THE EFFECTS OF THE COVID-19 OUTBREAK ON FOOD SUPPLY, DIETARY PATTERNS, NUTRITION AND HEALTH: VOLUME 1

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THE EFFECTS OF THE COVID-19 OUTBREAK ON FOOD SUPPLY, DIETARY PATTERNS, NUTRITION AND HEALTH: VOLUME 1

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EDITORIAL
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Editorial: The Effects of the COVID-19 Outbreak on Food Supply, Dietary Patterns, Nutrition, and Health: Volume 1

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Editorial on the Research Topic

The Effects of the COVID-19 Outbreak on Food Supply, Dietary Patterns, Nutrition, and Health: Volume 1

INTRODUCTION

The COVID-19 coronavirus outbreak has affected populations across the world. In a short time we were exposed to a critical situation and faced with a multitude of medical, social and economic challenges. While the medical community focused on developing successful diagnostic and medical treatments, many countries introduced far-reaching restrictions on daily life to prevent and control the spread of the virus. In many cases, this resulted in a complete lockdown of whole cities, regions, countries, and even countries. The resulting changes to working patterns (e.g., extended working hours, loss of jobs, working from home) and living circumstances have had a large impact on the supply, procurement, preparation, and consumption of food.

Typical measures that governments took to curb the spread of COVID-19 included limiting social and physical interactions, closing schools, hospitality and entertainment venues and other non-critical infrastructure, encouraging people to work from home, limiting the operation of food stores (including the ability for adequate inspection and enforcement activity to take place), and limiting people's ability to leave their home.

Many international borders were closed, which limited the supply of goods, including food. In some areas food supply chains were completely broken or drastically changed with food business operators needing to adopt new business models (e.g., suppliers reorienting themselves to new markets, an increased demand for home delivery). Supplying food also presents possible risks for infection—either environmentally (for example in food stores) or through contaminated foods/packaging. Changes in purchase patterns (e.g., bulk buying of perishable foods that may lead to consumption that is no longer safe or sub-optimal in terms of nutrient content, stockpiling) has led to certain foods being in very limited supply. Increased demand of certain products may result in difficulties in maintaining supply. Communication about food by governments, public health authorities, individual experts and influencers has also increased, using all available media channels and very diverse guidelines.

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The measures to prevent and control the spread of COVID-19 and their outcomes have had a profound effect on the food supply, dietary patterns, and nutrition of billions of people. This has given rise to a number of research questions, which are addressed in the Research Topic "Nutrition Eating Behavior Frontiers in Psychology Eating Behavior," hosted by the Eating Behavior section in Frontiers in Nutrition, and Frontiers in Psychology.

PANDEMIC AND THE DIETARY BEHAVIORS

The studies in this issue have all investigated the effect of the pandemic on various aspects of dietary behaviors, using a wide range of methodological approaches. Furthermore, the nature of the pandemic was such that it also affected research methodologies and approaches to data collection. Many countries included lockdowns and self-distancing recommendations, sometimes making on-line studies the only possible option. In some cases, on-line panels were used to assure better representativeness of the study sample, while snow-balling and combinations of different approaches were also used. This editorial presents an overview of these studies, with a particular focus on sampling approaches, and how they were adapted to the circumstances of the pandemic.

Studies Using Personal Invitations and Face-to-Face Interviews

While the pandemic limited the use of personal approaches to enroll participants, some studies also included face-to-face interviews. Pham et al. investigated determinants of healthy dietary intake and depression on a large sample ($N = 8{,}291$) of outpatients at 18 hospitals across Vietnam; the data was collected during the waiting time (before/after physical examination). While at the outset interviews were done face-to-face, as the pandemic progressed, self-administered questionnaires were used—either an online version accessible through a QR code, or a printed version. This cross-sectional study was conducted between February and May 2020; collected data included characteristics of patients, health literacy, dietary intake (HES; healthy eating score), and depression (PHQ; patient health questionnaire score; with depression defined as PHQ $\geq$ 10). Overweight and alcohol consumption were associated with lower healthy eating scores. Furthermore, patients under lockdown with the lowest healthy eating scores had 10-times higher depression odds, while the opposite effect was observed in those with healthier dietary patterns. Higher age, self-employment, lockdown and suspected COVID-19 symptoms were associated with both lower HES scores and likelihood for depression. In contrast, higher education, health literacy, social status and physical activity were identified as protective factors.

On-Line Studies With a Controlled Sampling Approach

Janssen et al. investigated changes in food consumption during the first COVID-19 lockdown in early 2020. The study was conducted via an on-line survey during the hard lockdown period in three countries—Denmark, Germany, and Slovenia ($N = 2{,}680$). Quota sampling was used to assure representative age, sex, and regional distribution. The study highlighted that, depending on the type of food, 15–42% of study participants changed their consumption frequency during the pandemic, compared to before. Food categories with the highest change were frozen food, canned food, and cake and biscuits in all three countries. Participants shopped less frequently during lockdown in all three countries, and reported an overall reduction in the consumption of fresh foods, and an increase in the consumption of food with a longer shelf life. The authors further investigated how lockdown measures, pandemic-induced income loss and socio-demographic factors affected changes in consumption patterns. They highlighted a number of differences between the observed countries, such as changes in the consumption of particular food categories from people who had stopped eating in work canteens during the pandemic, which are probably related to the different food cultures.

Similarly, Castellini et al. also used a representative sample of Italian citizens ($N = 1{,}004$), extracted by stratified sampling through an on-line survey, conducted in May 2020, but their objective was focused on the environmental sustainability of people's diets. Their study revealed that during first COVID-19 phase, about one third of the population reported more frequent consumption of certified sustainable food products, while about 20% indicated an intention to increase such consumption in near future. Researchers highlighted that the psychological impact of the pandemic introduced changes in consumers' attitudes, particularly an increased interest in environmental and health issues.

Bertmann et al. used a Qualtrics on-line panel in a representative state-wide survey in Vermont (US) residents ($N = 600$). They investigated perceptions of food banks and food pantries and their relationship to fruit and vegetable intake and food security in the first half year of the pandemic. Their study results showed more common use of food pantries among households with children and among food insecure households. Respondents from food insecure households not using food pantries repored lower consumption of fruits and vegetables during the pandemic compared to those that did, showing the importance of food banks and pantries for supporting diet quality in at-risk populations during emergency situations.

Clay and Rogus also used sampling with a Qualtrics on-line panel, but with a different sampling approach. Instead of using quotas for population-representative sampling, they used a cross-sectional proportional quota sampling ($N = 525$) to oversample Black, Hispanic, low-income and low-education participants, which were considered to have increased risk for food insecurity and for adverse consequences related to COVID-19. Researchers investigated the relationship between food access concerns, food assistance use, and purchasing behaviors and food insecurity in the state of New York (US) during the pandemic (July–December 2020). The study was conducted using an adapted validated food access survey, developed by the National Food Access and COVID-19 Research Team (NFACT). Higher food insecurity was associated with Hispanic ethnicity, higher food

worries, and with the use of food assistance and delivery. The authors concluded that monetary measures would be useful to alleviate barriers to accessing healthy food during pandemic in specific population groups.

Additionally, the pandemic has been shown to be a driver for the increased use of food supplements. For example, in Slovenia Žmitek et al. conducted a repeated cross-sectional study on a representative on-line panel sample ($N = 835$), which showed considerable increase in the use of vitamin D supplements after an educational intervention about the high prevalence of the deficiency during winter time. They further investigated knowledge-related factors of the supplementation. Key predictors for supplementation were knowledge about the health-related impact of vitamin D, dietary sources of vitamin D, and about the widespread prevalence of deficiency in the population. Recommendations for future awareness campaigns were proposed.

While the above-mentioned studies showed the usefulness of the on-line panels for public health research during the pandemic, some researchers used more specific channels in order to target particular populations. For example, Khayyam et al. used specific social platforms (WeChat and QQ) of Pakistani international students to access Pakistani students living in China ($N = 462$) in the wake of the COVID-19 pandemic. The study investigated background factors of food safety and health consciousness in the framework of the theory of planned behavior (TPB) and highlighted the importance of food safety and health consciousness as factors affecting dietary behaviors and intentions.

Somewhat similarly, Bhutani et al. used a specialized channel to recruit participants with a particular profile, but they combined it with a snowball sampling approach. In this cross-sectional study, majority (71%) of the participants ($N = 1,779$) were reached through a Amazon Mechanical Turk platform, enabling the access to younger and underemployed participants with below average incomes. The remainder of the sample were recruited through social media, word of mouth and email invitations. The authors noted that the use of these two methods allowed them to involve a more diverse population. The study was conducted in April/May 2020, and aimed to determine the relationships of health and psychological markers with energy balance-related behaviors during the lockdown. The study highlighted that better food consumption self-control and positive mood were linked with lowering both energy intake and energy expenditure risks. On the other hand, boredom and cravings for sweet and savory foods were linked with higher risk for unhealthy eating and sedentary behavior.

