet, the Traditional Nordic /New Nordic Diets and the MD, which incorporate in their definition not only the food pattern, but also cooking methods, celebrations, customs, lifestyle, and typical products of a region. As UNESCO highlighted when adding the MD to its list of Intangible Cultural Heritage of Humanity in 2010, it is "a set of skills, knowledge, practices and traditions from landscape to table, including crops, harvesting, fishing, conservation, processing, preparation and, in particular, food consumption" (128). While MD represents the dietary and overall lifestyle patterns of a small proportion of the global population, some of the basic principles that shape this diet, preference for local and seasonal foods, daily consumption of vegetables, fruits, whole grains, and healthy fats can be applied and adapted to other territories and cultures.

Moreover, the MD is not a strict dietary pattern, since foods show variations among countries within the Mediterranean basin. Indeed, it consists of a flexible dietary pattern that can be locally adapted based on food availability and cuisine traditions (129), which has led to being promoted in regions and dietary guidelines of countries far from its geographic origin.

## MEDITERRANEAN DIET: AN ADAPTABLE AND FEASIBLE FOOD INTAKE PATTERN IN CHILE

Considering the particular Chilean context within Latin America, the MD model has shown to correspond to types of foods and culinary preparation that are part of the traditional eating culture in Chile. Remarkably, Chile is one of the five areas of the planet with a Mediterranean-type ecosystem, being its local agricultural, livestock, and aquaculture production very abundant in foodstuffs associated with the conventional MD (130, 131). Indeed, the majority of annual food exports from our country fits very well with a Mediterranean food basket (132). Using food availability data from the Food and Agriculture Organization (FAO) of the United Nations, the diet consumed by Chileans in the 1990s decade still showed similarities to the traditional MD of Spain and Italy in 1960 (133).

Moreover, Chilean culinary and gastronomic traditions apply food items and cooking methods that mimic those used in traditional cuisines from Southern Europe (134–137). Many dishes contain cooked vegetable and legume products and are prepared based on a sofrito. Likewise, tomato salad with onion and *pebres* are also mixtures rich in antioxidants and fiber, derived from the use of tomato, onion, garlic, parsley, chili pepper, cilantro, and vegetable oils. On the other hand, avocado is a typical food in our culinary culture, but not in the Mediterranean basin. However, it is characterized by a low contribution of saturated fats and high content in monounsaturated fatty acids as occurs in olives and olive oil. In addition, chestnuts, Chilean hazelnuts, and pine nuts are important in the Chilean aboriginal food culture. Indeed, pine nuts obtained from araucarias are considered the sacred fruit of the Mapuche indians.

When Mediterranean dietary culture first developed, typical families did not eat large amounts of meat and had no access to imported produce or foods out of season. Global food consumption levels and patterns have changed significantly, influenced among other factors, by population growth, urbanization, Westernization, and a rise in affluence and living standards (138). We are experiencing a nutritional transition in which problems of undernutrition coexist with overweight, obesity, micronutrient deficiencies, and food-related chronic diseases (5). Thus, it is important to understand drivers and barriers in consumer food choices and how these are shaped, since a greater adherence to a MD has been associated to its health outcomes (139–141) and also lower environmental pressure and impact (124–126, 142). Even though MD is a sustainable healthy diet, many people are unlikely to adhere to a food pattern if it is not culturally acceptable at population levels. In fact, there has already been a decline in adherence to the MD in the Mediterranean countries (143) and also in Chile (18).

At individual level, health professionals must fulfill the role of informing and advising based on their knowledge and applicability of MD-type nutritional recommendations to the context of each patient, without imposing beliefs, preferences, or ethical judgments. Therefore, it is essential to counsel taking into account personal, family, economical, and cultural circumstances as long as the basic criteria for plant-based MD healthy eating pattern described above are met. Also, LM moves broadly in a field going from prevention to therapy and reversal of chronic diseases. Therefore, lifestyle goals, including diet, must be individualized, and in the case of more complex chronic diseases, advised by specialists in each subject with solid professional training and balancing multiple variables.

Overall, we believe that the MD spectrum has great potential for its adaptation in our cultural context and may prove to be a feasible, affordable, and flexible model of healthy eating for the general Chilean population.

## POTENTIAL HEALTH IMPACT OF MEDITERRANEAN DIET INTAKE IN CHILE

As just discussed, promotion of MD adherence in Chile seems reasonable and doable offering a great potential for handling the increased prevalence of risk factors and NCDs in our country.

It is well-known that the most effective strategies for promoting long-lasting healthy habits that reduce the risk of NCDs, are the ones targeting the earliest ages along the human vital cycle (144–147). Therefore, it is important to create interventions to improve adherence to healthy diets considering the entire family, and specially targeting children and adolescents. Interestingly, there is an ongoing clinical trial (the Happy Heart) (148) evaluating the effectiveness of an educational program to improve healthy habits in children and their families, as compared to routine adult outpatient care. Also, it is worthy noticing that in Latin America, still much of what is eaten within the family context is driven by women decisions, therefore, strategies that account for their specific food choices and dietary habits remain important, in order to design effective and tailored interventions. Even more, targeting pregnant mothers is increasingly highlighted and has a lot of potential to be further explored, as it may influence the fetal programming of chronic diseases, and therefore, the offspring's health after birth (148–150). Indeed, a recently published study (151) showed that a higher adherence to a Mediterranean diet score and a lower dietary inflammatory index during pregnancy was associated to lower BMI z-score trajectories in the offspring from birth to adolescence.

However, the real health impact of implementing the MD remains to be evaluated appropriately in Latin America. Furthermore, limited and exploratory work has been executed to assess the impact of MD in associations studies or interventions in Chile. We have reported that just one-tenth of Chilean adults exhibited a high adherence score when applying a locally adapted and validated Chilean Mediterranean dietary index (18). Those highly adherent subjects showed cross-sectionally a lower prevalence of overweight, obesity, and metabolic syndrome (152), suggesting that improvement in adherence to MD may lead to significant reduction in these high-risk conditions. In small studies, MD implementation improved several biomarkers (e.g., blood fatty acid profile, haemostasis, oxidative stress, endothelial function, and advanced glycated products) (153–157) linked to NCD pathogenesis. In addition, an uncontrolled study aimed to mediterranize food availability at workplace showed that increasing adherence to MD was associated with reduction in abdominal obesity and blood pressure and increased HDL cholesterol levels, leading together to lower metabolic syndrome prevalence (158). Thus, evidence supporting health benefits of the MD in Chileans subjects shows potential, but studies available are scarce and have many limitations such as cross sectional or non-randomized controlled design, no control comparators for interventions, small sample size, lack of theory-based behavior change advice, short follow-up, biomarker-based end points only, and very limited clinical outcomes. Additional intervention studies using a locally adapted MD index, a feasible MD intervention, and a more comprehensive outcome evaluation are required –as an *in situ* proof of concept- to further emphasize and more extensively implement this dietary pattern for prevention and treatment of chronic diseases in our population.

More recently, a randomized clinical trial has been registered (ClinicalTrials.gov NCT03524742) to evaluate the effect of MD supplemented with avocado on LDL cholesterol levels in Chilean patients with high risk of recurrent ischemic stroke. In addition, we will perform the ChileMed study, a 1-year randomized controlled intervention that will assess the efficacy of a locally adapted MD -vs. a low-fat diet- for treatment of Chilean subjects with metabolic syndrome. MD adherence at baseline and follow-up will be evaluated with the Chilean MD index and 24-h dietary recalls as well as diet-derived biomarkers. Cardiometabolic risk parameters, including measures of inflammatory, oxidated stress, and metabolomic status, will be analyzed to elucidate possible mechanisms underlying a favorable outcome. Hopefully, these intervention studies will further support the beneficial impact of a plant-based MD approach in Latin America as expected from the ecosystem, food production and availability, culinary traditions, and cultural context of Chile.

## CONCLUSIONS

Abandonment of traditional habits and emergence of unhealthy lifestyles associated with socio-economic and cultural changes have become main threats to human health. Thus, promotion and preservation of healthy dietary patterns more aligned with our culinary and local traditions is crucial for a sustainable development to counteract food insecurity and malnutrition.

Overall, scientific evidence is consistently showing that a diet rich in various plant-based and whole foods is the pattern most associated with reduced morbidity, longevity, increased quality of life, and lower mortality.

In addition, plant-based dietary patterns are more sustainable food models that help balance and promote optimal planetary health. On the other hand, it is fundamental to use an individualized work model grounded to the sociocultural reality of each person and family. The most effective nutrition approaches are those that take into account cultural preferences and practices, rather than going against them.

We believe that the MD is a pattern well-aligned with mostly plant-based food intake as well as LM principles and practices and is strongly evidence-based. Therefore, it may be implemented and should be reinforced as an important tool at the level of public health policymaking beyond the Mediterranean basin. This could be particularly relevant and feasible in countries and word regions -such as Central Chile- where geography, food supply, gastronomy, and culture offer fertile soil to adopt and adapt this dietary pattern. Further research should help to substantiate this statement and to expand its implementation worldwide.

Even more, the definition of the MD not only includes food intake guidance, but it is also considered like a comprehensive lifestyle. Meal preparation, enjoying food with moderation and socially in a calm and relaxed environment, which together with the practice of regular physical activity, appropriate rest/sleep and positive psychosocial resources, community life, and a sense of belonging and sharing, are all part of the Mediterranean way of life (159).

Going back to LM work model, MD emphasizes within its definition not only healthy eating habits, but all of the other pillars of this emerging field that summons a variety of medical specialties and other health professions to promote human health and well-being.

## AUTHOR CONTRIBUTIONS

CFi wrote the first draft of the manuscript. CFi, AR, XM, and GV wrote sections of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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# Development and Usability Study of an Open-Access Interviewer-Administered Automated 24-h Dietary Recall Tool in Argentina: MAR24

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**Background:** Latin American countries show a fast-growing rate of non-communicable diseases (NCDs) and diet is a critical risk factor that must be properly assessed. Automated dietary assessment tools to collect 24-h dietary recalls (24HR) are lacking in Argentina.

**Objective:** This study aimed to develop an open-access automated tool (MAR24) for collecting 24HR using a multiple pass method and a database containing foods and recipes commonly consumed in Argentina.

**Methods:** MAR24 was developed based on data from 1,285 24HR provided by male and female participants aged 18 to 68 years from the six Argentinian geographical regions. The main structure and interface of the tool were designed using Visual Basic for Applications programming language in Excel Microsoft Office 365, integrating the five steps of the United States Department of Agriculture (USDA) Automated Multiple-Pass Method (AMPM) for the application of 24HR in Spanish. The tool underwent alpha testing and expert assessment to address structural and usability issues. Critical feedback and face validation from researchers and experienced dietitians, and repeated testing to collect 24HR were used to adjust and improve the tool.

**Results:** A total of 968 food items and 100 standard Argentinian recipes were added to its database. MAR24 allows the estimation of the nutrient profile of dietary intake. The analytic food composition includes energy and 50 nutrients including water, macronutrients, total dietary fiber, total sugar, 10 minerals, 19 vitamins, eight fatty acids, cholesterol, ethyl alcohol, caffeine, and theobromine. MAR24 includes a user manual and technical manual to guide users to apply changes (e.g., add foods or recipes, or change food designation according to local terms) to fit different research and clinical applications.

**Conclusions:** MAR24 is the first tool that uses the AMPM methodology for 24HR applications in Argentina. The tool may be used in clinical practice and clinical trials for monitoring purposes, and in validation of food frequency questionnaires (FFQ) for nutritional epidemiology studies addressing dietary-associated risk factors for NCDs.

**Keywords: 24-h dietary recall, nutritional assessment, open-access tool, AMPM, food chemical composition, Argentina, Spanish**

## INTRODUCTION

Diet is a variable of interest when investigating chronic disease etiology. Foremost among the dietary assessment methodologies utilized in population studies are the 24-hr dietary recall, food diary or record, and food frequency questionnaire. While each of these methods has its strengths and limitations, the 24-h dietary recall (24HR) is often the method of choice when respondent burden is a concern, such as in populations with limited literacy or patience and motivation to comply with the rigors of food recording (1, 2). In conducting 24HR, detailed information on food, drinks, and supplements consumed during the past 24 h (3, 4) is collected via interviews or through self-report. A single 24HR may be used in clinical practice and research to measure a day's food, nutrient or energy intake but multiple 24 HRs would be needed to estimate usual or habitual intake (5, 6), the exposure that is often associated with health outcomes (7, 8). Since 24HR allows a high level of specificity due to open-ended food lists and detailed food preparation and description, and uses short-term, episodic memory that is less subject to recall bias than the memory used for food frequency questionnaires (FFQ), multiple or repeated 24 HRs are particularly useful as a reference standard for validating FFQ, the less-costly dietary assessment method used in large epidemiological studies to estimate habitual diet (7, 8).

Assessing dietary habits is important since these habits impact non-communicable disease (NCD) development and mortality (5, 9–11). Studies carried out in the Argentine population by our group and others have found that the majority of this population does not meet the nutritional recommendations of national health agencies, particularly the intake of fruits, vegetables, whole grains, legumes, nuts, and seeds (12–15). NCDs are known to be the leading causes of death in the world, disproportionately affecting medium- and low-income countries where half of the premature deaths from NCDs occur (9, 10). According to the World Health Organization (WHO), nearly 80% of the total deaths in Argentina are associated with NCDs (10) while unhealthy eating habits rank second among the ten risk factors associated with disabilities and deaths (11). The other main risk factors for NCDs, such as elevated fasting blood glucose, high body mass index, high blood pressure, and dyslipidemia are also diet-related (5, 9, 10). These data indicate the need for accurate assessment of dietary exposure in observational and intervention studies that investigate the role of diet in NCDs. However, there is still a lack of tools to facilitate the collection of reliable information on food consumption in Argentina and other Latin America countries.

The need for effective ways to collect nutritional data and estimate food consumption at the population level paved the way for the development of technology-based dietary assessment tools for various population groups (e.g., age, country/language) (16–18). Most 24HR applications, in particular, are based on the automated multiple-pass method (AMPM) approach, a reliable 24HR collection method designed by the United States Department of Agriculture (USDA) to reduce misreporting or underreporting bias (19, 20). In general, the applications are either self-administered, where a participant completes the recall in the absence of a researcher (21–31), or interviewer-administered, where the interviewer uses the application to collect/analyze dietary recall data in the presence of a participant (32–38).

Two interviewer-administered tools have been developed and used among Spanish-speaking adults: the bilingual interactive multimedia diet recall tool for low-literacy Hispanic population in the US (39), and the GloboDiet for the Mexican population (40). Argentina, however, has yet to develop a culturally-specific dietary assessment tool using locally-named foods, and that integrates all the steps of a 24HR using the AMPM and systematizes the assessment of a dietary intake. Therefore, we developed an automated interviewer-administered tool for collecting Multiple-Pass 24HR containing foods and recipes commonly consumed in Argentina (MAR24). The tool was devised to be available as an open-access source and with the possibility of being expanded with the addition of foods and recipes for fitting different research and clinical applications.

## MATERIALS AND METHODS

MAR24 is an open-access tool whose main structures and interfaces were designed using Visual Basic for Applications programming language in Excel Microsoft Office 365. MAR24 was developed in the Spanish language and was designed to be operated by trained nutrition professionals for an interviewer-administered application of the multiple-pass 24HR. The tool integrates the five steps of the AMPM (19, 20), along which respondents receive cues to assist them to remember and describe the foods consumed the previous day (the preceding 24 h). The steps include: (1) "*quick food list,*" which involves listing foods and beverages consumed during the previous day; (2) "*forgotten*

**Abbreviations:** AMPM, automated multiple-pass method; MAR24, *Método Automatizado de Recordatorio de 24 horas* (Automated 24-h recall method); NCDs, non-communicable diseases; 24HR, 24-h dietary recall; SARA, *Sistema de Análisis y Registro de Alimentos*; USDA: United State Department of Agriculture; WHO, World Health Organization.

*foods,*" inquiry is made for foods possibly forgotten during the quick list; (3) "*time and occasion,*" adding the time and eating occasion for each food: (4) "*detailed cycle,*" a detailed description, amount, and additions for each food is done, then the 24-h day is reviewed; and, (5) "*final probe,*" a final inquiry for anything else consumed is done. The tool was developed over approximately 30 months. A user's instruction manual and a technical manual, as well as a how-to-use tutorial video in Spanish, were created for MAR24. The technical manual provides instructions for: adding, modifying, or deleting foods; creating recipes; and, modifying food names according to language variations. A visual aid for the portion size references goes with the tool and can be provided to the respondent/interviewee. The tool and its manuals can be downloaded from the website http://investigacion.uap.edu.ar/MAR24-Argentina. Users may register to receive notifications and updates about the tool.

## Creation of the MAR24 Database

MAR24 was initially constructed using 120 audio-recorded 24HR collected via telephone interviews. Improvements and adjustments to the tool resulted in the expansion of its database. A total of 1,165 24HR served as the basis for identifying the foods and recipes to be included in the MAR24 database. Male and female participants aged 18–68 years from the six Argentinian regions—Central ($n = 237$), Northwest ($n = 140$), Northeast ($n = 191$), Buenos Aires ($n = 267$), South ($n = 170$), and Cuyo ($n = 160$)—provided these 24HR through recorded telephone interviews.

The Food Analysis and Registration System from the Ministry of Health of Argentina, "*Sistema de Análisis y Registro de Alimentos*" (SARA) Version 1.2.29 (41) was utilized to build the database of food items and standard recipes for MAR24. The database includes simple foods consisting of a single ingredient (e.g., vegetables, fruits, nuts, milk) and complex foods containing a few ingredients (e.g., cakes, biscuits, bread). These simple and complex foods were defined as *single food* items. SARA allows the use of two types of recipes: *standard* and *compound*. *Standard* recipes are traditional preparations of Argentine cuisine commonly mentioned in the 24HR and extracted from the SARA. Although the standard recipes have predefined ingredients, there is an option to include or exclude ingredients. *Compound* recipes describe meals reported during the interview, but which do not currently exist in the database. Their content is added using details provided by the interviewee. For example, report of a vegetarian dough recipe would not facilitate use of the existing recipe (which includes animal fat). Amendments to this compound recipe can be made using the tool to select the appropriate plant-based fat. Also, if the interviewee mentions allergy to a specific type of food and reports the consumption of a different version of a standard recipe, this may be created as a compound recipe. Both *simple* and *complex* foods can be linked to recipes. This feature allows interviewers to specifically input information that reflects diversity of eating preferences and needs. Modifications, additions, and deletions of foods and recipes are included in the user manual. All modifications remain in the database of the user once the tool is downloaded on a device.

## Amount and Portion Sizes

The most common utensils and household measures used in Argentina were identified based on the information of the initial 120 24 HRs collected through telephone interviews with no visual aid from 6 Argentinian regions (center, northwest, northeast, Buenos Aires, south, and Cuyo). From this information, a visual aid containing photographs of 16 common household measures was constructed (**Figure 1**) to serve as portion size reference during the application of 24HR.

A database of weight equivalents of household measures, portions and units was built and correspond to the "equivalences sheet" of the tool. For most items ($n = 781$), such weight equivalents were extracted from literature sources (41–43). The remaining measurements were either weighted or estimated by the following procedure: (1) foods with similar density and/or characteristics were grouped, for example, corn flour, wheat flour, rice flour, etc. were put under the "flour" group, while olive oil, corn oil, sunflower oil, etc. were grouped under "oils"; (2) weights of 2–6 foods from each group were measured in the 16 utensils; and (3) corroborated with the measures and weights of foods reported in Argentina (41, 42). A total of 100 food items, in 16 different utensils (1,600 weights), were measured in the Laboratory of Nutrition and Dietetics by two researchers using Aspen model precision balances for small and large volumes (MH-500, range 0.1 to 500 g and EK3052, range 1 g to 2 kg). The results served as a basis to establish the proportionality relations of weight between the different household measures for each food group. The weight equivalents of 87 food items were estimated according to the measurements of the representative items from each food group. A bivariate correlation test was performed between the weights of the foods in the same group resulting in correlation ($r$) values $\geq 0.99$ ($p < 0.0001$). The complete list of foods and their weights in the different household measures is found in the technical manual of MAR24.

Standardized portion weights for preparations such as a piece of cake or a slice of pizza were obtained from the SARA program. Some fruits and vegetables have weights per unit for different sizes (small, medium, and large), when appropriate.

## Nutrient Profile of Foods

The nutrient profile of all food items was taken from the USDA Food Composition Databases (43), except for 5 particular foods (*Amargo serrano*, *Amargo serrano diet*, *Bizcochos de grasa*, *Chipá* and *pan criollo*) for which the composition was obtained from the SARA program (41). Each food item selected from the USDA database has its nutrient composition (water, energy, fiber, macro- and micronutrients) and ingredient(s) (when applicable) compared and checked for similarity with data from the following available Argentinian databases: SARA (41), ArgenFood Food Composition Table (44), Nutrinfo database (45), or from the Central American Food Composition Table of the Institute of Nutrition of Central America and Panama (INCAP) (46). For cooked foods, all cooking methods were searched for each food and those used in Argentina were selected. As there is no information on cooked foods from local databases for comparison, cooked versions of the raw foods from the

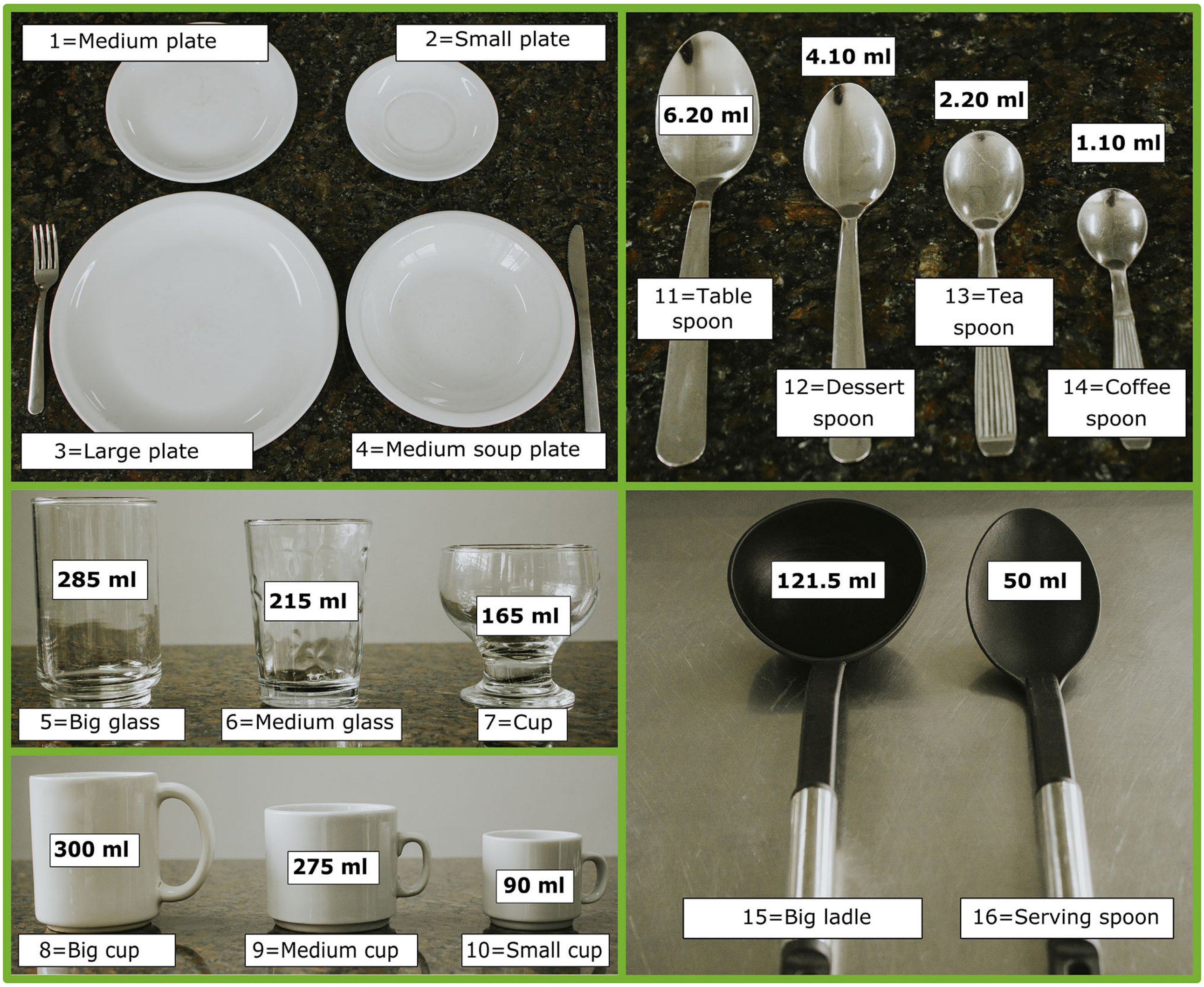


**FIGURE 1 |** Household measures references of the MAR24 photo album.

same USDA data source (Legacy, Survey, or Foundation) were selected (43).

## Quality Control of the Tool

The initial version of MAR24—developed from audio-recorded 120 dietary recalls performed by five trained interviewers using the AMPM methodology—underwent alpha testing to address structural and usability issues. During the entry of the 24 HRs onto the MAR24, interviewers provided weekly reports of their experiences and discussed their difficulties and suggestions for adjustments to the tool with the researchers. In addition, two researchers independently compared the data that was entered onto the MAR24 system by the five interviewers against the audio records of the recalls to check for data entry accuracy.

After completing the entry of 1,165 additional 24 HRs sometime in 2020, seven dietitians/experts from different states of Argentina with experience in the field of nutritional assessment and research were invited to assess the MAR24. A questionnaire with nine Likert-type scale and three open-ended questions was used for the evaluation. The dietitians/experts were asked whether the tool was intuitive, comprehensive, user-friendly, suitable, and if it was effective to optimize the dietary data collection for 24HR applications in the context of research and/or professional practice. The open-ended questions pertained to observations and suggestions for improvement of the sections on interviewer and respondent information, available foods and recipes, portion sizes, utensils and household measures, nutrient composition database, layout, and design.

## Ethical Aspects

The MAR24 tool was developed in the context of an ongoing research study that had been evaluated and approved by the Research Ethics Committee (resolution N° 1.7-8/2016), affiliated to the National Registry of Health Research (N° 237), Ministry of Health, Argentina. Participants were included in the study by invitation and acceptance of the terms of the Informed Consent.

# RESULTS

The current MAR24 version contains a total of 968 food items including simple and complex food and 100 standard recipes commonly consumed in Argentina and 50 nutrients and other food components in its database. The tool is open access whose main structures and interfaces are in Excel Microsoft Office 365.

## Background Capture Information

During the first interview step, information on the interviewee, the interviewer, and the recall day (date and whether intake is considered habitual or atypical by the respondent) is collected (**Figures 2A,B**). The button to add or search participant opens the screen shown in **Figure 2C**, which has a search engine for information stored in the database along with three options of controls to transfer information to the form, to close, or to delete the data.

## Dietary Intake Capture Information

**Figure 2D** shows the section intended for managing food data from the 24HR and lists the foods consumed according to the loading order. This section has three buttons to either open the module to add food data, transfer the information to the database, or delete the data.

**Figure 3** shows the entry fields window to input foods reported to have been eaten over the past 24-h period through the steps of the AMPM. During the "quick food list" step, the interviewer enters all foods, recipes and beverages from the "quick list items," with no additional details or quantification. The interviewer checks the completeness of the "quick food list" focusing the respondent's attention on some food groups that are often forgotten, such as sweets, sodas, snacks, dressings, broths, condiments, and others. The "time, place and occasion" step is used to indicate the time, the place where the meal was eaten (e.g., home, restaurant, family home), and the eating occasion (e.g., breakfast, lunch, snack, dinner).

The "detailed food loading" cycle is used to load a complete description of each food or recipe from the quick list into the tool using an intelligent search in the database. During this step, ingredients may be excluded from standard recipes, if needed. Furthermore, some foods with different options have a drop-down list to choose the appropriate option (e.g., options for milk are milk powder, whole milk, soymilk). Foods and recipes have local names (Argentine), including vegetarian and vegan dishes.

Determination of the appropriate foods is optimized by having a selection of several forms of a specific food. For example, carrots can be "cubed carrot, sautéed with oil and salt" or "raw grated carrot," etc. Alternatively, each food may be loaded separately, and the cooking method selected accordingly (e.g., fried, baked, cooked or boiled, steamed or sautéed). When selecting the fried or baked option, an amount of oil corresponding to 10 and 3%, respectively, of the total weight of the food will be added automatically to the list, indicating the absorption of oil according to the cooking method (41). In the field dedicated to food quality, the interviewer can type-in additional details about the food that are not reflected in the automated list (e.g., lactose-free).

The foods that include certain cooking methods in their description are defined based on the information provided by the USDA. Cooked and raw items are selected from the same database (i.e., Survey, SR Legacy). Although we sought to introduce in the tool as many cooking options as possible for each food, the USDA database has only one cooking method for some foods.

The quantity of foods and beverages consumed is chosen with the aid of a photographic album of the 16 household measures and utensils (**Figure 1**). A fraction of the utensil may be used to quantify the amount of food consumed or the food unit. A household measure will appear in the list if the corresponding weights are available in the MAR24 "*Equivalencies*" sheet. The quantity is chosen according to the selected utensil or unit. By pressing the "*calculate*" button, the corresponding weight in grams will show up. Food quantity loading is in grams and net weight. Liquid quantities and measures are indicated in milliliters (mL), and supplements in milligrams (mg), micrograms (μg), or International Units (IU).