Studies Using Convenience Sampling, Including Snowball Sampling Approaches

Convenience sampling methods are those that draw on easy to access samples of participants based on location or internet/social media services. These can include snowball sampling where participants are asked to recruit further participants a method that has been used in numerous studies.

De Backer et al. used convenience sampling through social media banners and press releases; their study was conducted in 38 countries, and included 37,207 valid responses. The study was conducted between April and June 2020, and aimed to investigate changes in planning and preparing foods with consideration of personal factors and COVID-19-related social distancing policies. The researchers highlighted that increases in planning/preparing healthy foods were associated with perceived time availability and policies, which caused people to stay at home during pandemic. Financial stress was identified as an important barrier for healthier food choices, highlighting that health inequalities need to be considered very carefully in crisis circumstances.

Within the "International Civil Science Project" Jordan et al. also used international convenience sampling through social media, personal contacts and e-mailing. They investigated changes in the consumption of vegetables during the early pandemic period—April-August 2020, using a semi-structured on-line questionnaire, with about 20% completion rate. Their studied constraints affecting food intake around the world, with particular attention on the consumption of vegetables. The key parameters related to changes in dietary intake were mental stress, home-working, and time spent at home. About a quarter of participants reported changes in the quantity of vegetables and food consumed. The degree of the decrease in the diversity of vegetable intake was commonly linked with sex, occupational and educational status, and household environment. The authors concluded that food systems are subject to prompt pandemic-related transitions, highlighting a need for a strategy that would strengthen the resilience of vulnerable households and support a diverse diet during emergency situations.

Exclusive snowball sampling has been also used in several national studies. Giacalone et al. investigated changes in dietary habits during the COVID-19 lockdown in Denmark, but with a snowball sampling approach. They used an on-line survey, which was distributed to using instant messaging apps e.g., WhatsApp, social media platforms such as Facebook and Twitter, social networking sites such as LinkedIn and ResearchGate and email. The Danish COVIDiet Study had 2,462 respondents (non-representative sample), which reported changes in food intake, focusing on specific food categories that are important in the Mediterranean diet. The study showed a limited effect of the lockdown on dietary habits in the adult population. Very important findings were that many participants reported eating more, snacking more, exercising less, and gaining weight during lockdown, with women generally be more affected than men. The authors highlighted that observed changes are particularly concerning, if sustained for long-term.

Pertuz-Cruz et al. adapted the COVIDiet questionnaire to the dietary behaviors of Colombians, and included 2,745 adults from Colombia using a variety of different channels (social media, conferences, mailings, and press communications) during the first COVID-19 confinement period. The study highlighted several changes in dietary habits, including increased snacking frequency and cooking at home. Overall, a trend toward unhealthier dietary patterns was observed, with notable regional differences.

In Brazil, Liboredo et al. also used snowball convenience sampling to recruit participants during the COVID-19 lockdown. This on-line cross-sectional survey ($N = 1,368$) was conducted between August and September 2020, when Brazil was among the most COVID-19 affected countries in the world. A survey link was distributed through social media, a university website and e-mail invitations. The objective of the study was to investigate the relationship between pandemic related eating behaviors with perceived stress and independently associated factors. Various socioeconomic variables, dietary habits and lifestyle factors were associated with eating behaviors during the quarantine. For example, uncontrolled eating was linked with increased food delivery, while emotional eating was linked with increased food intake and graduation in a non-health-related course.

Studies Using Sales Data

Sales data were shown to provide very interesting insights into changes in dietary behaviors. For example, Revoredo-Giha and Russo investigated the sale of meats and fish during the first lockdown period in Great Britain. Time sequenced purchases (expenditure and quantities) from a scanner panel dataset, which included about 30,000 households were used to reveal relatively constant proportions of quantities of food. However, the calories provided from saturated fats and the level of sodium in the purchased quantities showed a notable increasing trend, highlighting the reduced nutritional quality of meat/fish purchases in most income groups.

PANDEMIC AND FOOD MARKETING

The COVID-19 pandemic also affected food supply and marketing, with concerns that food companies could mislead vulnerable populations during a time of increased stress and hardship with increased marketing of unhealthy products. Considering that social media is poorly regulated/controlled and therefore commonly used for the promotion of unhealthy beverages and foods, Gerritsen et al. investigated the social media marketing of foods during the pandemic in New Zealand. Their goal was to assess COVID-washing (specific cause marketing, where companies align themselves with COVID-19 pandemic to enhance their own image) in social media accounts owned by major food and drink brands in the beginning of the pandemic and during lockdown periods (February to May 2020). Public posts from the 20 largest brands were selected for a content analysis, revealing that the majority of brands referenced COVID-19 in posts during the 4-month period, with the peak observed during lockdown. Approximately a quarter (27%) of posts from these brands, particularly fast-food brands, referenced COVID-19. Overall, the study showed that COVID-washing was used to increase brand loyalty and encourage consumption, highlighting that advertising standards should be updated to protect public health.

CONCERNS DUE TO PANDEMIC-RELATED LOWERING PRIORITIES FOR THE REDUCTION OF DIET-RELATED NON-COMMUNICABLE DISEASES

In the last 2 years, the COVID-19 pandemic has been taken in center stage—becoming the most important health issue, and pushing aside many other public health matters. As explained by Bösch et al. policymakers have largely ignored non-communicable diseases, a major contributor to mortality, causing 71% of deaths worldwide. It should also be noted that those with NCDs, particularly cardiovascular disease, have been identified as being at high risk for unfavorable COVID-19 outcomes, highlighting that deprioritising NCDs in favor of COVID is not prudent and can have long-lasting negative effects. This deemphasis has resulted in initiatives designed to combat NCDs, such as food reformulation and the elimination of industrially-produced trans fatty acids, being put aside when they should not be.

INCREASED DELIVERY OF FOOD TO PEOPLE'S HOMES

Several of the above-mentioned studies indicate that food systems are changing quickly and reported an increased use of food delivery services. This trend is logically reflected in increased offers, not only from specialized delivery service providers, but also restaurants adapting their business models to include delivery or pick-up options, when forced to close their dining rooms to be able to continue operating. This challenging situation forced even high-end restaurants to offer home-delivery meals and take-away foods, simply to survive. Spence et al. reviewed approaches to the delivery of high-end dining experience in home environments and the challenges of the explosive pandemic-related growth of this sector. This review highlighted several promising routes for catering providers to optimize multisensory dining experience in people's home.

CONCLUSIONS

The studies in this special issue demonstrate the negative effect of the COVID-19 pandemic on diet and physical and mental health. On average, people's eating behavior was less healthy during the COVID-19 pandemic, particularly during lockdowns, which was in turn associated with weight gain. These studies also shed light on potential mechanisms for this change, such as depression (Pham et al.), reduced frequency of shopping which is associated with a reduction in the consumption of fresh food (Janssen et al.), and the increased marketing of fast food (Gerritsen et al.). Some studies highlighted specific populations that are particularly vulnerable to a decrease in diet quality, including those of a lower socioeconomic status (e.g., Bertmann et al.; Clay and Rogus; De Backer et al.) and those who have NCDs (Bösch et al.). The pandemic further increases the vulnerability of these populations by weakening economic security and food accessibility, and health, respectively. Ironically, the lockdown

restrictions that are intended to protect people's health are also those that make it more difficult for them to eat healthily, which in turn can worsen COVID-19 outcomes. This suggests that measures that improve the healthiness of people's diets, such as food banks, financial aid and easier access to fresh food are needed to protect people's health and counter the effects of the pandemic.

AUTHOR CONTRIBUTIONS

IP: conceptualization and first draft. BC and MMR: manuscript revision. All authors have read and approved the final version of the manuscript.

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Conflict of Interest: IP has led and participated in various other research projects in the areas of nutrition, public health, and food technology, which were (co)funded by the Slovenian Research Agency, Ministry of Health of the Republic of Slovenia, the Ministry of Agriculture, Forestry and Food of the Republic of Slovenia, and in cases of specific applied research projects, also by food businesses. BC was employed by European Food Information Council. MMR's research centre has provided consultancy to and received travel funds to present research results from organisations supported by food and drinks companies.

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ORIGINAL RESEARCH
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Healthy Dietary Intake Behavior Potentially Modifies the Negative Effect of COVID-19 Lockdown on Depression: A Hospital and Health Center Survey

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Background: The COVID-19 pandemic causes a huge burden for affected countries. Several public health interventions were applied to contain the infection. However, the pandemic itself and the lockdown measure negatively influence people's lifestyles and psychological health.

Purpose: To explore determinants of healthy dietary intake and depression, and examine the interaction between healthy dietary intake and COVID-19 lockdown on depression.

Methods: A cross-sectional study was conducted at 18 hospitals and health centers from February 14 to May 31, 2020. Data of 8,291 outpatients were collected including patients' characteristics, clinical parameters, health literacy, healthy dietary intake (using the healthy eating score, HES), other health-related behaviors, and depression (using the patient health questionnaire, PHQ). Depression was defined as PHQ score $\geq$ 10.

Results: Protective factors of healthy dietary intake and depression were higher education, better medication payment ability, higher social status, more physical activity, and higher health literacy, whereas older age, ever married, own business or other types of occupation, lockdown, suspected COVID-19 symptoms, and comorbidity were associated with lower HES scores and a higher depression likelihood. Besides, overweight/obesity and alcohol drinking were associated with lower HES scores. As compared with patients not under lockdown and with lowest HES score, those who were under lockdown and with lowest HES score had 10.6 times higher depression likelihood (odds ratio, OR, 10.60; 95% CI 6.88, 16.32; $p < 0.001$), whereas people with higher HES score had 15% lower depression likelihood (OR 0.85; 95% CI 0.82, 0.89; $p < 0.001$).

Conclusions: Healthy dietary intake and depression were determined by several sociodemographic, clinical, and behavioral factors. Lockdown measure affects people's dietary intake behavior and depression. Importantly, healthy dietary intake potentially modifies the negative effect of lockdown on depression.

Keywords: COVID-19, coronavirus, lockdown, healthy eating, psychological, physical activity, comorbidity, obesity

INTRODUCTION

The COVID-19 pandemic is caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which sets the whole world in unprecedented challenges (1–6). It creates a huge burden, in terms of socioeconomic effects (7), morbidity, and mortality (8, 9). Infections and deaths are dramatically increasing in all the affected countries (10). Multidisciplinary and multidimensional approaches are required to contain the pandemic (11–13). In the situation of unavailable effective treatments and vaccination, social and behavioral changes are highly recommended to control the massive global health crisis (14, 15).

Among COVID-19 management strategies, healthy diet and nutrition show potential impacts on immune system and health outcomes (16–18). A diversified and balanced diet can improve the immune response to viral infection (19). Healthy foods have been found as a potential therapy to enhance immunity, to improve the acute respiratory symptoms and health outcomes which may help to protect people during the COVID-19 pandemic (20). Some food groups (e.g., fruits and vegetables, fish and fish oils) and key nutrients (e.g., fiber, vitamins A, B, C, D, and E, selenium, iron, copper, zinc) have shown the benefit for protecting against viral infection (17, 21, 22). Adequate intake of relevant nutrients can help to reduce inflammation and oxidative stress, which further strengthens the immune system of individuals during the COVID-19 pandemic (22, 23).

The COVID-19–induced lockdown or home confinement measure was applied in many countries including Vietnam (24). This measure is a necessary public health approach to protect people from virus infection. However, it has undesirable consequences (25), e.g., negative impacts on psychological consequences (26, 27), eating behavior, and changes in dietary habits (28–31). Fortunately, healthy diet has potential benefits to reduce the risk of severity (32) and complications of COVID-19 (33). People with a better diet quality intake had a lower risk of depression (34, 35). Moreover, assessment of dietary intake behavior is critically important for identifying the comprehensive approach to manage COVID-19 (36) and indicating the sustainable food intake during the lockdown (37). The healthy eating score (HES-5) is a short, simple, and valid tool to quickly assess the overall diet quality which is comparable with the 2015 health eating index (38). The HES-5 has an advantage of timely and easy assessment of healthy dietary intake behavior in the time of COVID-19 pandemic.

Therefore, we investigated the associated factors of healthy dietary intake behavior and depression, as well as examined the interaction of COVID-19 lockdown and healthy dietary intake on depression among people who visited outpatient departments from 18 hospitals and health centers across Vietnam.

METHODS

Study Design and Settings

A cross-sectional study was conducted from February 14 to May 31, 2020. Study duration in each hospital/health center was 7–10 days. The study participants were consecutively recruited at outpatient departments (OPDs) from 15 hospitals and three health centers across Vietnam. The study sites were conveniently selected, including 10 hospitals and one health center in the North, one hospital and one health center in the Center, and four hospitals and one health center in the South.

Study Sample

Participants were those who visited the OPDs of selected hospitals and health centers. The recruited participants were those aged 18 to 85 years, understood Vietnamese, and without emergency conditions. After excluding 60 individuals with age <18 years (26 cases), more than 85 years (19 cases), and incomplete survey (15 cases), a total sample of 8,291 outpatients were analyzed. Participants in studied hospitals and health centers are presented in **Table 1**.

Assessments and Measurements

Participants' Characteristics

Participants self-reported their information, including age (years), gender (women vs. men), marital status (never married vs. ever married), educational attainment (illiterate/elementary, junior high school, senior high school, college/university or higher), occupation (employed, own business, and others), ability to pay for medication (very difficult to very easy), and social status (patients placed themselves into the society regarding education, career, and salary, at three levels from low, middle to high). Vietnam had applied the nationwide lockdown measure from April 1 to 22, 2020 (24, 39). Therefore, the lockdown was defined for patients who took the survey during that period.

Clinical Parameters

Patients were asked to report their body height (cm) and weight (kg). Body mass index (BMI, kg/m^2) was calculated. The suspected COVID-19 symptoms (S-COVID-19-S) were assessed (40), including common symptoms (fever, cough, dyspnea) and less common symptoms (myalgia, fatigue, sputum production, confusion, headache, sore throat, rhinorrhea, chest pain, hemoptysis, diarrhea, and nausea/vomiting). Patients were classified as having S-COVID-19-S if they had any of those symptoms. Items of the Charlson Comorbidity Index were used to screen for comorbidity (41).

Health-Related Behaviors

Patients reported their current behaviors as compared with before the pandemic, including smoking status (never/stop/less vs. unchanged or more), drinking status (never/stop/less vs. unchanged or more), and physical activities (never/stop/less vs. unchanged or more).

Health Literacy

The short-form health literacy questionnaire with 12 items (HLS-SF12) was used to assess health literacy (HL). The tool was

TABLE 1 | Participants in studied hospitals and health centers.

Geographic location	Hospital/health center	Studied participants
North		
Ha Noi city	Military Hospital 103	1,028
	E hospital	183
	General Hospital of Agricultural	300
Thai Nguyen province	Thai Nguyen National Hospital	469
Bac Ninh city	Bac Ninh Obstetrics and Pediatrics Hospital	500
Hai Phong city	Hai Phong University of Medicine and Pharmacy Hospital	982
	Kien An Hospital	492
	Kien Thuy District Health Center	484
Quang Ninh province	Quang Ninh General Hospital	309
	Bai Chay Hospital	364
	Quang Ninh Obstetrics and Pediatrics Hospital	280
Center		
Quang Tri province	Trieu Phong District Health Center	495
Da Nang city	Da Nang Oncology Hospital	421
South		
Ho Chi Minh city	Thu Duc District Hospital	489
	Thu Duc District Health Center	497
	Hospital District 2	248
	Tan Phu District Hospital	242
Can Tho city	Can Tho University Of Medicine and Pharmacy Hospital	508
Total		8,291

validated and used in Asian countries (42) including Vietnam (43–46). Patients were asked to rate their perceived difficulty of each item based on 4-point Likert scales from 1 = "very difficult" to 4 = "very easy." The overall score was standardized to an index ranged from 0 to 50, with higher score presenting better HL, using the formula (1):

$$Index = (Mean - 1) \times (\frac{50}{3}) \quad (1)$$

where *Index* is the specific index score calculated, *Mean* is the mean of 12 items for each individual, 1 is the minimal possible value of the mean (leading to a minimum index value of 0), 3 is the range of the mean, and 50 is the chosen maximum value of HL index.

Health Dietary Intake Behavior

The 5-item healthy eating score (HES-5) was used to assess healthy dietary intake behavior. HES-5 was validated and used in previous studies (38, 47). The utilization of HES-5 was comparable with the 2015 health eating index and quickly assesses the overall diet quality (38). The tool is expected to be useful for assessing the healthy dietary intake behavior during the sensitive period of the pandemic. The questionnaire was translated into Vietnamese by researchers. The content was then validated by an expert panel (28 medical doctors, 7 nurses, 9 nutrition and public health professionals). The expert panel suggested using the rating and the scoring of the original scale. The unidimensional construct was expressed with all five items loaded on one component (factor loadings ranged from 0.63 to 0.75), which explained 49.43% of the variance. The tool was showed with adequate convergent validity (item–scale correlation ranged from 0.57 to 0.73), satisfactory reliability (Cronbach's alpha of 0.74), and without floor or ceiling effects (**Supplementary Table 1**). Participants were asked about how often did they eat/drink fruits, vegetables, whole grains, dairy, and fish over the last 30 days. The rating scale was from 0 = "Rarely or never," 1 = "1–2 times per week," 2 = "3–6 times per week," 3 = "once per day," 4 = "twice per day," to 5 = "3 or more times per day." The total score of healthy dietary intake (HDI-score, or HES) ranged from 0 to 25, with the higher score indicating the better healthy eating behavior.