There is a section to calculate the amount of food consumed from a non-standard compound recipe. For example, "The participant prepared a salad for five people using four tomatoes. He reported having consumed two servings of the salad. How many tomatoes did the participant eat?" The following equation is used to determine the amount of food consumed:

$$\textit{Quantity} = \frac{\textit{Portion consumed}}{\textit{Total portions}} * \textit{Total amount of ingredient}$$

Where:

*Quantity* = *Amount of food consumed*
*Portion consumed* = *Number of portions consumed by the participant*
*Total portions* = *Number of portions prepared*
*Total amount of ingredient* = *Total amount of added ingredient(s).*

For each entered food, the button to send information to the form is pressed and the corresponding box to that food in the quick list is checked. If the respondent does not provide enough information about a meal or preparation, the interviewer should delve further and ask additional questions until the required level of description is obtained.

To end the survey, the "final probe" step is carried out, verifying that all the foods mentioned in the quick list are included, and encouraging the respondent to remember any missing item even if consumed in small quantities. The forgotten food is then added to the quick list and detailed loading is carried out.

## Processing and Analysis of Nutritional Information

At the completion of food intake loading, all data obtained in the 24HR will be shown in **Figure 2D**. Once the information is in the database, modifying a specific food will entail deleting

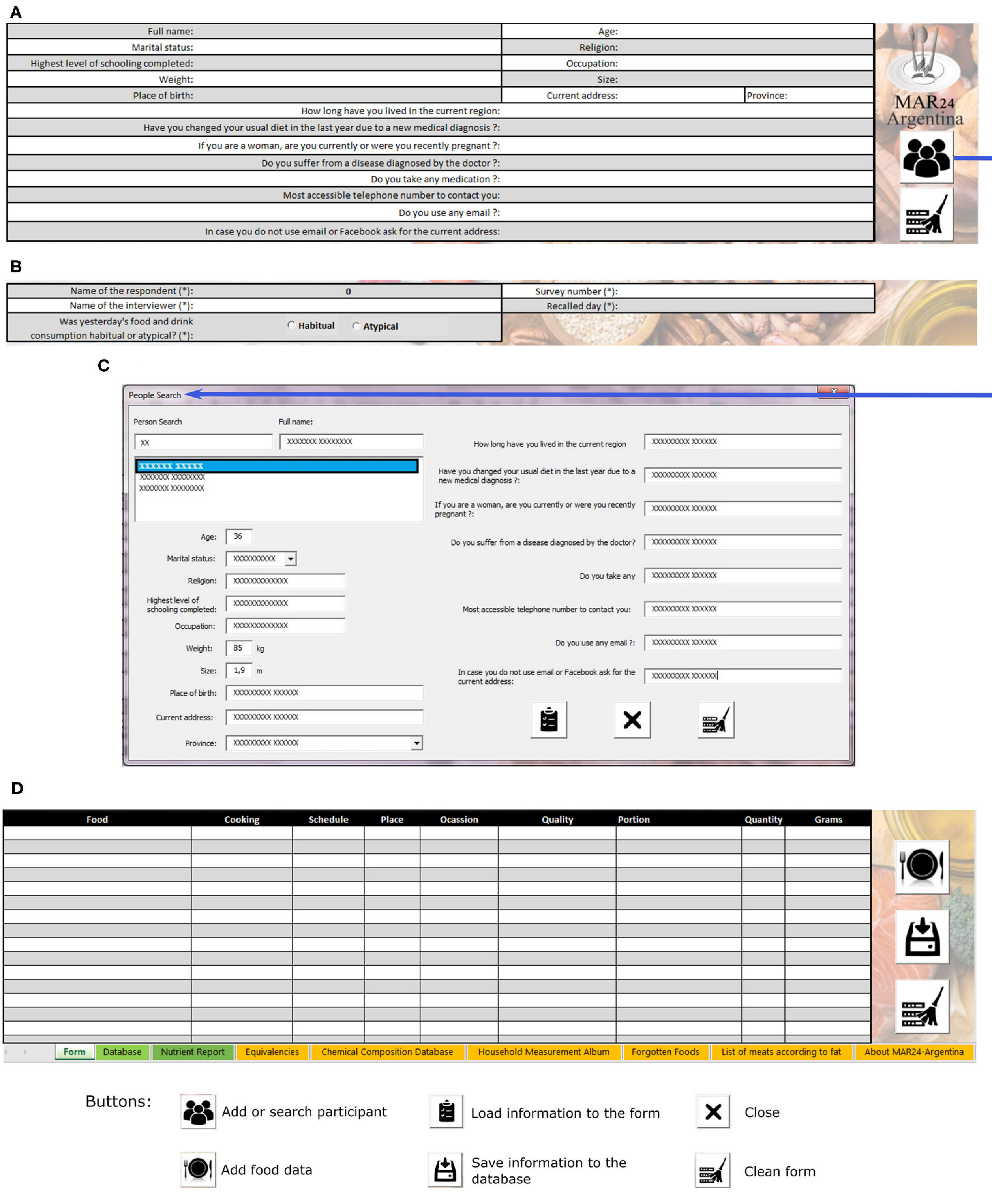


**FIGURE 2 |** Sections of the main form of the MAR24. **(A)** Interviewee data module with sociodemographic, health, and contact information; **(B)** Identification section of the 24-h dietary recall and interviewer; **(C)** Module for adding or searching participants; **(D)** Food data module resulting from the 24HR.

the record (row) from the database and reloading the food, then sending it back to the database. The tool has a button to assess the nutrient profile of the food intake inside the "database" section. The energy and nutrient report includes 50

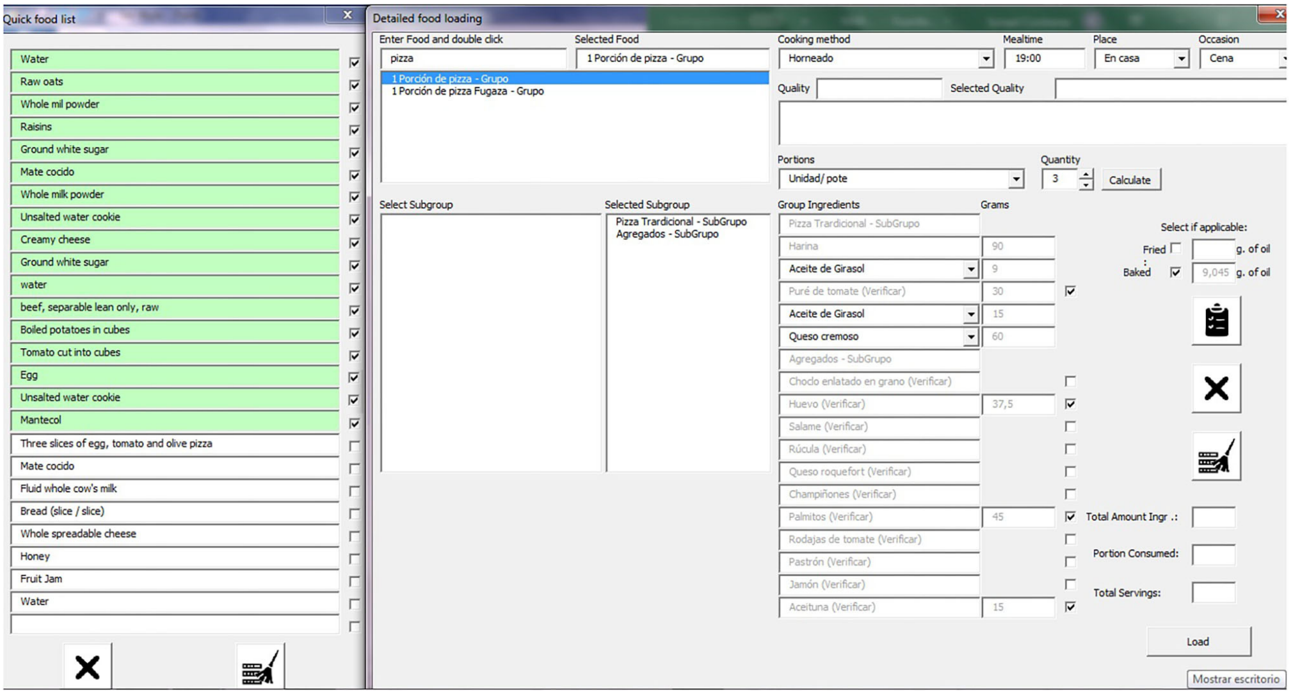


**FIGURE 3 |** Dietary intake module of the MAR24.

nutrients and other food components: water, macronutrients (carbohydrates, proteins including from vegetable and animal sources, lipids), ash, total dietary fiber, total sugar, 10 minerals (calcium, iron, magnesium, phosphorous, potassium, sodium, zinc, copper, manganese, selenium), 13 vitamins (ascorbic acid, thiamin, riboflavin, niacin, pantothenic acid, pyridoxine, folate, choline, vitamin B12, vitamin A, retinol, beta-carotene, alpha-carotene, alpha-tocopherol, vitamin D, Vitamin K), 8 fatty acids (saturated, monounsaturated, polyunsaturated, n-3 18:3, n-3 20:5, n-3 22:5 n-3 22:6, n-6 18:2), beta-cryptoxanthin, lycopene, lutein, zeaxanthin, cholesterol, ethylic alcohol, caffeine, and theobromine. **Table 1** presents an example of the output, showing the nutrient report totals of a 24HR loaded into MAR24 that reflects **Table 2**.

A food loading flow diagram is summarized in **Figure 4**. Due to the need to apply multiple 24HR to the same person, the names of the participants are recorded in a database. To maintain confidentiality when analyzing the data in the nutrient report section, the MAR24 can replace the participant's name with a code based on the record of each 24 h and the questionnaire number.

## Assessment of the Tool

The initial version of the tool was constructed based on the alpha test of 120 24HR. The subsequent application of 1,165 24HR allowed a dynamic improvement of the tool as observations and suggestions were pointed out by researchers while conducting the dietary recalls. The tool underwent adjustments to facilitate the implementation of the five steps of the AMPM. The database of foods and standard recipes expanded due to food items reported in the 24HR. The tool was checked for accuracy in processing data. Likewise, the algorithms were improved optimizing the response time of the program in estimating energy intake and the nutrient composition of foods. Additionally, it was confirmed that the smart search engine obtained the most updated user information, and that no food was left in the database outside of the search. Improvements were also made in the interface to make the tool user-friendly.

The seven external dietitians "agree" or "totally agree" with the easy handling, usefulness, and comprehensiveness of MAR24 as an application for dietary recalls and its efficiency in processing 24HR data. However, they "neither agree nor disagree" on the "intuitive aspect of the tool" (**Supplementary Figure 1**). Feedback for improvement of MAR24 from the same expert group resulted in expanding the nutrient composition database by adding more nutrients, for example, n-3 fatty acids, and providing the option to add the exact measure of food in grams or milliliters aside from the household measures (**Supplementary Figure 2**). The instructional information found in the technical and user manuals were correspondingly completed.

# DISCUSSION

MAR24 is the first tool that uses the AMPM methodology for an automated application of 24HR in Argentina. The tool was developed to be culture-specific by including commonly consumed foods in their local names from the six regions

**TABLE 1 |** Example of nutrient totals report of a 24HR loaded into MAR24.

| Name | Amount | Unit |
|---|---|---|
| Water | 1903.100 | mL |
| Energy | 2131.090 | kcal |
| Protein | 89.604 | g |
| Total lipid (fat) | 90.997 | g |
| Ash | 8.084 | g |
| Carbohydrate, by difference | 238.448 | g |
| Fiber, total dietary | 11.755 | g |
| Sugars, total including NLEA | 79.564 | g |
| Calcium, Ca | 1331.836 | mg |
| Iron, Fe | 15.306 | mg |
| Magnesium, Mg | 475.152 | mg |
| Phosphorus, P | 1421.732 | mg |
| Potassium, K | 2651.657 | mg |
| Sodium, Na | 1613.296 | mg |
| Zinc, Zn | 13.944 | mg |
| Copper, Cu | 1.128 | mg |
| Manganese, Mn | 1.208 | mg |
| Selenium, Se | 133.513 | µg |
| Vitamin C, total ascorbic acid | 32.895 | mg |
| Thiamin | 1.810 | mg |
| Riboflavin | 2.841 | mg |
| Niacin | 34.814 | mg |
| Pantothenic acid | 3.535 | mg |
| Vitamin B-6 | 1.613 | mg |
| Folate, total | 376.745 | µg |
| Choline, total | 457.463 | mg |
| Vitamin B-12 | 6.730 | µg |
| Vitamin A, RAE | 618.622 | µg – RAE |
| Retinol | 543.216 | µg |
| Carotene, beta | 778.990 | µg |
| Carotene, alpha | 143.701 | µg |
| Cryptoxanthin, beta | 8.139 | µg |
| Lycopene | 4414.760 | µg |
| Lutein + zeaxanthin | 671.352 | µg |
| Vitamin E (alpha-tocopherol) | 9.208 | mg |
| Vitamin D (D2 + D3), International Units | 250.703 | µg |
| Vitamin K (phylloquinone) | 30.257 | µg |
| Fatty acids, total saturated | 33.616 | g |
| Fatty acids, total monounsaturated | 36.752 | g |
| Fatty acids, total polyunsaturated | 13.063 | g |
| Omega 3 (18:3) | 0.554 | g |
| 20:5 n-3 (EPA) | 0.007 | g |
| 22:5 n-3 (DPA) | 0.018 | g |
| 22:6 n-3 (DHA) | 0.038 | g |
| Omega 6 (18:2) | 11.892 | g |
| Cholesterol | 482.997 | mg |
| Alcohol, ethyl | 0.000 | g |
| Caffeine | 624.000 | mg |
| Theobromine | 0.000 | mg |

of Argentina and to optimize the dietary assessment process by improving the accuracy of collecting dietary data and reducing recall bias. The tool was designed to be flexible so its food and nutrient database can potentially expand, and open access so it would be useful in different research and clinical settings. The food and nutrient composition database of MAR24 includes SARA, the USDA Food Composition Database, and other databases.

The collection and processing of human dietary intake are complex tasks (47). Because of this, modern technology had been utilized to develop more efficient dietary assessment approaches to assess the dietary intake of individuals and groups and provide a comprehensive system of data collection, coding, and intake calculation (5). Such methods are needed for clinical and epidemiological investigations, since they improve the quality and reliability of the information obtained, reducing possible errors associated with manual coding, as well as optimizing resources for information processing (6).

Not many interviewer-administered automated tools have been described in the literature for administering 24HR to adults from different parts of the world. Two were designed for Korea (33, 36), one for India (specifically New Delhi, Mumbai, and Trivandrum) (37), one for Brazil (34), one for Serbia and Balkan region (35), one for the US low-literate Spanish- and English-speaking citizens (39), and one for the European Union (32). The latter, originally called EPIC-Soft (32) has been renamed to GloboDiet and adapted to the Brazilian and Mexican populations (40). There is no existing automated tool to collect 24HR in Argentina. The development of the MAR24 tool is an option to meet this current need. While other tools could potentially be adapted for use in Argentina, the lack of a national food composition database (48) is a present limitation. The only food composition table generated on a national scale in Argentina was developed in the mid-1900. Later, some compilations were produced by the University of Cordoba and the National University of La Plata using the very first food composition table, individual publications of laboratories, research groups, and foreign nutritional databases. More recently, an *ad hoc* food composition table was prepared for the analysis of nutrient intake for the first National Nutrition and Health Survey in 2004/2005, and its data was incorporated into the SARA software. In 2015 a systematic review searched for newer information to expand the current food composition table of Argentina and collected individual food items and multi-ingredient foods (49).