Depression

The patient health questionnaire with 9 items (PHQ-9) was used to assess depression. PHQ-9 is a screening tool that helps clinicians in making the diagnosis of depression, quantifying depression symptom, and monitoring the severity (48). This tool was used in Vietnam (45). Patients were asked about how often they have been bothered by nine symptoms during the last 2 weeks on the scale from 0 (not at all), 1 (several days), 2 (more than half the days), to 3 (nearly every day). The overall PHQ-9 score ranges from 0 to 27. Patients were classified as having depression if their PHQ score ≥10 (48).

Data Collection Procedure

Before the data collection, we provided research assistants (doctors, nurses, and medical students) a 4 h training session on data collection. Research assistants also received the infection control training from each health facility, e.g., using masks, washing hands, and physical distancing according to guidelines of the Centers for Disease Control and Prevention (49), World Health Organization (50), and Vietnam Ministry of Health (51).

Research assistants contacted and asked patients who visited the OPDs for voluntary participation. The OPD visitors were consecutively invited to the survey. The consent form was obtained from qualified patients before administering the survey. The survey took place during the waiting time, before and/or after physical examination. At the early stage of the pandemic, face-to-face interviews were conducted. At the peak stage of the pandemic, self-administered questionnaires were used via an online version (QR code provided at each OPD) or printed version. It took about 20–30 min to complete survey questionnaires. Finally, data were confidentially analyzed by researchers.

Ethical Consideration

The study was reviewed and approved by each participating hospital, and the Institutional Ethical Review Committee of Hanoi University of Public Health, Vietnam (IRB No. 029/2020/YTCC-HD3 for the first period from February 14 to March 31, 2020; and IRB No. 133/2020/YTCC-HD3 for the second period from April 1 to May 31, 2020).

Statistical Analysis

First, distributions of studied variables were explored using the χ^2 test and one-way ANOVA test appropriately. Second, associated factors of healthy dietary intake behavior (HES) and depression (PHQ) were examined using linear regression models and logistic regression models, respectively. To minimize residual effects of confounders on the associations, factors associated with HES or PHQ at $p < 0.20$ in the bivariate model were selected into the multivariate model (52). To avoid the multicollinearity in the multivariate models, the correlations of factors were tested using Spearman correlation. If the moderate or high correlations exist, a representative factor was selected to final models. Finally, the interaction analysis was conducted to examine the potential mental health benefits of healthy dietary intake behavior. Data were analyzed using the IBM SPSS version 20.0 (IBM, Armonk, NY, USA). The significance level was set at a $p < 0.05$.

RESULTS

Participants' Characteristics

Mean values of age, health literacy, and healthy eating score (HES) were 43.6 ± 16.9, 28.1 ± 9.4, and 11.9 ± 4.6, respectively. Proportions of people who participated during the lockdown measure and with depression (PHQ ≥ 10) were 28.7% (2,376/8,291) and 12.5% (1,033/8,291), respectively. The HES was varied by different categories of age, gender, marital status, education, occupation, ability to pay for medication, social status, lockdown, S-COVID-19-S, BMI, comorbidity, smoking, drinking, and physical activity ($p < 0.001$), whereas the prevalence of depression was varied by different categories of age, marital status, education, occupation, ability to pay for

TABLE 2 | Participants' characteristics, healthy dietary intake behavior, and depression.

Variables	Overall (*N* = 8,291)	HES (*N* = 8,291)		PHQ < 10 (*N* = 7,258)	PHQ ≥ 10 (*N* = 1,033)	
	N (%)	Mean ± SD	p^*	*N* (%)	*N* (%)	p^{**}
Age, years			<0.001			<0.001
18–39	3,955 (47.7)	12.6 ± 4.7		3,688 (50.8)	267 (25.8)	
40–59	2,473 (29.8)	11.5 ± 4.5		2,220 (30.6)	253 (24.5)	
60–85	1,863 (22.5)	11.3 ± 4.4		1,350 (18.6)	513 (49.7)	
Gender			<0.001			0.906
Women	4,890 (53)	12.1 ± 4.6		4,279 (59.0)	611 (59.1)	
Men	3,401 (41)	11.7 ± 4.6		2,979 (41.0)	422 (40.9)	
Marital status			<0.001			<0.001
Never married	1,635 (19.8)	12.4 ± 4.5		1,496 (20.7)	139 (13.5)	
Ever married	6,628 (80.2)	11.8 ± 4.6		5,734 (79.3)	894 (86.5)	
Education attainment			<0.001			<0.001
Elementary school or illiterate	593 (7.2)	11.3 ± 4.7		480 (6.6)	113 (10.9)	
Junior high school	1,630 (19.7)	11.1 ± 4.3		1,431 (19.8)	199 (19.3)	
Senior high school	2,277 (27.5)	11.8 ± 4.4		1,995 (27.5)	282 (27.3)	
College/university or higher	3,776 (45.6)	12.5 ± 4.8		3,337 (46.1)	439 (42.5)	
Occupation			<0.001			<0.001
Employed	2,390 (28.9)	12.2 ± 4.7		2,149 (29.7)	241 (23.3)	
Own business	3,044 (36.8)	11.7 ± 4.6		2,709 (37.4)	335 (32.4)	
Others	2,843 (34.3)	12.1 ± 4.5		2,386 (32.9)	457 (44.2)	
Ability to pay for medication			<0.001			<0.001
Very or fairly difficult	4,475 (54)	11.5 ± 4.7		3,710 (51.2)	765 (74.1)	
Very or fairly easy	3,805 (46)	12.4 ± 4.4		3,537 (48.8)	268 (25.9)	
Social status			<0.001			<0.001
Low	1,403 (16.9)	10.9 ± 4.7		1,187 (16.4)	216 (20.9)	
Middle or high	6,879 (83.1)	12.2 ± 4.5		6,062 (83.6)	817 (79.1)	
Lockdown measure			<0.001			<0.001
No	5,915 (71.3)	12.4 ± 4.5		5,428 (74.8)	487 (47.1)	
Yes	2,376 (28.7)	10.9 ± 4.6		1,830 (25.2)	546 (52.9)	
S-COVID-19-S[a]			<0.001			<0.001
No	5162 (62.3)	12.7 ± 4.7		4,827 (66.5)	335 (32.4)	
Yes	3129 (37.7)	11.0 ± 4.6		2,431 (33.5)	698 (67.6)	
BMI, kg/m^2			0.026			0.028
Underweight (BMI < 18.5)	783 (9.5)	12.3 ± 4.7		709 (9.8)	74 (7.2)	
Normal weight (18.5 ≤ BMI < 25.0)	6,518 (78.8)	11.9 ± 4.6		5,685 (78.4)	833 (81.0)	
Overweight/obese (BMI ≥ 25.0)	974 (11.8)	11.7 ± 4.6		853 (11.8)	121 (11.8)	
Comorbidity			<0.001			<0.001
None	6,415 (77.5)	12.5 ± 4.6		5,877 (81.1)	538 (52.1)	
One	1,458 (17.6)	10.4 ± 4.1		1,132 (15.6)	326 (31.6)	
Two or more	409 (4.9)	8.7 ± 3.2		241 (3.3)	168 (16.3)	
Smoking[b]			<0.001			0.867
Never, stopped, or smoke less	7,541 (91.0)	12.1 ± 4.6		6,600 (90.9)	941 (91.1)	
Unchanged or smoke more	750 (9.0)	10.6 ± 4.6		658 (9.1)	92 (8.9)	
Drinking alcohol[b]			<0.001			0.680
Never, stopped, or drink less	7,044 (85.1)	12.1 ± 4.6		6,178 (85.1)	866 (84.7)	
Unchanged or drink more	1,235 (14.9)	11.1 ± 4.6		1,078 (14.9)	157 (15.3)	
Physical activity[b]			<0.001			<0.001
Never, stopped, or exercise less	2,778 (33.6)	11.6 ± 4.9		2,190 (30.3)	588 (57.1)	
Unchanged or exercise more	5,480 (66.4)	12.1 ± 4.4		5,038 (69.7)	442 (42.9)	
HL index, 1-score increment	28.1 ± 9.4			28.7 ± 9.3	24.1 ± 9.6	<0.001*
HES, 1-score increment	11.9 ± 4.6			12.1 ± 4.6	10.9 ± 4.6	<0.001*

HES, healthy eating score; PHQ, patient health questionnaire; S-COVID-19-S, suspected corona virus disease-2019 symptoms; BMI, body mass index; HL, health literacy.

**Result of one-way ANOVA test.*

***Result of χ^2 test.*

[a]The suspected COVID-19 symptoms including common symptom (fever, cough, dyspnea), less common symptom (myalgia, fatigue, sputum production, confusion, headache, sore throat, rhinorrhea, chest pain, hemoptysis, diarrhea, and nausea/vomiting).

[b]People were asked whether their health-related behaviors are getting worse, better, or unchanged during COVID-19 pandemic as compared with those before the pandemic.

medication, social status, lockdown, comorbidity ($p < 0.001$), and BMI ($p = 0.028$; **Table 2**).

Associated Factors of Healthy Dietary Intake

In bivariate analysis, patients with lower HES were those with older age, being male, ever married, having own business, during the lockdown period, with S-COVID-19-S, underlying comorbidity, and smoking and drinking at unchanged or more level ($p < 0.001$). In contrast, patients with higher HES were those with higher educational attainment, better ability to pay for medication, higher social status, doing physical activity at unchanged or more level, and higher health literacy ($p < 0.05$; **Table 3**). Correlations among covariates were checked to eliminate the multicollinearity. Moderate correlations were found between age and marital status (rho = 0.38), education (rho = −0.42), comorbidity (rho = 0.31), and health literacy (rho = −0.32); between S-COVID-19-S and comorbidity (rho = 0.31); between lockdown measure and physical activity (rho = −0.38); and between smoking and drinking (rho = 0.45; **Supplementary Table 2**). Therefore, age, gender, occupation, ability to pay for medication, social status, lockdown, S-COVID-19-S, BMI, and drinking alcohol were selected to multivariate models. Results showed that as compared with counterparts, people with lower HES were those with older age (regression coefficient, B, −0.81, 95% CI −1.03, −0.58, $p < 0.001$ for age 40–59 years; and B, −0.70, 95% CI −0.95, −0.44, $p < 0.001$ for age 60–85 years), having own business (B,; 95% CI −0.53, −0.04; $p = 0.021$), during the lockdown period (B, −1.35; 95% CI −1.57, −1.13; $p < 0.001$), with S-COVID-19-S (B, −1.14; 95% CI −1.35, −0.94; $p < 0.001$), being overweight/obese (B, −0.34; 95% CI −0.64, −0.04; $p = 0.025$), and drinking alcohol at unchanged or more level (B, −1.29; 95% CI −1.57, −1.00; $p < 0.001$; **Table 3**). On the other hand, people with higher HES were those with better ability to pay for medication (B, 0.26; 95% CI 0.05, 0.47; $p = 0.016$) and higher social status (B, 0.92; 95% CI 0.65, 1.19; $p < 0.001$; **Table 3**).

Associated Factors of Depression

In bivariate analysis, odds of depression were significantly higher in older people, those ever married, other types of occupation, in lockdown period, with S-COVID-19-S, and underlying comorbidity as compared with their counterparts ($p < 0.001$). Odds of depression were significantly lower in people with higher education, better ability to pay for medication, higher social status, being underweight, doing physical activity at unchanged or more level, higher health literacy, and higher HES as compared with their counterparts ($p < 0.01$). To avoid multicollinearity, age, gender, occupation, ability to pay for medication, social status, lockdown measure, S-COVID-19-S, BMI, comorbidity, physical activity, and HES were included in multivariate models. The results showed that people with higher odds of depression were those with older age (odds ratio, OR, 1.33, 95% CI 1.10, 1.60, $p = 0.004$ for age 40–59 years; OR 3.03, 95% CI 2.52, 3.64, $p < 0.001$ for age 60–85 years) as compared with age 18–39 years, other type of occupation (OR 1.27; 95% CI 1.05, 1.54; $p = 0.013$) as compared with employed group, during lockdown (OR 1.85; 95% CI 1.56, 2.18; $p < 0.001$) as compared with not during the lockdown period, with S-COVID-19-S (OR 2.40; 95% CI 2.05, 2.81; $p < 0.001$) as compared with those without S-COVID-19-S, and those with comorbidity (OR 1.51, 95% CI 1.26, 1.80, $p < 0.001$; OR 2.19, 95% CI 1.68, 2.85, $p < 0.001$) as compared with those without chronic conditions. In contrast, people with lower odds of depression were those with better ability to pay for medication (OR 0.66; 95% CI 0.56, 0.78; $p < 0.001$) and doing physical activity at unchanged or more level (OR 0.62; 95% CI 0.53, 0.73; $p < 0.001$; **Table 4**).

Mental Health Benefits of Healthy Dietary Intake

The results of interaction analysis showed that as compared with people who were not under the lockdown period and lowest HES, those who were under the lockdown period and lowest HES score had 10.6 times higher likelihood of depression (OR 10.60; 95% CI 6.88, 16.32; $p < 0.001$), whereas during the lockdown period, people with one score increment of HES resulted in 15% lower depression likelihood (OR 0.85; 95% CI 0.82, 0.89; $p < 0.001$; **Table 5**).

DISCUSSION

In the current study, people who were under the lockdown period had lower healthy dietary intake scores. This was similar to previous studies which illustrated that lockdown or home confinement measure negatively influenced dietary eating behaviors and habits (28–31, 54, 55). In addition, overweight and obese people ate less healthy than normal-weight individuals, which was found in the current study and previous studies (30). Besides, people with older age, being ever married, with S-COVID-19-S, comorbidity, and smoking and drinking behaviors also had worse dietary intake behavior. Social and environmental factors were found as determinants of eating behavior in a previous study (56). Therefore, nutrition support programs are important for vulnerable people to improve their dietary intake behavior (57, 58), especially during the pandemic and home confinement (30, 31).

Our study shows that people who were under the lockdown period had a higher likelihood of depression. Previous studies found that the proportion of psychological problems (e.g., depression, anxiety, and stress) has risen during the lockdown in general populations (27, 59) and in psychiatric patients (26). People with S-COVID-19-S had higher depression likelihood that was found in the current study and the previous one (45). In addition, people with older age and comorbidity were vulnerable to depression in the present study. The psychological consequence of COVID-19 pandemic was well-reported (53, 60), especially in the elderly (61, 62). Besides, people with underlying health conditions had a worse clinical course that was also reported (63, 64). Strategic mental health interventions are highly recommended to manage the psychological consequence of COVID-19 pandemic (65–68).

TABLE 3 | Associated factors of healthy dietary intake behavior via linear regression analysis ($N = 8,291$).

Variables	HES			
	Bivariate		Multivariate	
	B (95% CI)	*p*	B (95% CI)	*p*
Age, years				
18–39	0.00		0.00	
40–59	−1.09 (−1.32, −0.86)	<0.001	−0.81 (−1.03, −0.58)	<0.001
60–85	−1.27 (−1.52, −1.02)	<0.001	−0.70 (−0.95, −0.44)	<0.001
Gender				
Women	0.00		0.00	
Men	−0.37 (−0.57, −0.17)	<0.001	−0.04 (−0.24, 0.17)	0.710
Marital status				
Never married	0.00			
Ever married	−0.56 (−0.81, −0.31)	<0.001		
Education attainment				
Elementary school or illiterate	0.00			
Junior high school	−0.16 (−0.59, 0.27)	0.460		
Senior high school	0.54 (0.13, 0.96)	0.010		
College/university or higher	1.16 (0.77, 1.56)	<0.001		
Occupation				
Employed	0.00		0.00	
Own business	−0.51 (−0.76, −0.27)	<0.001	−0.28 (−0.53, −0.04)	0.021
Others	−0.12 (−0.37, 0.13)	0.363	0.02 (−0.23, 0.27)	0.878
Ability to pay for medication				
Very or fairly difficult	0.00		0.00	
Very or fairly easy	0.94 (0.74, 1.14)	<0.001	0.26 (0.05, 0.47)	0.016
Social status				
Low	0.00		0.00	
Middle or high	1.31 (1.05, 1.57)	<0.001	0.92 (0.65, 1.19)	<0.001
Lockdown measure				
No	0.00		0.00	
Yes	−1.51 (−1.72, −1.29)	<0.001	−1.35 (−1.57, −1.13)	<0.001
S-COVID-19-S[a]				
No	0.00		0.00	
Yes	−1.46 (−1.67, −1.26)	<0.001	−1.14 (−1.35, −0.94)	<0.001
BMI, kg/m^2				
Underweight (BMI $<$ 18.5)	0.33 (−0.01, 0.67)	0.059	0.14 (−0.19, 0.47)	0.410
Normal weight (18.5 $\leq$ BMI $<$ 25.0)	0.00		0.00	
Overweight/obese (BMI $\geq$ 25.0)	−0.27 (−0.58, 0.04)	0.091	−0.34 (−0.64, −0.04)	0.025
Comorbidity				
None	0.00			
One	−2.15 (−2.40, −1.89)	<0.001		
Two or more	−3.86 (−4.30, −3.41)	<0.001		
Smoking[b]				
Never, stopped, or smoke less	0.00			
Unchanged or smoke more	−1.48 (−1.82, −1.13)	<0.001		
Drinking alcohol[b]				
Never, stopped, or drink less	0.00		0.00	
Unchanged or drink more	−0.99 (−1.27, −0.71)	<0.001	−1.29 (−1.57, −1.00)	<0.001
Physical activity[b]				
Never, stopped, or exercise less	0.00			
Unchanged or exercise more	0.54 (0.33, 0.75)	<0.001		
HL index, 1-score increment	0.10 (0.09, 0.11)	<0.001		

HES, healthy eating score; B, regression coefficient; PHQ, patient health questionnaire; S-COVID-19-S, suspected corona virus disease-2019 symptoms; BMI, body mass index; HL, health literacy.