In our study, the substantial number of 24HR collected from all six regions of Argentina allowed us to identify and include into the MAR24 database a greater number of foods, preparations, and recipes than those reported by the SARA (41), a free access system containing the chemical composition of 379 foods commonly consumed in Argentina. However, it should be noted that food monotony is a reported challenge associated with the usual dietary intake in Argentina (14). For this reason, the MAR24 food database is equipped with fewer food items ($n$ = 968) than other tools, which usually have more than 1,000 items (18).

The use of the USDA food composition tables for the construction of MAR24 is justified because of the lack of a

**TABLE 2 |** Sample of food list from a 24HR loaded into MAR24.

| Food | Schedule | Place | Occasion | Portion | Quantity | Grams |
|---|---|---|---|---|---|---|
| Water (mL) | 7:30:00 | At home | | 1 Big cup (8) | 1 | 300.0 |
| Raw oats | 8:00:00 | At home | Breakfast | 1 Tablespoon (11) | 3 | 18.0 |
| Whole milk powder | 8:00:00 | At home | Breakfast | 1 Teaspoon (13) | 2 | 4.0 |
| Raisins | 8:00:00 | At home | Breakfast | Medium unit | 10 | 4.0 |
| Ground white sugar | 8:00:00 | At home | Breakfast | 1 Coffee spoon (14) | 1 | 2.0 |
| Brown coffee (mL) | 8:00:00 | At home | Breakfast | 1 Big cup (8) | 1 | 300.0 |
| Unsalted water cookie | 8:00:00 | At home | Breakfast | Unit / pot | 5 | 30.0 |
| Creamy cheese | 8:00:00 | At home | Breakfast | 1 Teaspoon (13) | 5 | 41.1 |
| Ground white sugar | 8:00:00 | At home | Breakfast | 1 Coffee spoon (14) | 2.5 | 5.0 |
| Water (mL) | 9:30:00 | At home | | 1 Big glass (5) | 1 | 285.0 |
| Beef, separable lean only, raw | 13:00:00 | At home | Lunch | Medium unit | 1 | 110.0 |
| Boiled potatoes in cubes | 13:00:00 | At home | Lunch | 1 Big ladle (15) | 1 | 103.0 |
| Tomato cut into cubes | 13:00:00 | At home | Lunch | 1 Big ladle (15) | 1 | 82.0 |
| Egg | 13:00:00 | At home | Lunch | Unit / pot | 1 | 42.0 |
| Unsalted water cookie | 13:00:00 | At home | Lunch | Unit / pot | 2 | 12.0 |
| Mantecol (portion) | 13:00:00 | At home | Dessert | Unit / pot | 1 | 20.0 |
| Three slices of pizza (egg, tomato and olives) | 19:00:00 | Out of home | Dinner | Unit / pot | 3 | 301.5 |
| Water (mL) | 19:00:00 | Out of home | Dinner | 1 Big glass (5) | 1 | 285.0 |
| Brown coffee (mL) | 19:00:00 | Out of home | Dinner | 1 Big cup (8) | 1 | 300.0 |
| Fluid whole cow's milk (mL) | 19:00:00 | Out of home | Dinner | 1 Tablespoon (11) | 2 | 12.4 |
| Bread (slice / slice) | 19:00:00 | Out of home | Dinner | Unit / pot | 4 | 48.0 |
| Whole spreadable cheese | 19:00:00 | Out of home | Dinner | 1 Coffee spoon (14) | 4 | 7.9 |
| Honey | 19:00:00 | Out of home | Dinner | 1 Teaspoon (13) | 2 | 12.6 |
| Fruit jam | 19:00:00 | Out of home | Dinner | 1 Teaspoon (13) | 2 | 10.0 |

national database (48). In addition, this offers the possibility of expanding nutrient reports. The use of the USDA database in MAR24 allowed the generation of more detailed nutritional chemical composition information than would be possible using other databases. As a result, the MAR24 has 50 elements available in the chemical composition table in contrast with around 25 elements currently found in the database SARA (41).

To minimize biases in the quantification of bioactive and other food compounds in the MAR24, the composition of each selected food from the USDA was compared with the tables of food composition from SARA, ArgenFoods, Nutrinfo, and the Central American Food Composition Table of the Institute of Nutrition of Central America and Panama (INCAP). For each food, a non-fortified or a fortified version was sought seeking to match the consumption in Argentina. After obtaining one or more options for each food, its composition was compared with local data. The food items that were most similar in description and nutrients were selected. This procedure was applied for the selection of both raw and industrialized foods. For foods prepared by simple food processing (e.g., boiled, sauté, baked, etc.), for which there was no local composition information for comparison, we selected the processed version of a corresponding raw food within the same USDA database source (Legacy, Survey or Foundation) (43). All possible cooking methods were searched for each food and those used in Argentina were selected.

The USDA Food Survey Research Group has developed automated methods to assess dietary intake using standardized procedures and streamlining the availability of survey results (47). The USDA dietary intake instrument incorporates the AMPM which is one of the most widely used and comprehensive methods used for collecting dietary recall data nowadays (50). The MAR24 standardizes 24HR collection using the AMPM steps (20), thus increasing the quality of data collection. This procedure would not be possible with the use of SARA (41), since it does not provide the systematic structure to administer 24HR.

Trained interviewers are required for the proper conduct of 24HR (4, 6, 51, 52). They can be applied remotely through phone calls or through in-person interviews (53). MAR24 assists the interviewer to guide the participant in recalling and providing specific and detailed description of the foods and beverages consumed during the previous day, including their quality (types of food, cooking method, recipe ingredients, trade names, and others). If used to assess or estimate habitual intake, multiple 24 HRs need to be collected; if unannounced, respondents will be prevented from modifying their habitual consumption which can then reduce bias (5).

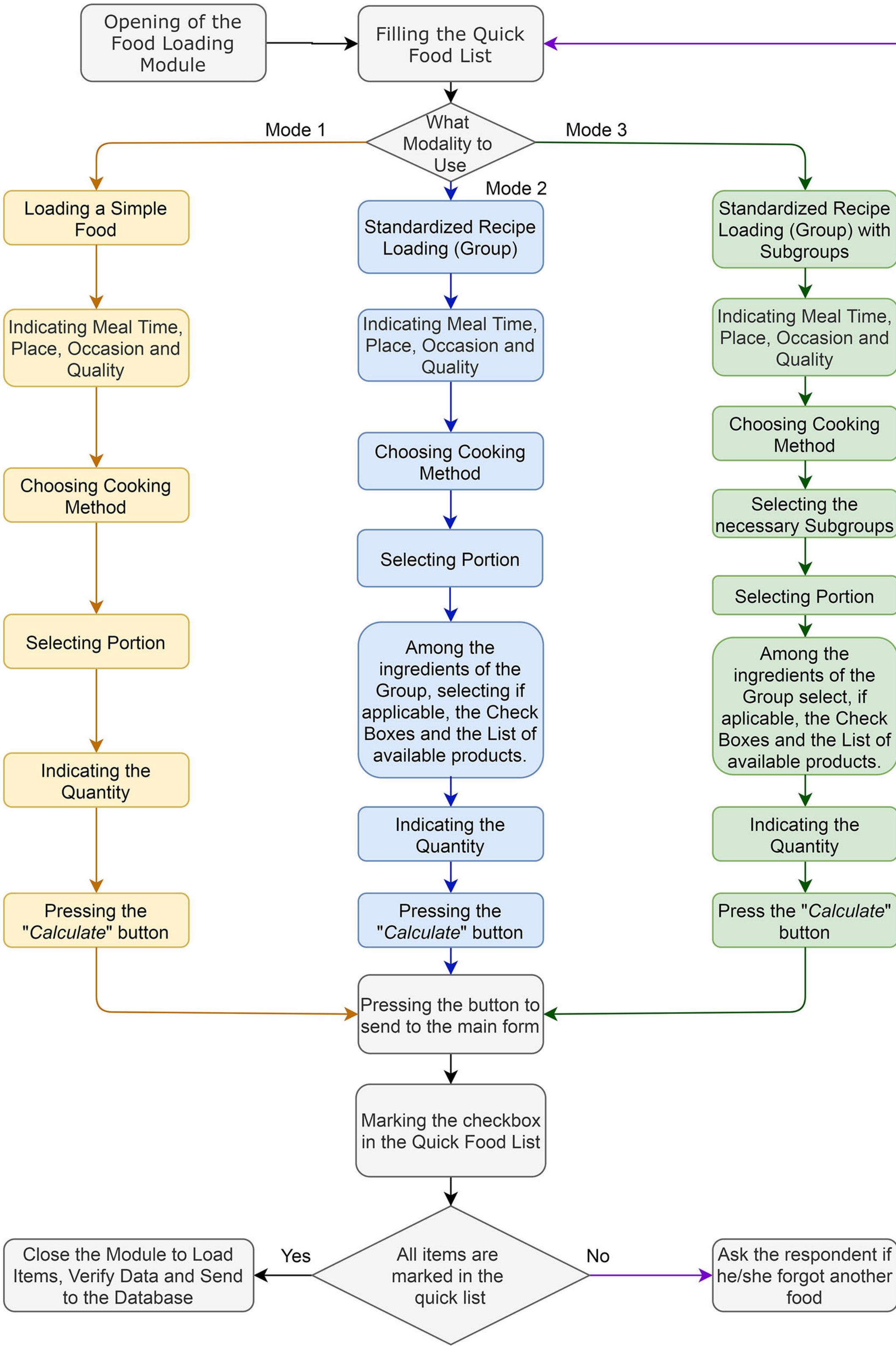


**FIGURE 4 |** Loading food flowchart of the MAR24.

Reliable estimates of the amount of food consumed in a 24HR must be supported by visual resources, such as photographic atlases, images of household measures, or food models (3, 4, 6). Weights and portion sizes of food amounts in the MAR24 are determined based on the portion size visual aid (**Figure 1**). During the administration of MAR24 to collect 24HR, it is recommended that both the interviewer and the respondent have the portion size visual aid (54).

Automated collection of dietary intake data maintains consistency in all the phases of the interviews and a systematic data entry (50) which improves the accuracy of food and nutrient intake estimates (55). For 24HR data collection, automated methods also avoid biases that may occur during the manual loading of information, whether it is the omission or inappropriate addition of data, imprecise estimation of portions and weights, coding failures, and gross weight and net weight problems, among others (3, 55). These new technology-based tools are considered appropriate instruments for nutrition surveillance, as they are efficient in terms of both data collection (front end) and analysis (back end) for the study staff. As an automated method, the MAR24 may be used to collect dietary data in epidemiological studies combined with other instruments such as FFQ (22, 56). The instrument may also be useful in clinical practice by health professionals, mainly dietitians, to control the consumption of food and beverages of patients or to perform food recall.

Latin America has one of the fastest-growing rates of NCDs (57), despite that, a systematic scoping review showed that only about 0.5% of all health intervention studies targeting multiple risk factors for chronic diseases were done in South America (58). There is a critical need for more studies to address NCDs in Latin America. The use of automated tools to assess dietary intakes such as the MAR24 and other dietary assessment approaches may be helpful for the advancement of nutritional research and to implement tailored health interventions. Therefore, the tool may be used to assess food intervention studies addressing risk factors for NCDs (10).

## LIMITATIONS

The usefulness and comprehensiveness of this tool have been tested but its performance in analyzing dietary intake is yet to be compared with other similar tools that employ the AMPM method and the USDA nutrient database (39). The use of the MAR24 tool requires a license of Excel Microsoft Office, which is widely used but may not be available on some systems. Despite its intended use in Argentina, one of MAR24's limitations is the heavy reliance on the USDA food composition database. This is because the current food chemical composition tables of Argentina are still limited in scope and undergoing slow development (48). Food composition may vary depending on the characteristics of the soil, cultivars, season, fortification uses, and many other aspects, thus the chemical composition of foods grown in Argentina may not be accurately reflected by the chemical composition estimates for the same foods on the USDA database. However, developers of the Argentinian software SARA also acknowledged in its program the use of information from the USDA food database and other foreign databases. Therefore, the MAR24 may contribute significantly to the field of nutrition, although with its limitations, considering the demands for studies addressing dietary risk factors for NCDs in Argentina.

## CONCLUSIONS

This study presents the MAR24 as the first tool that uses the AMPM methodology for the automated collection of 24HR in Argentina. This dietary data collection tool includes 968 foods, including 100 recipes that represent foods and recipes from the six regions of the country and 50 nutrients and other food components. The food database uses local names for food and recipes, a visual aid for portion size estimation, and is freely accessible to researchers and health professionals. The MAR24 may be used to optimize dietary data collection and nutrient consumption analyses in clinical practice and clinical-trials for monitoring purposes and the validation processes of food frequency questionnaires (FFQ) for nutritional epidemiology studies addressing dietary-associated risk factors for NCDs.

## DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Research Ethics Committee, affiliated to the National Registry of Health Research (N° 237), Ministry of Health, Argentina. The patients/participants provided their written informed consent to participate in this study.

## AUTHOR CONTRIBUTIONS

SP, FP, and IC-G participated in the design of the study. IC-G and DX participated in the programming and development of the tool. SL, RG, and BC participated in data collection. MM, MZ, GS-S, FP, IC-G, DX, SL, RG, BC, and SP participated in data analyses and evaluation of the tool. IC-G, SP, FP, MZ, GS-S, MM, JS, SL, RG, and BC provided critical comments and worked in manuscript preparation. All authors reviewed the content of the manuscript and approved the final version.

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## SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fnut.2021.642387/full#supplementary-material

**Supplementary Figure 1 |** Quantitative experts' assessment on the MAR24 tool.

**Supplementary Figure 2 |** Qualitative experts' assessment on the MAR24 tool.

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# Comparison of Anthropometric Indicators That Assess Nutritional Status From Infancy to Old Age and Proposal of Percentiles for a Regional Sample of Chile

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**Objectives:** Anthropometric variables are used to evaluate health, dietary status, disease risks, and changes in body composition. The purpose of this study was to compare weight, height, and Body Mass Index (BMI) with American references from the National Center for Health Statistics (NCHS-2012), using BMI and Tri-Ponderal Mass Index (TMI) to propose percentiles for evaluating nutritional status of children, adolescents, and adults, ages 5–80 years old.

**Methods:** A descriptive cross-sectional study was conducted in 15,436 (8,070 males and 7,366 females) children, youths and adults in the Maule region (Chile). The age range ranged from 5.0 to ∼80 years of age. Weight and height were assessed. Body mass index BMI and tri-ponderal mass index (TMI) were calculated. The LMS method was used to generate percentiles.

**Results:** The results illustrated that children were heavier and had more BMI during childhood compared to the NCHS references. During adolescence, reference values were greater until approximately ages 70–79. For height, children were relatively similar to those of the NCHS references, but during adolescence, differences became evident. Adolescence until approximately age 80, the population showed lower values for height. Percentiles were calculated using BMI and TMI by age range and sex. Differences occurred between the American NCHS references and the population with regard to the anthropometric variables of weight, height, and in BMI.