[a] *The suspected COVID-19 symptoms including common symptom (fever, cough, dyspnea), less common symptom (myalgia, fatigue, sputum production, confusion, headache, sore throat, rhinorrhea, chest pain, hemoptysis, diarrhea, and nausea/vomiting).*

[b] *People were asked whether their health-related behaviors are getting worse, better, or unchanged during COVID-19 pandemic as compared with those before the pandemic.*

TABLE 4 | Associated factors of depression via logistic regression analysis ($N = 8,291$).

Variables	Depression (PHQ ≥ 10)			
	Bivariate		Multivariate	
	OR (95% CI)	*p*	OR (95% CI)	*p*
Age, years				
18–39	1.00		1.00	
40–59	1.57 (1.32, 1.88)	<0.001	1.33 (1.10, 1.60)	0.004
60–85	5.25 (4.47, 6.16)	<0.001	3.03 (2.52, 3.64)	<0.001
Gender				
Women	1.00		1.00	
Men	0.99 (0.87, 1.13)	0.906	0.93 (0.81, 1.08)	0.358
Marital status				
Never married	1.00			
Ever married	1.68 (1.39, 2.02)	<0.001		
Education attainment				
Elementary school or illiterate	1.00			
Junior high school	0.59 (0.46, 0.76)	<0.001		
Senior high school	0.60 (0.47, 0.76)	<0.001		
College/university or higher	0.56 (0.44, 0.70)	<0.001		
Occupation				
Employed	1.00		1.00	
Own business	1.10 (0.93, 1.31)	0.273	0.97 (0.80, 1.17)	0.766
Others	1.71 (1.45, 2.02)	<0.001	1.27 (1.05, 1.54)	0.013
Ability to pay for medication				
Very or fairly difficult	1.00		1.00	
Very or fairly easy	0.37 (0.32, 0.43)	<0.001	0.66 (0.56, 0.78)	<0.001
Social status				
Low	1.00		1.00	
Middle or high	0.74 (0.63, 0.87)	<0.001	1.16 (0.96, 1.40)	0.115
Lockdown measure				
No	1.00		1.00	
Yes	3.33 (2.91, 3.80)	<0.001	1.85 (1.56, 2.18)	<0.001
S-COVID-19-S[a]				
No	1.00		1.00	
Yes	4.14 (3.60, 4.75)	<0.001	2.40 (2.05, 2.81)	<0.001
BMI, kg/m^2				
Underweight (BMI < 18.5)	0.71 (0.55, 0.91)	0.008	0.78 (0.59, 1.02)	0.066
Normal weight (18.5 ≤ BMI < 25.0)	1.00		1.00	
Overweight/obese (BMI ≥ 25.0)	0.97 (0.79, 1.19)	0.755	0.96 (0.76, 1.20)	0.709
Comorbidity				
None	1.00		1.00	
One	3.15 (2.70, 3.66)	<0.001	1.51 (1.26, 1.80)	<0.001
Two or more	7.61 (6.14, 9.45)	<0.001	2.19 (1.68, 2.85)	<0.001
Smoking[b]				
Never, stopped, or smoke less	1.00			
Unchanged or smoke more	0.98 (0.78, 1.23)	0.867		
Drinking alcohol[b]				
Never, stopped, or drink less	1.00			
Unchanged or drink more	1.04 (0.87, 1.25)	0.680		
Physical activity[b]				
Never, stopped, or exercise less	1.00		1.00	
Unchanged or exercise more	0.33 (0.29, 0.37)	<0.001	0.62 (0.53, 0.73)	<0.001
HL index, 1-score increment	0.95 (0.94, 0.96)	<0.001		
HES, 1-score increment	0.94 (0.93, 0.95)	<0.001	1.00 (0.99, 1.02)	0.687

PHQ, patient health questionnaire; OR, odds ratio; S-COVID-19-S, suspected corona virus disease-2019 symptoms; BMI, body mass index; HL, health literacy; HES, healthy eating score.
[a]The suspected COVID-19 symptoms including common symptom (fever, cough, dyspnea), less common symptom (myalgia, fatigue, sputum production, confusion, headache, sore throat, rhinorrhea, chest pain, hemoptysis, diarrhea, and nausea/vomiting).
[b]People were asked whether their health-related behaviors are getting worse, better, or unchanged during COVID-19 pandemic as compared with those before the pandemic.

TABLE 5 | Interactions of the lockdown measure and healthy dietary intake behavior on depression ($N = 8,291$).

Interaction	Depression (PHQ ≥ 10)			
	Model 1		Model 2	
	OR (95% CI)	*p*	OR (95% CI)	*p*
No lockdown and lowest HES	1.00		1.00	
Lockdown and lowest HES	30.51 (20.78, 44.80)	<0.001	10.60 (6.88, 16.32)	<0.001
No lockdown and HES, 1-score increment	1.05 (1.03, 1.07)	<0.001	1.06 (1.04, 1.08)	<0.001
Lockdown and HES, 1-score increment	0.81 (0.79, 0.84)	<0.001	0.85 (0.82, 0.89)	<0.001

PHQ, patient health questionnaire; OR, odds ratio; HES, healthy eating score. Model 1: Interactions between the lockdown measure and healthy eating behavior on depression. Model 2: Adjusted for age, gender, occupation, ability to pay for medication, social status, suspected COVID-19 symptoms, body mass index, comorbidity, and physical activity.

The most important finding of our study was that people with better healthy dietary intake behavior had lower depression likelihood during the lockdown period. This could be explained that better diet quality had benefits for lower risk of depression (34, 35). Anti-oxidant and anti-inflammatory nutrients from healthy foods can boost the immune function, reduce infection risk, and modulate the prognosis of COVID-19 disease (16, 17, 22, 23). In addition, depression has been protected and improved by doing the physical activity which was found in the current study and previous studies (69, 70). Furthermore, physical activity was linked to healthier eating behavior in the current study which further protects the people's mental health. Dietary intake and exercise was recognized as a key to healthy living (71). The findings provide important evidence to governments and organizations to develop strategic nutrition support programs to contain the pandemic and its adverse psychological consequences (21). HES-5 tool is suggested to use in clinical settings to quickly assess people' healthy eating behavior (38, 47), especially during the sensitive time of COVID-19 pandemic.

The current study shows that people with higher health literacy scores had a lower likelihood of depression. Health literacy has demonstrated an important role in evaluating online health information (72) in the digital world with diverse information and sources (73). Therefore, it is a critical skill for people during the COVID-19 pandemic and lockdown period. In addition, higher HL scores were independently associated with healthier behaviors (e.g., exercise, balanced diet) (74, 75) which further contribute to improve mental health (76). The policy-makers should be aware of and emphasize the roles and interplay between information providers and receivers which can improve people's understanding of medication information (77). Moreover, improving people's health literacy can help fight the infodemic and flatten the curve during the global health crisis (78, 79).

The current study has some limitations. First, research assistants and patients were vulnerable to virus infection during the pandemic. It was required to strictly follow the guidelines during the survey. Fortunately, researchers received great support from participating hospitals and health centers. In addition, there was no new case detected in the study settings during the data collection period (51). Second, the cross-sectional design with a non-random sample cannot generate a causal relationship. We have conducted the study on a large sample from 18 hospitals and health centers across Vietnam which can help in exploring the associations and interactions, and the findings can be cautiously generalized. Third, subjective measures with patients' self-reported information (e.g., height, weight) potentially bias the analysis. Therefore, findings should be interpreted with caution. Even though the HES-5 questionnaire was used for assessing the quality of the diet, and lack specificity, it is fast and easier than other validated questionnaires to measure healthy dietary intake, especially during the pandemic. Despite the mentioned limitations, findings of the current study substantially provide the evidence and direction for future research and practices to contain the COVID-19 disease and its related consequences.

CONCLUSIONS

The COVID-19–induced lockdown or home confinement is a necessary measure to contain the viral infection. It shows negative impacts on dietary intake behavior and mental health. Fortunately, healthy dietary intake behavior can protect people's psychological health during the pandemic, especially during the lockdown period. The strategic public health approaches are required to develop nutritional support programs to improve the healthy eating behavior which further improves people's mental health and response to the pandemic.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available on reasonable request to the corresponding author.

ETHICS STATEMENT

The study protocol was approved by each participating hospital, and the Institutional Ethical Review Committee of Hanoi School

of Public Health, Vietnam (IRB No. 029/2020/YTCC-HD3 for the first stage from 14th February to 31st March 2020; and IRB No. 133/2020/YTCC-HD3 for the second stage from 1st April to 31st May 2020). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

KP and TVDu analyzed the data and drafted the article. KP, LP, DP, TT, HoaN, MN, HuuN, TH, HD, PN, MT, ThinD, HunN, TN, NN, CT, KT, TranD, LN, ThaoD, TV, BD, ThaiD, TP, TL, ND, HoaiN TM, DH, HuoN, KN, S-HY, JC, and TuyeD contributed to conceptualization, investigation, methodology, validation, writing review, and editing. KP, LP, DP, TT, HoaN, MN, HuuN, TH, HD, PN, MT, ThinD, HunN, TN, NN, CT, KT, TranD, LN, ThaoD, TV, BD, ThaiD, TP, TL, ND, HoaiN, TM, DH, HuoN, KN, and TuyeD conducted data curation. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

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Reported Changes in Dietary Habits During the COVID-19 Lockdown in the Danish Population: The Danish COVIDiet Study

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This paper focuses on the effect of the COVID-19 lockdown on the dietary habits of adult Danes. Two aspects were specifically considered: 1) reported changes in intake of specific food categories and 2) effect on healthy eating, operationalized as adherence to the Mediterranean diet (MEDAS score). Respondents ($N = 2{,}462$) completed a 44-items self-administered online survey designed for the assessment of their socio-demographic characteristics, general food habits, and consumption frequency of selected foods (mainly related to the MedDiet) during the lockdown. The data indicated that the lockdown has affected dietary habits of adult Danes to a relatively limited degree. The most important findings were that a substantial proportion of respondents (≥28%) reported eating more, snacking more, exercising less, and gaining weight during the lockdown. Results could be linked to the amount of time spent at home (e.g., a higher cooking frequency) a higher degree of emotional eating during the lockdown (e.g., a higher consumption of pastries and alcohol). Women were generally affected to a higher degree than men. Additionally, dietary changes during the lockdown to a certain degree reflected pre-existing (un)healthy eating habits, as positive health outcomes were observed in respondents with a high MEDAS score and negative outcomes (e.g., weight gain and higher intakes of pastries and carbonated beverages) were associated with respondents with a low MEDAS score. These changes, if sustained long-term, are potentially concerning from a public health perspective, especially given that more than half of the respondents were characterized by a low adherence to the MedDiet.

Keywords: COVID-19, lockdown, dietary habits, public health nutrition, Denmark

INTRODUCTION

Impact of COVID-19 on Dietary Habits—The COVIDiet Project

The 2019 coronavirus (COVID-19) pandemic, caused by SARS-CoV-2, has expanded from Wuhan, China to a growing number of countries (1). At the time of writing (October 21, 2020), more than 40 million confirmed cases of COVID-19 have been reported worldwide, of which about 5.2 million were in Europe according to the European Centre for Disease Prevention and Control (2).

In an effort to mitigate the spread of the pandemic, most European countries implemented a variety of measures limiting their citizens' freedom of movement (e.g., social distancing, ban on travel and public gathering) and mandated a lockdown of most societal activities (3). These extraordinary measures understandably caused significant disruption to most people's routines and lifestyle, and are expected to have exerted significant effects on dietary habits and physical activity (4, 5). For instance, as people spent much more time at home than usual, they had more time for cooking, as well as for snacking (5); restrictions to freedom of movement may have impacted food provisioning practices as well as access and availability for specific food items (6); boredom, stress and anxiety associated with the lockdown measures (7) likely increased emotional eating (8), and so on.

In this context, the COVIDiet_INT project has been established to estimate the impact of COVID-19 related lockdown measures on eating habits among the adult population. COVIDiet INT (9) is an international, crowd-sourced online study translated in 16 languages and conducted in 19 European countries, as well as four non-European countries (Colombia, Egypt, India, and Kuwait). Cross-sectional data from this project have recently been presented with respect to the effect on the Spanish population (5), as well as in a comparative paper (Rodríguez-Pérez et al., submitted).

These results indicate some reason for concerns, particularly as many respondents reportedly ate more, gained weight, and exercised less, due to limitation in outdoors and in-gym physical activity. However, the results also indicated a higher adherence to the Mediterranean Diet (MedDiet) during the lockdown, including higher intake of fruits, vegetables or legumes and lower intake of red meat, alcohol, fried foods, or pastries compared to people's usual habits (5). Since the MedDiet is regarded as the standard for healthy nutrition (10) this result could be seen as a positive outcome that, if it can be sustained in the long term, could help prevent the onset of chronic diseases and COVID-19 related complications.

It remains to be seen whether these effects extend to other countries, given the existence of local difference in dietary habits and in the severity of the lockdown measures. Therefore, this brief report, situated within the COVIDiet international project, seeks to replicate these earlier results and to provide a more detailed characterization of the effect of the lockdown measures on the Danish adult population.

Brief Description of the Lockdown Measures in Denmark

This section provides a brief description of the lockdown measures undertaken by the Danish government. It is mainly based on publicly available information provided by the Danish Health Authority ("Sundhedstyrelse," https://www.sst.dk/en/English). Denmark was among the first European countries to introduce lockdown measures, following similar measures introduced in countries such as China and Italy. While a number of recommendations were already issued in late February/early March, the first actual lockdown measures were officially declared on March 13, 2020, when all people working in non-essential functions in the public sector were ordered to stay home for two weeks. Concurrently, authorities urged employers in the private sector to allow their employees to work from home wherever possible (with the exception of workers in essential functions, such as, e.g., pharmacies, food retailers, and maintenance of critical infrastructure). Also, on 13 March, all secondary education institutions, universities, libraries, indoor cultural institutions and similar places were closed, initially for 2 weeks. Primary schools and daycare facilities were also closed down soon thereafter (March 16, 2020), with virtual (online) schooling used to some degree as a replacement. Further restrictions were implemented on March 18th: specifically, it became illegal to assemble more than 10 people in public, all shopping centers and stores involving close human contacts (e.g., hairdressers and nightclubs) were closed down, and restaurants could be open but only for take-away. On 23 March, the authorities announced that all lockdown measures would be extended and remain in place until 13 April. By late March, lockdown measures proved largely successful in mitigating the number of new cases and were gradually rolled back from mid-April. Specifically, nurseries, kindergartens and primary schools opened again on 15 April, whereas a broader reopening of activities took place on 11 May (shops) and 18 May (schools from 6th grade on, cafés, restaurants, hairdresser).

At the time of writing (October 21, 2020) Denmark has had more than 37,000 confirmed COVID-19 cases (11).

Research Objectives and Study Design

As previously mentioned, this study is part of a larger effort to study changes in dietary behavior in the adult population (5). This specific paper presents data obtained from a Danish cohort and mainly focuses on two research objectives: (1) to report changes in the intake of specific food categories during the lockdown and (2) estimating the effect of lockdown on adherence to MedDiet. To this end, a self-administered web-based questionnaire was carried out with questions aimed at assessing the dietary behaviors of the adult Danish population during the lockdown period. The results from the survey are also compared with reports from companies, media and public institutions regarding observed changes in purchase behavior etc., to ascertain whether the observed impact of the reported changes are generalizable.

METHODS

Measures

A 44-item self-administered online questionnaire was designed for the assessment of the respondent's socio-demographic characteristics, general food habits, and consumption frequency of selected foods (mainly related to the MedDiet). The selected foods included 14 items with reference to the MedDiet pattern based on the validated PREDIMED MedDiet Adherence Screener (MEDAS), whose score ranges from 0 to 14 points (12); for each item, participants were asked whether they had made any actual change due to the lockdown. Participants were also asked to answer 21 in-house items aimed at investigating changes in their general dietary habits during the lockdown, including frequency of cooking and snacking, alcohol intake, cooking methods, among others. All questions were designed to gauge whether participants increased, decreased or maintained their habits during the lockdown period. Additionally, participants were also asked whether their physical activity and body weight had changed since the lockdown started.

The full survey is available online at https://www.mdpi.com/2072-6643/12/6/1730/s1 (the Danish translation can be obtained from the authors upon request). We further refer to Rodríguez-Pérez et al. (5) and to the COVIDiet registered trial on clinicaltrials.gov (Identifier: NCT04449731) for a detailed walkthrough of the survey items. The study was approved by the Research Ethics Committee of the University of Granada (1526/CEIH/2020).

Participants

Participants—reached using various channels, including internal databases, word of mouth and social media—completed the COVIDiet survey during the lockdown period (from 24 April to 5 May). There were no specific inclusion or exclusion criteria except that participants had to be of at least 18 years of age in order to give their informed consent. Respondents received no monetary incentive for their participation. A detailed breakdown of the characteristics of the sample population is given in **Table 1**.

Data Analysis

Descriptive statistics for all variables were computed at an aggregate level as well as by demographics, BMI and level of adherence to the MedDiet (MEDAS score). Adherence to the MedDiet was based on a 14-point scoring system (12) using the same cut-offs (Low: ≤5; Medium: 6–8; High: ≥9) used by Rodríguez-Pérez et al. (5). Depending on the nature of the variable, differences between the segments were evaluated by the Analysis of Variance (ANOVA) or Pearson's Chi-squared (χ^2) test for count data with Yates continuity correction. Accordingly, Hedge's g and Cramer's V (13) were used as measures of effect size, respectively, for quantitative and count data.