**Conclusion:** Discrepancies with the American NCHS reference were verified in the anthropometric variables of weight, height and BMI. Reference percentiles of BMI and TMI were developed for the evaluation of the nutritional status of the regional population of Maule (Chile). Its use is suggested in clinical and epidemiological contexts.

**Keywords: nutritional state, percentiles, children, adolescents, adults**

# INTRODUCTION

Access to adequate nutrition is a critical component necessary for a human being during all stages of life. The human body needs a proper well-balanced nutritional diet to meet the body's requirements and maintain basic body physiology (1).

Currently, the primary nutritional problems that affect children, adolescents, youth adults, adults, and older adults include malnutrition, underweight, overweight, and obesity. In general, malnutrition (for underweight or overweight) affects future physical development of a human being. Malnutrition reduces the capacity to work, resistance to physical exertion, and the ability to concentrate. Over eating predisposes individuals to chronic diseases, such as diabetes, cardiovascular diseases (2), among others.

Many regions of the world are actually experiencing the double burden of nutritional problems (1). This translates into a public health threat for countries with low and medium incomes (3).

In this sense, epidemiological surveys worldwide need to adopt strategies that help evaluate nutritional conditions using diverse methods. In general, a person's nutritional status can be measured with the popular method known as ABCDE (4). A represents anthropometric measurements, such as height and weight; B, biochemical parameters, such as serum albumin level and hemoglobin count; C, clinical assessment, which includes an assessment of functional, social and mental status, medical history and physical examination; and D, dietary history, such as supplement use and adequacy of diet; and E, evaluation.

In fact, to assess the nutritional status of large populations, one of the most widely used techniques is anthropometry. This technique is considered to be a key component in the evaluation of the nutritional status of children and adults (5). In addition to its long historical tradition, it is an inexpensive and non-invasive method that provides detailed information about the different body structures, especially muscular and fat components (6). Furthermore, it is considered to be a universally applicable method for evaluating body size, composition, and proportion (7).

To understand the nutritional condition and/or goals of an individual population, it is necessary to assess anthropometric variables. For example, when these are applied to children, these help show the general health status, dietary adequacy, and help monitor growth and development over time. However, when applied to adults, anthropometric variables are used to evaluate health, dietary status, disease risks, and analysis of possible changes in body composition during adulthood (8).

In this context, an anthropometric evaluation of the nutritional status of the regional population of Maule in Chile is important, since it merits a formal and consistent means that contributes to risk assessment, monitoring of nutritional changes and possible comparisons with national and international studies, since this information could provide greater opportunities for comparison, not only with other regions of the country, but also with neighboring countries in South America.

Actually, a number of institutions around the world have been interested in proposing curves for evaluating physical growth and nutritional status in children and adolescents (9–11). However, very few studies exist that evaluate the trajectory of the nutritional status of individuals from birth to old age, except for population studies from the National Center for Health Statistics (NCHS) form the United States (8, 12). The NCHS has developed anthropometric references for children and adults, spanning the entire lifecycle.

These references, in general, are used by a number of countries for assessing physical growth trajectories and the nutritional condition of children, adolescents, youth, and adults. Only recently in Chile, percentiles have been developed to evaluate physical growth and body adiposity in children and adolescents (13, 14). However, to date, these references are incomplete because they do not take into account other life stages, such as young adulthood, adulthood, and old age.

As a result, the references, in general, use anthropometric indexes to assess the nutritional status of populations. Therefore, they appear to remain the most commonly used tools for public health and, particularly, in developing countries for evaluating and monitoring physical growth and nutritional status (15).

Developing references based on Body Mass Index (BMI) and the Tri-Ponderal Mass Index (TMI) for a regional population in Chile, spanning all stages of life, could have implications relevant for evaluating nutritional status and for developing public policies. In addition, they could be important for prevention and control for the health status for the population of the Maule Region of Chile.

As a result, for decades, BMI has been recommended and considered as the classic indicator for detecting underweight, overweight, and obesity in diverse populations around the world (16, 17). However, recently, TMI (weight divided by height cubed) has been considered as an indicator of satisfactory body adiposity in relation to BMI (17, 18). Thus, its inclusion in the nutritional state is relevant.

From this perspective, in this study, we hypothesized that it is possible that different anthropometrics exist between the CDC-2012 references and the regional study of the Maule. Therefore, these discrepancies could give rise to the proposed percentiles for assessing the nutritionals state from childhood to old age. Thus, the first initial objectives for this study were to compare weight, height, and BMI with the American references from the NCHS-2012 and to propose percentiles to assess the nutritional statues using BMI and TMI in a regional sample of individuals between the ages of 5–80 years old in the Maule Region of Chile.

# MATERIALS AND METHODS

## Type of Study and Sample

A descriptive cross-sectional study was carried out with 15,436 (8,070 males and 7,366 females) children, adolescents, and adults from the Maule Region (Chile). The sample selection was non-probabilistic (quotas). This sample is 2.2% of the urban population of the Maule region. In general, according to the latest report of the Chilean Ministry of Social Development (19), 709,418 inhabitants (341,700 men and 367,718 women) ranging from 5 to 80 years old live in the urban area of the Maule region. All subjects recruited volunteered from public schools, universities (public and private). Youth, adults, and older adults volunteered from social programs offered by the Municipality of Talca (Maule Region of Chile). Age ranged from 5.0 to 80 years old. Maule is the seventh region of Chile. Talca is the capital city. The region consists of four provinces: Cauquenes, Curicó, Linares, and Talca. The Maule Region is located 230 km south of Santiago, the capital of Chile. The region is 102 meters above sea level.

According to the United Nations Development Program (20), the Human Development Index (HDI) of Chile highlighted that for 2018, the HDI was 0.847. Life expectancy is 80 years of age, and the average education is ∼16.5 years. In the Maule Region, the HDI was 0.872. **Table 1** shows some social development indicators as described by the Ministry of Social Development Chile (19). The indicators in **Table 1** illustrate the small differences between the Maule Region (Talca) with the capital (Santiago) and the northern regions of Arica and Parinacota and the southern region of Magallanes.

All school children, university students, and adults providing informed consent and completing the evaluations of the anthropometric variables were included in the study. Nevertheless, subjects excluded were those of another nationality as well as those not consenting to the anthropometric assessments. This study was carried out according to the Declaration of Helsinki for Human Subjects and the suggestions from the Ethics Committee from the Universidad (UA, 238/2014). Parents and/or teachers signed the informed consent forms for minors under age 18, and those 18 and older (>18 years old) signed the informed consent themselves. The evaluations were conducted by experienced professionals trained in the necessary evaluation procedures (four professionals).

## Procedures

Data, such as age, sex, school, university, and workplace, were recorded in individual files. All anthropometric variables were evaluated in the school, university, work place, and laboratory from the Universidad. One of the researchers coordinated a work team consisting of 4 experienced evaluators to collect data.

The evaluations were carried out during 2015, 2016, 2017, and 2018 from 8:30 a.m. to 13:00 p.m. and 15:00 to 18:00 p.m. Furthermore, the assessments took place from Monday to Friday during the months of April to June and August to November during each year of the study.

The evaluations of the anthropometric variables of weight and height were carried out according to Ross and Marfell-Jones' (21) standardized protocol. During the assessments, subjects wore the least amount of clothing possible (shorts, T-shirt, and barefoot). To assess body weight (kg), an electric scale (Tanita, Glasgow, United Kingdom, Ltd), with a scale of 9 to 150 kg and an accuracy of 100 g. was used. Standing height was measured with a portable stadiometer (Seca Gmbh & Co. KG. Hamburg, Germany), with an accuracy of 0.1 mm. based on the Frankfurt Plane. Body Mass Index (BMI) was calculated using the following formula: BMI = weight (kg)/height$^2$ (m), and the TMI = weight (kg)/height$^3$ (m).

To ensure quality control of the anthropometric variables, 10% (1,550 subjects) of the sample was evaluated twice. The intra- and inter-evaluator TEM technical measurement error showed values between 1 and 2%.

Using the 50th percentile, the anthropometric variables (weight, height, and BMI) were compared with the curves of the U.S. National Center for Health Statistics (8). They were also compared with the World Health Organization (WHO) BMI medians (11).

## Statistics

The data for the normal distribution of the data was determined using the Kolmogorov-Smirnov test. Differences between the sexes were obtained using the *t* test for independent samples. To fit the data (weight and height), the best model was selected based on the $R^2$, residual standard error (RMSE) and significance. Different regression analysis models were used, with the eighth

**TABLE 1 |** Social development indicators of the Maule Region compared to Santiago (Chile).

| Indicators | Arica and Parinacota (Northern Region) | Santiago (Capital) | Maule (Central Region) | Magallanes (South Region) | Chile |
|---|---|---|---|---|---|
| **Education** | | | | | |
| Net rate of pre-school attendance (0–5 years) | 54.0% | 50.4% | 50.7% | 56.1% | 50.3% |
| Net rate of elementary school attendance | 91.5% | 91.1% | 92.8% | 94.6% | 91.5% |
| Net rate of secondary school attendance | 74.3% | 83.8% | 72.6% | 71.0% | 73.6% |
| Net rate of higher education attendance | 38.5% | 39.1% | 33.2% | 41.0% | 37.4% |
| Average number of years of education | 11.4% | ∼11.6 | ∼9.8 | 11.2% | 11.0% |
| **Employment** | | | | | |
| Participation rate in the labor market | 59.9% | 63.2% | 55.7% | 60.4% | 58.3% |
| Employment rate | 54.9% | 58.9% | 51.8% | 54.0% | 54.0% |
| Unemployment rate | 8.3% | 6.9% | 6.9% | 7.5% | 7.5% |
| **Health** | | | | | |
| Health care (State) | 76.3% | 71.0% | 86.2% | 69.9% | 77.3% |
| Health care (Private) | 10.9% | 21.3% | 5.9% | 15.9% | 15.1% |
| No health care | 3.9% | 3.3% | 3.0% | 3.0% | 3.1% |

degree cubic polynomial model being the most appropriate for weight and height. The calculations and graphs of the curves were obtained by means of the computer program implemented in the R. The proposed percentiles were created to evaluate BMI and PI: p3, p5, p10, p15, p25, p50, p75, p85, p90, p95, and p97. The LMS method was also used to create the percentiles (L: Box-Cox coefficient; M: median; S: coefficient of variation) (22). Graphs were created with *Chart Maker* version 2.3 software (23). Differences between the percentiles were performed using the fraction: 100 log (reference percentile/calculated percentile). For all cases <0.05 was adopted. Calculations were performed with Excel and SPSS 18.0.

## RESULTS

The anthropometric variables and body indices from age 5.0 to >80 years are shown in **Table 2**. For weight and height, there were no significant differences between the age ranges 5.0–7.9 years and 11.0–13.9 years. However, in males, from the age range of 14.0–16.9 to age 80 years, they were heavier and taller compared to females. There were no significant differences in both sexes for BMI in the age ranges from 5.0–7.9 to 50.0–59.9 years. However, there were differences from the age range 60.0–69.9 to 80 years, where females showed a higher BMI than males. For the TMI, no differences were observed in the age ranges 5.0–7.9, 8.0–10.9 and 40.0–49.9 years. However, for the rest of the age ranges, women presented higher values than males.

The fit of the data for the weight and height curve showed a polynomial regression of degree 8. This polynomial regression model indicated a significant relationship between chronological age with weight and height in both sexes (see **Figure 1**). The fit of the data for the height curve was $R^2 = 0.84$ for males and $R^2 = 0.75$ for females, while for the weights, these values were lower ($R^2 = 0.66$ for males and $R^2 = 0.54$ for females). In general, the adopted model (grade 8) reflected a good fit, with RMSE values ranging from 6.9 to 6.3 for height and from 11.5 to 10.7 for body weight.

**Figures 2**, **3** illustrate the comparisons of the anthropometric variables of weight, height, and BMI of the regional population of the Maule with the American references of the CDC-2012 (50th

**TABLE 2 |** Anthropometric characteristics of the sample studied.

| Age range | *n* | Weight (kg) | | Height (cm) | | BMI (kg/m$^2$) | | TMI (kg/m$^3$) | |
|---|---|---|---|---|---|---|---|---|---|
| | | X | SD | X | SD | X | SD | X | SD |
| **Males** | | | | | | | | | |
| 5–7.9 years | 634 | 26.37 | 6.33 | 121.03 | 8.33 | 17.84 | 2.87 | 14.78 | 2.29 |
| 8–10.9 years | 1,137 | 36.98 | 9.64 | 136.11 | 8.36 | 19.73 | 3.63 | 14.49 | 2.49 |
| 11–13.9 years | 1,340 | 50.04 | 12.00 | 153.51 | 9.74 | 21.07 | 3.85 | 13.76* | 2.55 |
| 14–16.9 years | 1,445 | 66.02* | 12.94 | 169.14* | 7.67 | 23.02 | 4.02 | 13.64* | 2.53 |
| 17–19.9 years | 1,641 | 71.75* | 12.13 | 172.03* | 6.57 | 24.24 | 3.91 | 14.12* | 2.45 |
| 20–29.9 years | 1,058 | 77.20* | 12.88 | 173.07* | 6.67 | 25.72 | 3.71 | 14.88* | 2.20 |
| 30–39.9 years | 111 | 81.38* | 12.25 | 175.34* | 9.45 | 26.39 | 2.77 | 15.09* | 1.74 |
| 40–49.9 years | 64 | 85.69* | 18.09 | 169.95* | 4.79 | 29.58 | 5.51 | 17.40 | 3.13 |
| 50–59.9 years | 117 | 81.36* | 13.22 | 169.49* | 6.87 | 28.30 | 4.12 | 16.73* | 2.56 |
| 60–69.9 years | 272 | 78.45* | 13.72 | 167.44* | 7.02 | 27.98* | 4.74 | 16.76* | 3.05 |
| 70–79.9 years | 203 | 76.50* | 10.86 | 165.61* | 6.85 | 27.92* | 3.90 | 16.91* | 2.66 |
| >80 years | 48 | 70.78* | 8.29 | 163.34* | 6.59 | 26.54* | 2.93 | 16.29* | 2.09 |
| Total | 8,070 | 60.09* | 20.71 | 159.13* | 18.50 | 22.92* | 4.74 | 14.43* | 2.62 |
| **Females** | | | | | | | | | |
| 5–7.9 years | 659 | 25.59 | 5.47 | 120.33 | 7.18 | 17.56 | 2.69 | 14.62 | 2.22 |
| 8–10.9 years | 789 | 36.64 | 9.49 | 136.40 | 9.00 | 19.47 | 3.51 | 14.29 | 2.44 |
| 11–13.9 years | 1,082 | 51.76 | 11.92 | 153.40 | 7.60 | 21.87 | 4.24 | 14.27 | 2.78 |
| 14–16.9 years | 918 | 60.19 | 11.16 | 159.01 | 6.20 | 23.79 | 4.16 | 14.99 | 2.74 |
| 17–19.9 years | 1,105 | 61.69 | 11.56 | 159.91 | 5.92 | 24.09 | 4.08 | 15.08 | 2.60 |
| 20–29.9 years | 949 | 64.10 | 11.32 | 161.23 | 5.91 | 24.64 | 4.02 | 15.31 | 2.60 |
| 30–39.9 years | 178 | 71.59 | 14.48 | 160.16 | 7.09 | 27.91 | 5.25 | 17.49 | 3.54 |
| 40–49.9 years | 190 | 69.40 | 13.17 | 157.50 | 6.55 | 27.98 | 5.04 | 17.81 | 3.37 |
| 50–59.9 years | 292 | 71.07 | 12.28 | 156.66 | 5.91 | 29.00 | 5.04 | 18.56 | 3.47 |
| 60–69.9 years | 701 | 69.81 | 11.70 | 155.20 | 7.14 | 29.04 | 4.84 | 18.79 | 3.46 |
| 70–79.9 years | 433 | 67.82 | 11.69 | 152.95 | 6.59 | 28.98 | 4.49 | 18.99 | 3.12 |
| >80 years | 70 | 64.23 | 12.75 | 152.50 | 7.00 | 27.62 | 5.13 | 18.16 | 3.58 |
| Total | 7,366 | 56.41 | 17.62 | 151.84 | 13.95 | 23.90 | 5.45 | 15.73 | 3.29 |

*X, average; SD, standard deviation; BMI, Body Mass Index; TMI, tri-ponderal mass index.*
** Significant difference in relation to females.*

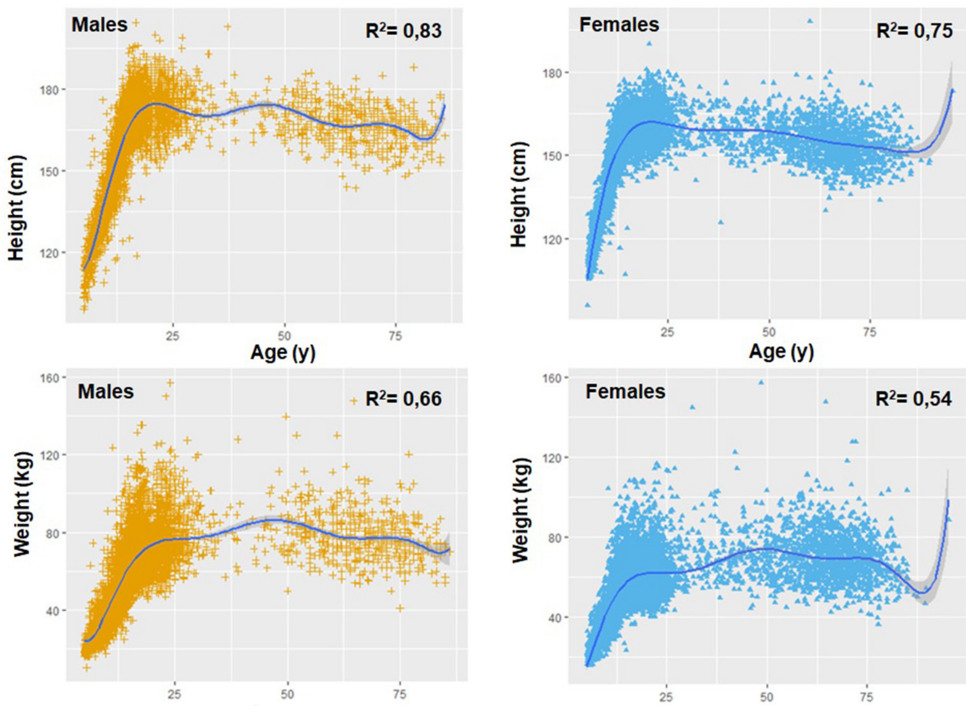


**FIGURE 1 |** Polynomial relationship of age with weight and height in both sexes.

percentile). With regard to body weight, from age 5.0 to 11.9 years old, children from the Maule Region showed greater weight than those for the CDC-2012 references (for males, from ∼0.09 to ∼5.40 kg and for females, from ∼1.28 to ∼5.13 kg). Then, from 12.0 to 80 years old, the CDC-2012 references presented higher values in both sexes (for males, from ∼0.45 to ∼5.93 kg and for females, from ∼0.05 to ∼4.80 kg), except for females at age 80 where they showed values higher of ∼3.10 kg.

For height, the growth patterns for both sexes were similar: for males until age 12.9 and for females until 11.9 years old. Then, the CDC-2012 reference values were higher than their Maule counterparts up to age 80. The differences for males were from ∼0.82 to ∼1.80 cm, and for females, it was from ∼0.32 to ∼1.89 cm.

With regard to BMI, the children of both sexes from the Maule showed higher values from age 5.0 to 11.9 years old. Differences for males were greater from ∼1.12 to ∼4.93 kg/m$^2$ while for females, differences began from ∼0.68 to ∼3.66 kg/m$^2$. Then, from 12.0 years old to age 17.9, the values were relatively similar, ranging for males, from ∼0.41 to ∼0.45 kg/m$^2$ and for females, from ∼0.01 to ∼0.97 kg/m$^2$. Commencing at age 18.0 until 70–79.9 years old, the CDC-2012 values were higher for both sexes. For example, the values for male were higher from ∼0.03 to ∼4.73 kg/m$^2$ and for females, from ∼0.61 to ∼3.66 kg/m$^2$. Finally, at age 80 years old. BMI values for both sexes were greater (in males, ∼0.64 kg/m$^2$ and in females, ∼4.09 kg/m$^{2)}$, vs. the CDC-2012 reference values.

In relation to comparisons of BMI among children and adolescents in Maule with the WHO 50th percentile, we can highlight that the WHO reference values reflect lower medians in both sexes (in males from ∼1.5 to 2.7 kg/m$^2$ and in females from ∼1.1 to 2.6 kg/m$^2$) and from 5 to 19 years of age.

**Tables 3–6** show the values for BMI and TMI from age 5.0 to 80 years of age. These results are presented in percentiles based on age ranges and sex (p3, p5, p10, p15, p25, p50, p75, p85, p90, p95, and p97). The curve for BMI values for both sexes increased linearly from age 5.0 to age 80. The BMI in both sexes was relatively similar and was slightly different in 50th percentile (∼0.10 to ∼0.80 kg/m$^2$) from ages 5.0–5.9 to 60.0–69.9 years of age. However, in the last two age ranges (70.0–79.9 and >80 years), females showed higher values when compared to males, between ∼1.2 to ∼1.5 kg/m$^2$.

The TMI value for 50th percentile moved curvi-linearly from ages 5.0–5.9 to 80 years old. For example, the values decreased slightly until ages 11.0–11.9, approximately. Then, these values remained stable until ages 16.0–16.9. Finally, TMI increased linearly until 80 years of age. The differences between both sexes began appearing from 12.0 to 12.9 years old onwards. It was greater in females when compared to males (from ∼0.6 to ∼2.5 kg/m$^3$) until approximately age 80.

## DISCUSSION

The results from this study indicate that during all stages of life, the regional population of the Maule showed similar trajectories for weight, height, and BMI to those of the American NCHS (8). However, differences occurred during childhood where the

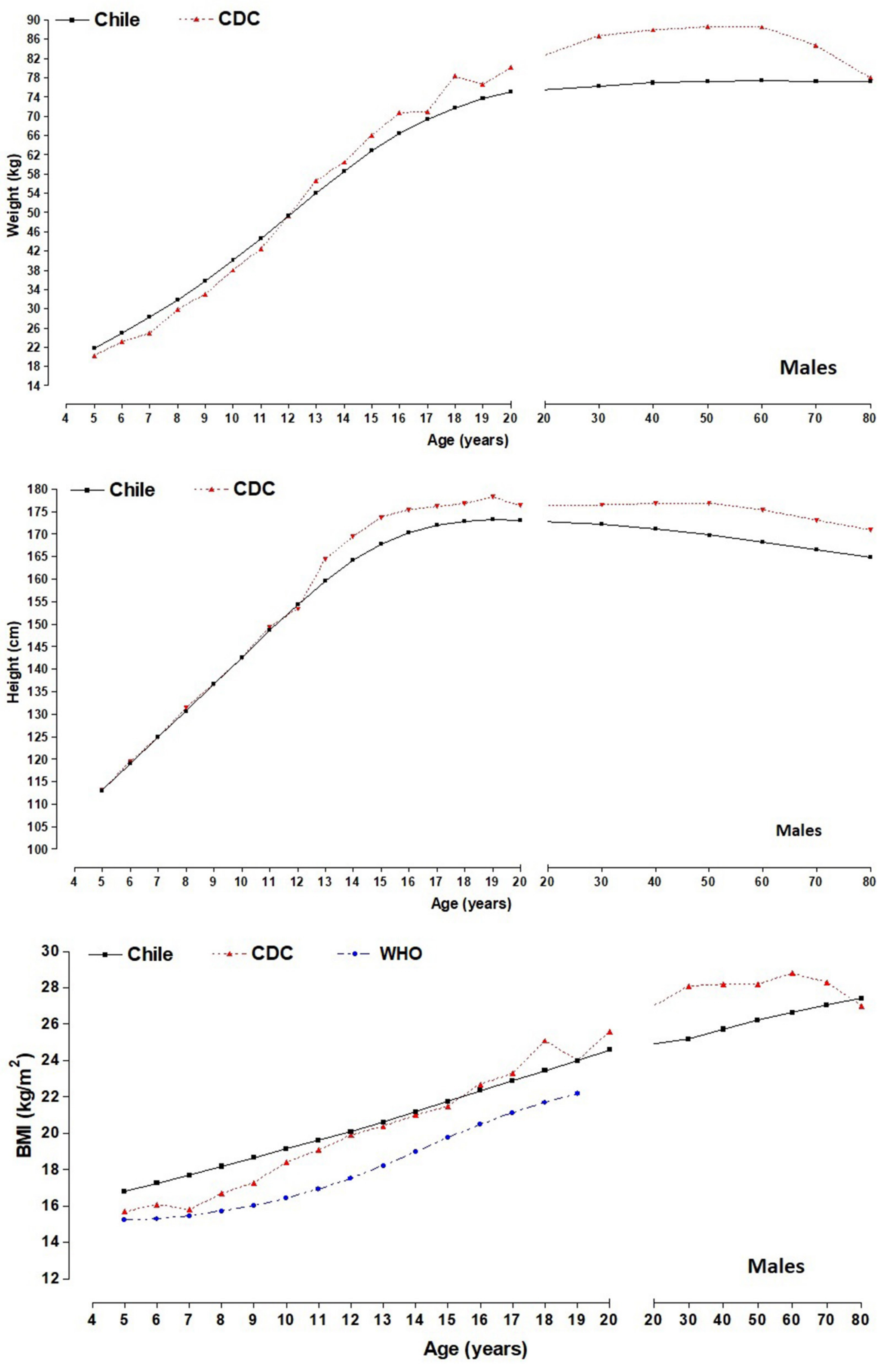


**FIGURE 2 |** Comparison of differences (50th percentile) of anthropometric variables (weight and height) between the Maule regional sample and the CDC-2012; and differences in BMI between the study sample, the CDC-2012 and the WHO reference for males.

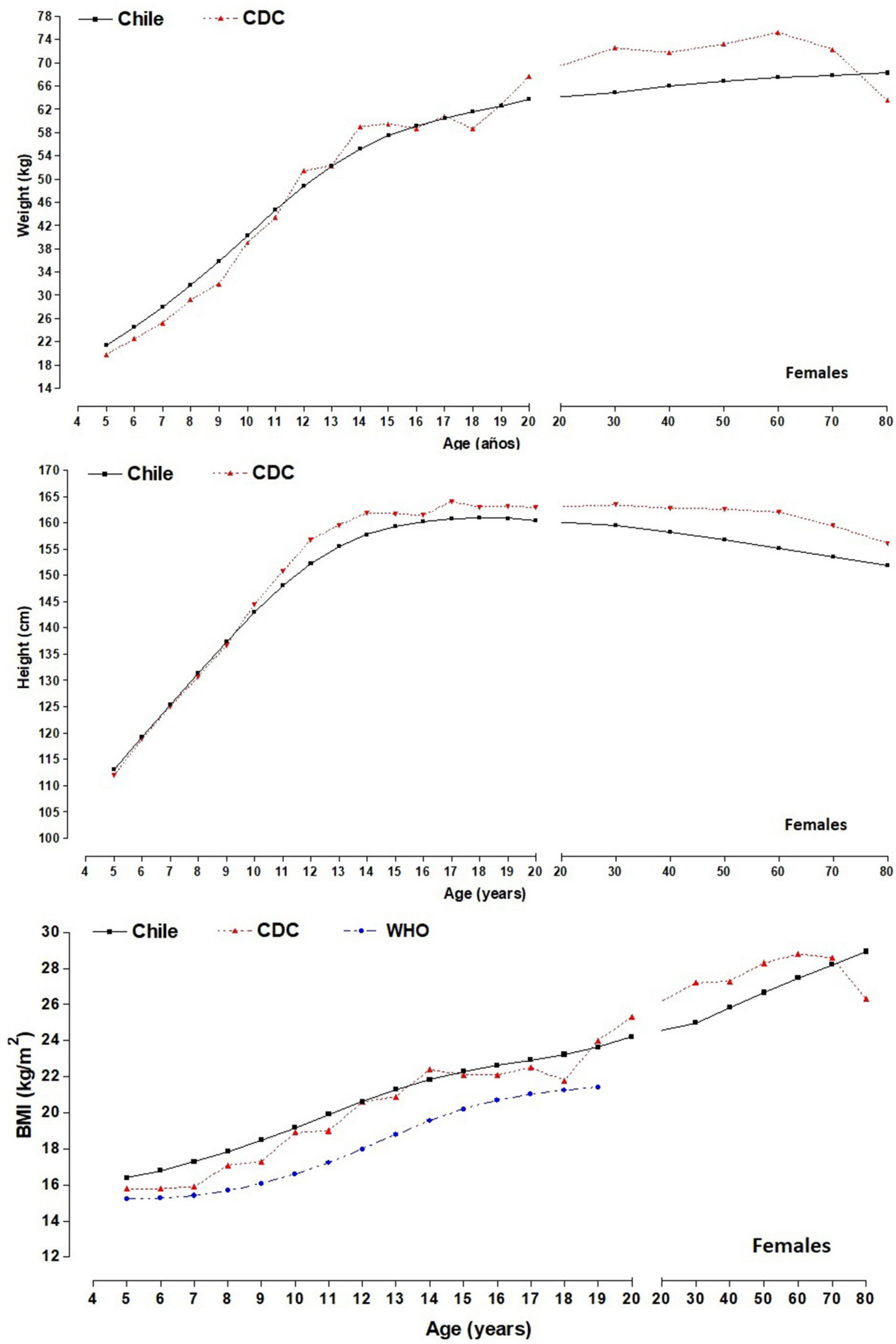


**FIGURE 3 |** Comparison of differences (50th percentile) of anthropometric variables (weight and height) between the Maule regional sample and the CDC-2012; and differences in BMI between the study sample, the CDC-2012 and the WHO reference for females.

**TABLE 3 |** Percentiles for evaluating BMI from 5 to 80 years old based on age range for males.

| Age | n | L | M | S | P3 | P5 | P10 | P15 | P25 | P50 | P75 | P85 | P90 | P95 | P97 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5.0–5.9 | 149 | 0.74 | 16.8 | 0.17 | 11.6 | 12.2 | 13.2 | 13.9 | 14.9 | 16.8 | 18.8 | 19.9 | 20.7 | 21.8 | 22.5 |
| 6.0–6.9 | 206 | 0.46 | 17.3 | 0.17 | 12.1 | 12.7 | 13.7 | 14.3 | 15.3 | 17.3 | 19.3 | 20.5 | 21.3 | 22.6 | 23.4 |
| 7.0–7.9 | 279 | 0.19 | 17.7 | 0.17 | 12.7 | 13.2 | 14.1 | 14.8 | 15.7 | 17.7 | 19.9 | 21.1 | 22.0 | 23.4 | 24.3 |
| 8.0–8.9 | 377 | −0.1 | 18.2 | 0.17 | 13.2 | 13.7 | 14.6 | 15.2 | 16.2 | 18.2 | 20.4 | 21.8 | 22.7 | 24.2 | 25.2 |
| 9.0–9.9 | 302 | −0.3 | 18.7 | 0.17 | 13.7 | 14.2 | 15.1 | 15.7 | 16.7 | 18.7 | 21.0 | 22.4 | 23.4 | 25.1 | 26.2 |
| 10.0–10.9 | 458 | −0.5 | 19.2 | 0.17 | 14.2 | 14.7 | 15.6 | 16.2 | 17.1 | 19.2 | 21.6 | 23.0 | 24.1 | 25.9 | 27.1 |
| 11.0–11.9 | 524 | −0.7 | 19.6 | 0.17 | 14.7 | 15.2 | 16.0 | 16.6 | 17.6 | 19.6 | 22.1 | 23.6 | 24.8 | 26.7 | 28.0 |
| 12.0–12.9 | 396 | −0.8 | 20.1 | 0.17 | 15.2 | 15.7 | 16.5 | 17.1 | 18.1 | 20.1 | 22.6 | 24.2 | 25.4 | 27.4 | 28.9 |
| 13.0–13.9 | 420 | −1 | 20.6 | 0.16 | 15.8 | 16.2 | 17.0 | 17.6 | 18.6 | 20.6 | 23.2 | 24.8 | 26.1 | 28.2 | 29.7 |
| 14.0–14.9 | 457 | −1.1 | 21.2 | 0.16 | 16.3 | 16.8 | 17.6 | 18.2 | 19.1 | 21.2 | 23.8 | 25.4 | 26.7 | 28.9 | 30.6 |
| 15.0–15.9 | 524 | −1.2 | 21.8 | 0.16 | 16.9 | 17.4 | 18.2 | 18.8 | 19.7 | 21.8 | 24.4 | 26.1 | 27.4 | 29.7 | 31.3 |
| 16.0–16.9 | 464 | −1.3 | 22.4 | 0.15 | 17.5 | 18.0 | 18.8 | 19.3 | 20.3 | 22.4 | 25.0 | 26.7 | 28.0 | 30.3 | 32.0 |
| 17.0–17.9 | 777 | −1.3 | 22.9 | 0.15 | 18.0 | 18.5 | 19.3 | 19.9 | 20.8 | 22.9 | 25.5 | 27.3 | 28.6 | 30.9 | 32.6 |
| 18.0–18.9 | 397 | −1.4 | 23.5 | 0.15 | 18.5 | 19.0 | 19.8 | 20.4 | 21.4 | 23.5 | 26.1 | 27.8 | 29.1 | 31.4 | 33.1 |
| 19.0–19.9 | 467 | −1.4 | 24 | 0.14 | 19.1 | 19.5 | 20.4 | 21.0 | 21.9 | 24.0 | 26.6 | 28.4 | 29.7 | 31.9 | 33.6 |
| 20.0–29.9 | 1,058 | −1.3 | 24.6 | 0.14 | 19.6 | 20.1 | 20.9 | 21.5 | 22.5 | 24.6 | 27.2 | 28.9 | 30.3 | 32.5 | 34.2 |
| 30.0–39.9 | 111 | −1.3 | 25.2 | 0.14 | 20.1 | 20.6 | 21.5 | 22.1 | 23.0 | 25.2 | 27.8 | 29.6 | 30.9 | 33.1 | 34.7 |
| 40.0–49.9 | 64 | −1.3 | 25.7 | 0.14 | 20.6 | 21.1 | 22.0 | 22.6 | 23.6 | 25.7 | 28.4 | 30.1 | 31.4 | 33.6 | 35.2 |
| 50.9–59.9 | 117 | −1.3 | 26.2 | 0.14 | 21.0 | 21.5 | 22.4 | 23.0 | 24.0 | 26.2 | 28.9 | 30.6 | 31.9 | 34.1 | 35.7 |
| 60.9–69.9 | 272 | −1.2 | 26.7 | 0.13 | 21.4 | 21.9 | 22.8 | 23.4 | 24.5 | 26.6 | 29.3 | 31.0 | 32.3 | 34.5 | 36.1 |
| 70.9–79.9 | 203 | −1.2 | 27 | 0.13 | 21.7 | 22.3 | 23.2 | 23.8 | 24.8 | 27.0 | 29.7 | 31.4 | 32.7 | 34.8 | 36.4 |
| >80 years | 48 | −1.2 | 27.4 | 0.13 | 22.1 | 22.6 | 23.5 | 24.2 | 25.2 | 27.4 | 30.1 | 31.8 | 33.1 | 35.2 | 36.7 |

*LMS, least-mean-square algorithm; L, Box-Cox coefficient; M, median; S, coefficient of variation.*

**TABLE 4 |** Percentiles for evaluating BMI from 5 to 80 years old based on age range for females.

| Age | *n* | L | M | S | P3 | P5 | P10 | P15 | P25 | P50 | P75 | P85 | P90 | P95 | P97 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5.0–5.9 | 137 | −0.28 | 16.40 | 0.16 | 12.2 | 12.7 | 13.4 | 13.9 | 14.7 | 16.4 | 18.3 | 19.5 | 20.3 | 21.6 | 22.5 |
| 6.0–6.9 | 220 | −0.35 | 16.81 | 0.16 | 12.6 | 13.0 | 13.7 | 14.3 | 15.1 | 16.8 | 18.8 | 20.0 | 20.9 | 22.3 | 23.3 |
| 7.0–7.9 | 302 | −0.43 | 17.29 | 0.17 | 12.9 | 13.4 | 14.1 | 14.6 | 15.5 | 17.3 | 19.4 | 20.7 | 21.6 | 23.1 | 24.1 |
| 8.0–8.9 | 267 | −0.50 | 17.85 | 0.17 | 13.3 | 13.8 | 14.6 | 15.1 | 16.0 | 17.8 | 20.0 | 21.4 | 22.4 | 24.0 | 25.1 |
| 9.0–9.9 | 182 | −0.58 | 18.49 | 0.17 | 13.8 | 14.3 | 15.1 | 15.7 | 16.6 | 18.5 | 20.8 | 22.2 | 23.3 | 25.0 | 26.2 |
| 10.0–10.9 | 340 | −0.67 | 19.19 | 0.17 | 14.4 | 14.9 | 15.7 | 16.3 | 17.2 | 19.2 | 21.6 | 23.1 | 24.3 | 26.1 | 27.4 |
| 11.0–11.9 | 369 | −0.75 | 19.92 | 0.17 | 15.0 | 15.5 | 16.3 | 16.9 | 17.8 | 19.9 | 22.4 | 24.0 | 25.3 | 27.2 | 28.7 |
| 12.0–12.9 | 397 | −0.84 | 20.63 | 0.17 | 15.6 | 16.1 | 16.9 | 17.5 | 18.5 | 20.6 | 23.3 | 24.9 | 26.2 | 28.3 | 29.9 |
| 13.0–13.9 | 316 | −0.92 | 21.29 | 0.17 | 16.1 | 16.6 | 17.5 | 18.1 | 19.1 | 21.3 | 24.0 | 25.8 | 27.1 | 29.3 | 31.0 |
| 14.0–14.9 | 323 | −0.98 | 21.85 | 0.17 | 16.6 | 17.1 | 18.0 | 18.6 | 19.6 | 21.9 | 24.6 | 26.4 | 27.8 | 30.2 | 31.9 |
| 15.0–15.9 | 276 | −1.04 | 22.30 | 0.17 | 17.0 | 17.5 | 18.4 | 19.0 | 20.0 | 22.3 | 25.1 | 27.0 | 28.4 | 30.8 | 32.6 |
| 16.0–16.9 | 319 | −1.07 | 22.65 | 0.17 | 17.3 | 17.8 | 18.7 | 19.3 | 20.4 | 22.6 | 25.5 | 27.4 | 28.8 | 31.2 | 33.1 |
| 17.0–17.9 | 405 | −1.09 | 22.94 | 0.16 | 17.6 | 18.1 | 19.0 | 19.6 | 20.7 | 22.9 | 25.8 | 27.7 | 29.1 | 31.6 | 33.4 |
| 18.0–18.9 | 215 | −1.08 | 23.24 | 0.16 | 17.8 | 18.4 | 19.2 | 19.9 | 20.9 | 23.2 | 26.1 | 28.0 | 29.5 | 31.9 | 33.8 |
| 19.0–19.9 | 485 | −1.04 | 23.64 | 0.16 | 18.1 | 18.7 | 19.6 | 20.2 | 21.3 | 23.6 | 26.6 | 28.5 | 29.9 | 32.4 | 34.2 |
| 20.0–29.9 | 949 | −0.99 | 24.23 | 0.16 | 18.6 | 19.1 | 20.1 | 20.7 | 21.8 | 24.2 | 27.2 | 29.1 | 30.6 | 33.0 | 34.8 |
| 30.0–39.9 | 178 | −0.91 | 24.99 | 0.16 | 19.1 | 19.7 | 20.7 | 21.4 | 22.5 | 25.0 | 28.0 | 30.0 | 31.5 | 33.9 | 35.7 |
| 40.0–49.9 | 190 | −0.81 | 25.84 | 0.16 | 19.7 | 20.3 | 21.3 | 22.1 | 23.3 | 25.8 | 29.0 | 31.0 | 32.4 | 34.9 | 36.7 |
| 50.0–59.9 | 292 | −0.70 | 26.68 | 0.16 | 20.2 | 20.9 | 22.0 | 22.8 | 24.0 | 26.7 | 29.9 | 31.9 | 33.4 | 35.9 | 37.6 |
| 60.0–69.9 | 701 | −0.57 | 27.48 | 0.16 | 20.7 | 21.4 | 22.6 | 23.4 | 24.7 | 27.5 | 30.8 | 32.8 | 34.3 | 36.8 | 38.5 |
| 70.0–79.9 | 433 | −0.44 | 28.23 | 0.16 | 21.2 | 21.9 | 23.1 | 24.0 | 25.3 | 28.2 | 31.6 | 33.7 | 35.2 | 37.6 | 39.3 |
| >80 years | 70 | −0.31 | 28.95 | 0.16 | 21.6 | 22.3 | 23.6 | 24.5 | 26.0 | 28.9 | 32.4 | 34.5 | 36.0 | 38.3 | 40.0 |

*LMS, least-mean-square algorithm; L, Box-Cox coefficient; M, median; S, coefficient of variation.*

**TABLE 5** | Percentiles for evaluating TMI from 5 to 80 years old based on age range for males.

| Age | *n* | L | M | S | P3 | P5 | P10 | P15 | P25 | P50 | P75 | P85 | P90 | P95 | P97 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5.0–5.9 | 149 | −0.5 | 14.9 | 0.2 | 11.2 | 11.6 | 12.2 | 12.7 | 13.4 | 14.9 | 16.7 | 17.9 | 18.7 | 20.0 | 20.9 |
| 6.0–6.9 | 206 | −0.5 | 14.7 | 0.2 | 11.0 | 11.4 | 12.0 | 12.5 | 13.2 | 14.7 | 16.5 | 17.6 | 18.4 | 19.7 | 20.6 |
| 7.0–7.9 | 279 | −0.6 | 14.5 | 0.2 | 10.9 | 11.3 | 11.9 | 12.3 | 13.0 | 14.5 | 16.2 | 17.3 | 18.1 | 19.4 | 20.3 |
| 8.0–8.9 | 377 | −0.7 | 14.2 | 0.2 | 10.8 | 11.1 | 11.7 | 12.1 | 12.8 | 14.2 | 16.0 | 17.0 | 17.8 | 19.1 | 20.0 |
| 9.0–9.9 | 302 | −0.7 | 14.0 | 0.2 | 10.7 | 11.0 | 11.6 | 12.0 | 12.6 | 14.0 | 15.7 | 16.8 | 17.5 | 18.8 | 19.7 |
| 10.0–10.9 | 458 | −0.8 | 13.8 | 0.2 | 10.5 | 10.9 | 11.4 | 11.8 | 12.4 | 13.8 | 15.4 | 16.5 | 17.3 | 18.5 | 19.4 |
| 11.0–11.9 | 524 | −0.9 | 13.6 | 0.2 | 10.4 | 10.7 | 11.2 | 11.6 | 12.2 | 13.6 | 15.2 | 16.2 | 17.0 | 18.2 | 19.2 |
| 12.0–12.9 | 396 | −0.9 | 13.4 | 0.2 | 10.3 | 10.6 | 11.1 | 11.5 | 12.1 | 13.4 | 14.9 | 16.0 | 16.7 | 18.0 | 18.9 |
| 13.0–13.9 | 420 | −1.0 | 13.2 | 0.2 | 10.2 | 10.5 | 11.0 | 11.4 | 12.0 | 13.2 | 14.8 | 15.8 | 16.6 | 17.8 | 18.8 |
| 14.0–14.9 | 457 | −1.1 | 13.2 | 0.2 | 10.2 | 10.5 | 11.0 | 11.4 | 11.9 | 13.2 | 14.7 | 15.7 | 16.5 | 17.8 | 18.7 |
| 15.0–15.9 | 524 | −1.2 | 13.2 | 0.2 | 10.3 | 10.6 | 11.1 | 11.4 | 12.0 | 13.3 | 14.8 | 15.8 | 16.6 | 17.9 | 18.8 |
| 16.0–16.9 | 464 | −1.2 | 13.4 | 0.2 | 10.5 | 10.8 | 11.2 | 11.6 | 12.2 | 13.4 | 15.0 | 16.0 | 16.7 | 18.1 | 19.1 |
| 17.0–17.9 | 777 | −1.2 | 13.6 | 0.2 | 10.7 | 11.0 | 11.4 | 11.8 | 12.4 | 13.6 | 15.2 | 16.2 | 17.0 | 18.3 | 19.3 |
| 18.0–18.9 | 397 | −1.2 | 13.8 | 0.2 | 10.9 | 11.2 | 11.7 | 12.0 | 12.6 | 13.8 | 15.4 | 16.5 | 17.3 | 18.6 | 19.6 |
| 19.0–19.9 | 467 | −1.2 | 14.1 | 0.1 | 11.1 | 11.4 | 11.9 | 12.3 | 12.9 | 14.2 | 15.8 | 16.8 | 17.6 | 19.0 | 20.0 |
| 20.0–29.9 | 1,058 | −1.2 | 14.5 | 0.1 | 11.4 | 11.8 | 12.3 | 12.6 | 13.2 | 14.5 | 16.2 | 17.2 | 18.0 | 19.4 | 20.4 |
| 30.0–39.9 | 111 | −1.2 | 14.9 | 0.1 | 11.8 | 12.1 | 12.6 | 13.0 | 13.6 | 14.9 | 16.6 | 17.7 | 18.5 | 19.9 | 20.9 |
| 40.0–49.9 | 64 | −1.2 | 15.4 | 0.1 | 12.1 | 12.5 | 13.0 | 13.4 | 14.0 | 15.4 | 17.1 | 18.1 | 19.0 | 20.4 | 21.4 |
| 50.0–59.9 | 117 | −1.2 | 15.8 | 0.1 | 12.5 | 12.8 | 13.4 | 13.7 | 14.4 | 15.8 | 17.5 | 18.6 | 19.4 | 20.9 | 21.9 |
| 60.0–69.9 | 272 | −1.2 | 16.1 | 0.1 | 12.8 | 13.1 | 13.7 | 14.1 | 14.7 | 16.2 | 17.9 | 19.0 | 19.9 | 21.3 | 22.3 |
| 70.0–79.9 | 203 | −1.2 | 16.5 | 0.1 | 13.1 | 13.5 | 14.0 | 14.4 | 15.1 | 16.5 | 18.3 | 19.4 | 20.3 | 21.7 | 22.8 |
| >80 years | 48 | −1.2 | 16.9 | 0.1 | 13.4 | 13.8 | 14.3 | 14.8 | 15.4 | 16.9 | 18.7 | 19.8 | 20.7 | 22.1 | 23.2 |

*LMS, least-mean-square algorithm; L, Box-Cox coefficient; M, median; S, coefficient of variation.*

**TABLE 6** | Percentiles for evaluating TMI from 5 to 80 years old based on age range for females.

| Age | n | L | M | S | P3 | P5 | P10 | P15 | P25 | P50 | P75 | P85 | P90 | P95 | P97 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5.0–5.9 | 137 | 0.15 | 14.73 | 0.16 | 10.8 | 11.3 | 12.0 | 12.5 | 13.2 | 14.7 | 16.4 | 17.4 | 18.0 | 19.1 | 19.8 |
| 6.0–6.9 | 220 | 0.02 | 14.49 | 0.16 | 10.7 | 11.1 | 11.8 | 12.3 | 13.0 | 14.5 | 16.2 | 17.1 | 17.8 | 18.9 | 19.6 |
| 7.0–7.9 | 302 | −0.12 | 14.26 | 0.16 | 10.6 | 11.0 | 11.6 | 12.1 | 12.8 | 14.3 | 15.9 | 16.9 | 17.6 | 18.7 | 19.4 |
| 8.0–8.9 | 267 | −0.26 | 14.08 | 0.16 | 10.5 | 10.9 | 11.5 | 11.9 | 12.6 | 14.1 | 15.7 | 16.7 | 17.4 | 18.6 | 19.4 |
| 9.0–9.9 | 182 | −0.40 | 13.94 | 0.16 | 10.4 | 10.8 | 11.4 | 11.8 | 12.5 | 13.9 | 15.6 | 16.6 | 17.3 | 18.5 | 19.3 |
| 10.0–10.9 | 340 | −0.53 | 13.87 | 0.16 | 10.4 | 10.8 | 11.4 | 11.8 | 12.5 | 13.9 | 15.5 | 16.6 | 17.3 | 18.5 | 19.4 |
| 11.0–11.9 | 369 | −0.66 | 13.86 | 0.16 | 10.5 | 10.8 | 11.4 | 11.8 | 12.5 | 13.9 | 15.6 | 16.6 | 17.4 | 18.7 | 19.6 |
| 12.0–12.9 | 397 | −0.78 | 13.93 | 0.16 | 10.6 | 10.9 | 11.5 | 11.9 | 12.5 | 13.9 | 15.7 | 16.7 | 17.5 | 18.9 | 19.9 |
| 13.0–13.9 | 316 | −0.89 | 14.06 | 0.17 | 10.7 | 11.0 | 11.6 | 12.0 | 12.6 | 14.1 | 15.8 | 16.9 | 17.8 | 19.2 | 20.2 |
| 14.0–14.9 | 323 | −0.97 | 14.21 | 0.17 | 10.8 | 11.2 | 11.7 | 12.1 | 12.8 | 14.2 | 16.0 | 17.2 | 18.0 | 19.5 | 20.6 |
| 15.0–15.9 | 276 | −1.04 | 14.36 | 0.17 | 11.0 | 11.3 | 11.8 | 12.3 | 12.9 | 14.4 | 16.2 | 17.4 | 18.3 | 19.8 | 21.0 |
| 16.0–16.9 | 319 | −1.07 | 14.49 | 0.17 | 11.1 | 11.4 | 12.0 | 12.4 | 13.0 | 14.5 | 16.3 | 17.6 | 18.5 | 20.1 | 21.3 |
| 17.0–17.9 | 405 | −1.08 | 14.61 | 0.17 | 11.1 | 11.5 | 12.1 | 12.5 | 13.1 | 14.6 | 16.5 | 17.7 | 18.7 | 20.3 | 21.5 |
| 18.0–18.9 | 215 | −1.06 | 14.76 | 0.17 | 11.2 | 11.6 | 12.2 | 12.6 | 13.3 | 14.8 | 16.7 | 17.9 | 18.8 | 20.5 | 21.7 |
| 19.0–19.9 | 485 | −1.01 | 15.00 | 0.17 | 11.4 | 11.7 | 12.3 | 12.8 | 13.5 | 15.0 | 16.9 | 18.2 | 19.1 | 20.8 | 22.0 |
| 20.0–29.9 | 949 | −0.94 | 15.41 | 0.17 | 11.7 | 12.0 | 12.7 | 13.1 | 13.8 | 15.4 | 17.4 | 18.7 | 19.6 | 21.3 | 22.5 |
| 30.0–39.9 | 178 | −0.84 | 16.00 | 0.17 | 12.1 | 12.5 | 13.1 | 13.6 | 14.3 | 16.0 | 18.1 | 19.4 | 20.4 | 22.0 | 23.2 |
| 40.0–49.9 | 190 | −0.73 | 16.68 | 0.17 | 12.5 | 12.9 | 13.6 | 14.1 | 14.9 | 16.7 | 18.8 | 20.2 | 21.2 | 22.8 | 24.0 |
| 50.0–59.9 | 292 | −0.60 | 17.38 | 0.17 | 13.0 | 13.4 | 14.1 | 14.7 | 15.5 | 17.4 | 19.6 | 21.0 | 22.0 | 23.7 | 24.8 |
| 60.0–69.9 | 701 | −0.46 | 18.06 | 0.17 | 13.4 | 13.9 | 14.6 | 15.2 | 16.1 | 18.1 | 20.3 | 21.7 | 22.8 | 24.4 | 25.6 |
| 70.0–79.9 | 433 | −0.31 | 18.71 | 0.17 | 13.7 | 14.3 | 15.1 | 15.7 | 16.7 | 18.7 | 21.1 | 22.5 | 23.5 | 25.2 | 26.3 |
| >80 years | 70 | −0.17 | 19.35 | 0.17 | 14.1 | 14.7 | 15.6 | 16.2 | 17.2 | 19.4 | 21.8 | 23.2 | 24.3 | 25.9 | 27.0 |

*LMS, least-mean-square algorithm; L, Box-Cox coefficient; M, median; S, coefficient of variation.*

children from this study showed increased weight and BMI than the references. Nevertheless, during adolescence, the NCHS references (8) showed higher values until around ages 70–79, respectively. In addition, we highlight that children and adolescents of both sexes in Maule (5–19 years of age) presented higher BMI values in relation to those of the WHO in all age ranges (from 5 to 19 years of age).

During early ages, height was relatively similar to the NCHS references (8). However, during adolescence, differences began to appear where the population of the Maule was shorter until approximately age 80.

Therefore, these findings are relevant for the regional population of the Maule because they confirm the anthropometric differences between populations, especially during the growth stages. Previous research in Chile (13, 14) and other neighboring countries have also highlighted such discrepancies (24, 25). However, during adulthood, between the ages of 20 to 59 years old, some studies carried out in China (26) and Colombia (27) showed values relatively lower in weight, height, and BMI than those of the Maule population. Nevertheless, other studies conducted in Canada (28) and the United States (29) have reported BMI values relatively similar to those described in this present research.

During old age, from 60 until age 80 years old, the BMI values of the Maule regional population were relatively similar to those reported in Brazil, Portugal, and Mexico (30–32) and even with the Chilean reference proposed for older adults (33).

One aspect that caught the researchers' attention was that the BMI of the Maule population did not decrease at age 80 as it did in other studies (8, 31, 32). This could be due, perhaps, to the loss of height with age. This translates into a significant increase in BMI (34). This pattern of decrease was observed in both sexes commencing at age 40 onwards.

These variations in the anthropometric profile between world populations from childhood to old age reflect genetic and environmental differences throughout life. For example, environmental factors tend to affect genetic potential and health differences in populations (9), including socio-demographic, dietary, and lifestyle factors (35). These could be involved in the differences observed. Although it is not ruled out that, during the last decades, Chile has faced an extremely rapid nutritional transition (36), which is congruent with the rapid economic growth observed between 1980 and 2014 (37), it is currently characterized as a post-transitional country, where the nutritional status of the population varies significantly according to sex, socioeconomic level and ethnicity (38).

In this context, an urgent need exists to gather additional measurements to provide a more holistic understanding of the anthropometric status of a population (39). Since the prevalence of underweight and overweight vary widely from one population to another (40), it is important to collect more data, especially if references proposed for other socio-cultural groups are used. These characteristics described deserve to be compared with reference studies as was done in this study, so this information could provide greater opportunities for comparison with other populations at the national and international level.

In this sense, based on the differences observed in this study and others, percentiles were developed to evaluate nutritional status from childhood to old age for the Maule Region (Chile). These were based on BMI and TMI by age and sex.

These results could help with the interpretation of the anthropometric differences and patterns in the phenotypical changes during growth and aging. This, during the growth and development stages, this information could facilitate evaluation of the nutritional state and serve to help monitor physical growth trajectories of children and adolescents (14).

During adulthood, these findings could help determine possible altered nutritional conditions that could be used as indicators for metabolic risk factors, especially when they are associated with overweight and obesity (41). In addition, nutrition and health, in general, in this stage are important for this group since adults are responsible for helping economically the rest of society (40).

In general, some common medical afflictions exist in old age related to aging and nutritional disorders that can be risk factors for older adults (42). For example, important changes occur in body composition expressed as the increase in fat mass, distribution of body fat, and the loss of muscle mass (43). These changes have adverse effects on functional ability, quality of life, and survival (44).

As a result, the researchers for this study used the LMS method to develop percentiles for BMI and TMI. This information may serve to complement the national (14, 33) and international (2, 7, 10, 45) references. A number of these were divided and directed to determined specific groups.

In essence, the references are data that are based on cross-sectional evaluations of a well-defined population (9). On the one hand, their interpretation needs to be oriented toward universal characteristics and human growth variables in order to research the links between growth, health, and nutritional state. On the other hand, it is necessary to evaluate thoroughly whether the international references are appropriate for all individuals, or whether sometimes specific references may be beneficial for a population (46).

Consequently, the applicability and tracking of the BMI trajectory during childhood, adolescence, and adulthood has demonstrated to be a satisfactory index for estimating body adiposity status once the changes body weight (47, 48), metabolic risks, and obesity (49) have been taken into account. In addition, it has been used traditionally as an indicator of obesity and for predicting health problems (50).

On the one hand, the use and applicability of TMI during the growth stage may be considered as a more appropriate tool to evaluate and classify nutritional status (underweight and obesity) for children and adolescents (51). A number of recent studies have reported that the TMI is more accurate than BMI for predicting body adiposity levels (17, 52) and for classifying overweight and obesity (53). It may also be used as a marker for metabolic syndromes (54) in diverse populations.

The cut-off points for this study were based on criteria adopted by the CDC (9) and the NCHS (8, 12). These need to be interpreted as references since they describe growth and nutritional status of an individual, and they provide a common foundation for comparing populations without making inferences about their significance (55). In addition, they may serve to formulate health policies, plan interventions, and supervise their efficiency, respectively (56).

We suggest the use of the Z-score for children and adolescents from 5 to 18 years old. This can be calculated using the formula:

$$Z = \frac{\left(\frac{BMI}{M}\right)^{L} - 1}{L\ x\ S}$$

Where the values of L, M, and S refer to age and sex of each child and adolescent in keeping with the references in the literature. On the other hand, from 19 years of age onwards, the cut-off points described above (<10th percentile low, 10th to 85th percentile normal, 85th to 95th percentile overweight and >95th percentile obese) can be used.

The present study has several strengths. The researchers in this study used 15,436 subjects (8,070 men and 7,366 women), spanning most life stages from infancy to senescence. This is the first research study of its kind carried out in Chile and Latin America. Moreover, the anthropometric variables were evaluated by only one experienced and well trained research team. The results may be used as a baseline for future comparisons for verifying secular tendencies. They may also help serve to create a national anthropometric standard.

This study had some limitations that need to be acknowledged. For example, the children (minors) <5.0 years old could not be included in the study due to lack of access to them. This limited us in evaluating the classic standard anthropometric variables of weight and height and their corresponding relationships (weight by height squared and weight by height cubed). The sample selection was non-probabilistical, so this procedure could limit the generalization of the results to other socio-cultural contexts in the country. Furthermore, it was not possible to collect socio-economic information, dietary habits, ethnicity and physical activity levels. Moreover, each age group considered in this study may be affected by different environmental, sociocultural, and political influences throughout their lives, especially during the military period from 1973 to 1990 and since the early 1980s with the rapid socioeconomic growth (37).

Other researchers should consider the present results with caution, as the mentioned components should be evaluated in the future, and even project the use of GWAS for more precise comparisons in terms of genetic variation.

In conclusion, by determining differences between the American NCHS references with the anthropometric variables of weight and height and in BMI, reference percentiles were developed for assessing the nutritional status for the regional population of the Maule (Chile). The results suggest using BMI and TMI by age and sex as a non-invasive tool for detecting individuals at risk of being underweight, overweight, and obese. Finally, these results may be used in clinical and epidemiological contexts to assess individuals, age 5–80 years old.

## DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Ethics Committee from Universidad Autonoma de Chile (238/2014). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

## AUTHOR CONTRIBUTIONS

MC-B, RG-C, AM, and EL conceived and designed the study. MC-B, RG-C, RV-E, LC, and LU-A performed the experiments. AM and EL contributed reagents/materials/analysis tools. RG-C, MC-B, and WC-B performed the statistical analysis. MC-B, RG-C, AM, EL, and RV-E drafted the manuscript. CA participated in the drafting, translation, and correction of the manuscript. All authors edited and revised the manuscript with critical feedback given.

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