All analyses were performed in R (14). Statistical significance was set at $\alpha = 5\%$.

TABLE 1 | Socio-demographic and anthropometric characteristics of the sample population ($N = 2,462$).

Background variable	$N = 2,462$	%
Gender		
Men	708	28.7
Women	1,750	71.1
Other	4	0.2
Age		
18-35	870	35.3
36-50	917	37.2
51-65	578	23.5
65+	97	3.9
BMI (Mean = 24.6 kg/m^2, SD = 4.4)		
Underweight (<18.5)	48	2.0
Normal weight (18.5–24.9)	1,473	59.8
Overweight (25–29.9)	691	28.1
Obese (≥30)	249	10.1
MEDAS (Mean = 5.4, SD = 2.1)		
Low (≤5)	1,250	50.8
Medium (6-8)	1,043	42.4
High (≥9)	169	6.9
Education		
Higher education (Bachelor and above)	2,180	88.5
Medium ed. (High school and vocational training)	266	10.8
Basic education	7	0.3
Other	9	0.4
Children in care		
Yes	1,259	51.1
No	1,203	48.9
Region		
Hovedstaden	841	34.2
Midtjylland	130	5.3
Nordjylland	21	0.9
Sjælland	126	5.1
Syddanmark	1,344	54.6
Place of residence		
Family home	1,936	78.7
Shared flat	157	6.4
Student residence	85	3.5
Alone	284	11.5

RESULTS AND DISCUSSION

According to **Table 1**, the sample population ($N = 2,462$) was well-distributed in terms of territorial coverage over the Danish regions. A prevalence of women (71.1%) and respondents with higher education was observed (88.5% completed higher education). These figures are virtually identical to those reported by Rodríguez-Pérez et al. (5), and likely reflect the fact that women and university educated respondents are more likely to voluntarily participate in food and health studies. The mean MEDAS score was 5.4 (SD: 2.1, Median: 5, Range: 0–12), about a point lower than that reported for the Spanish population [6.5,

TABLE 2 | Reported changes (%) in intake of selected product categories during lockdown, at an overall level as well as by gender and adherence to MedDiet.

		All	Gender[a]				MEDAS group				
			Male	Female	Cramer's V	p	Low	Medium	High	Cramer's V	p
Snacking	Lower	10.8	8.5	11.8	0.12	*<0.001*	9.7	11.4	15.4	0.06	*0.004*
	As before	47.5	56.9	43.6			45.8	48.5	53.8		
	Higher	41.7	34.6	44.6			44.5	40.1	30.8		
Cooking frequency	Lower	5.6	5.8	5.6	0.07	*0.003*	6.9	5.0	0.6	0.06	*<0.001*
	As before	64.5	69.2	62.5			65.5	63.9	60.4		
	Higher	29.9	25.0	31.9			27.6	31.2	39.1		
Eating more in general	No	57.2	65.0	54.0	0.10	*<0.001*	54.0	59.6	65.7	0.07	*0.002*
	Yes	42.8	35.0	46.0			46.0	40.4	34.3		
Physical activity	Not active	2.3	2.5	2.2	0.04	0.166	3.4	1.0	2.4	0.08	*<0.001*
	Lower	47.7	45.6	48.6			49.8	46.6	39.1		
	As before	21.0	23.7	19.8			20.3	20.3	29.6		
	Higher	29.0	28.1	29.3			26.4	32.1	29.0		
Weight gain	Yes	28.4	23.3	30.5	0.07	*<0.001*	31.6	25.6	21.9	0.07	*<0.001*
	No	49.4	57.3	46.2			45.0	53.0	59.2		
	Don't know	22.2	19.4	23.4			23.4	21.4	18.9		

Differences between gender and MEDAS groups were assessed by Pearson's χ^2 test. Associated effect sizes (Cramer's V) and p-values are reported. Significant p-values (<0.05) are italicized.

[a] *The four respondents who did not identify as either male or female (cf., **Table 1**) are not included in this analysis.*

(5)], indicating an expected lower adherence to the MedDiet in Denmark compared to Spain. Remarkably, more than 50% of the sample was classified as having a low adherence to MedDiet and only about 7% as having a high MEDAS scores (**Table 1**—the figures in the Spanish population were 17 and 28%, respectively).

Adherence to MedDiet in the Danish population was slightly higher in females than in males (mean MEDAS score 5.6 vs. 5.1, respectively, Hedges' $g = 0.25$ $p < 0.001$), and in older individuals (65+: 5.9, 51–65: 5.8) compared to younger (36–50: 5.2, 18–35: 5.4; all comparisons between older and younger groups were significant, Tukey $p \leq 0.02$, albeit effect sizes were small to moderate, Range (g) = 0.04–0.32). Furthermore, individuals in the "Low" MEDAS group had a significantly higher mean BMI (25.3 kg/m^2) than both the "Medium" (24.1, $g = 0.27$, $p < 0.001$) and "High" (23.3, $g = 0.41$, $p < 0.001$) groups, whereas the difference between the Medium and the High groups was smaller ($g = 0.20$), although approaching marginal significance ($p = 0.096$). This suggests, as expected, that a higher adherence to the MedDiet is associated with lower body mass, and was further confirmed by the observed negative correlation between the raw MEDAS score and BMI ($r_{(2,460)} = -0.19$, $p < 0.001$).

Table 2 shows changes in general dietary habits and physical activities reported by participants as having happened during the lockdown period. A substantial proportion of participants reported having snacked more frequently (41.7%), cooking more (29.9%), and overall having eaten more (42.8%) during the lockdown period (**Table 2**). These results reflect the fact that people spend a significant amount at home during the lockdown and are consistent with expectations that the stress and boredom associated with the lockdown may have increased emotional eating (5, 7). Importantly, all three figures were significantly higher in women than in men and were significantly lower in participants with a high MedDiet adherence compared to the medium and low groups (**Table 2**). With respect to physical activity, almost half of the sample (47.7%) reported having exercised less, most likely due to the limitations in place during the lockdown periods (fitness centers were closed, group sports were forbidden, etc.). Furthermore, almost 30% reported gaining weight during the lockdown. An additional 22% reported not being sure about weight change. These figures for the Danish population are consistent with available reports from other countries, notably Spain (5) and Italy (4). Again, results for physical activity and weight gain indicate respondents with medium-low adherence to MedDiet were more negatively affected, as these groups more often reported a decrease in physical activity and a weight gain compared to high MEDAS counterparts. It is also noteworthy, however, that 29% of the sample reported an increase in physical activity during lockdown, a figure that was slightly lower for the low MEDAS group than the other two groups (**Table 2**). With respect to gender, the results show no significant differences in changes to physical activity between males and females (**Table 2**). Yet, women still more often reported weight gain (female 30.5%, male 23.3%), and that corresponds to the fact that women also report eating more in general (female 46%, male 35% (**Table 2**).

Table 3 displays results pertaining to reported changes in the intake of individual food categories related to the MedDiet patterns. At the aggregate level, the lockdown resulted in a number of major changes (**Table 3**). The food categories that were most notably affected by the lockdown were a higher intake of both commercial (21.1%) and (especially) homemade pastries (38.1%), and a higher intake of alcohol and carbonated beverages (**Table 3**). These results appear fully consistent with the expectation of a higher rate of emotional eating during

TABLE 3 | Reported changes (%) in general dietary habits and physical activity level during lockdown, at an overall level as well as by gender and adherence to MedDiet, with associated χ^2 *p* values.

		All	Gender[a]				MEDAS group				
			Male	Female	Cramer's V	p	Low	Medium	High	Cramer's V	p
Olive oil	Lower	5.7	5.2	5.9	0.02	0.680	5.4	6.3	3.6	0.08	*<0.001*
	As before	88.8	89.7	88.5			91.0	87.1	83.4		
	Higher	5.5	5.1	5.7			3.6	6.6	13.0		
Vegetables	Lower	19.5	12.4	22.4	0.11	*<0.001*	21.4	18.4	16.3	0.07	*<0.001*
	As before	69.2	76.4	66.3			69.9	67.6	69.7		
	Higher	11.3	11.2	11.3			8.6	14.0	14.0		
Fruit	Lower	24.9	21.0	26.5	0.08	*<0.001*	27.0	23.6	17.2	0.05	*0.022*
	As before	64.0	70.2	61.5			62.9	64.7	68.0		
	Higher	11.1	8.8	12.0			10.1	11.7	14.8		
Red meat	Lower	12.3	9.9	13.2	0.05	0.071	10.2	14.1	16.0	0.07	*<0.001*
	As before	76.2	78.7	75.3			75.5	76.7	78.7		
	Higher	11.5	11.4	11.5			14.2	9.2	5.3		
Carb beverages	Lower	5.6	6.9	4.9	0.05	*0.028*	5.0	6.3	5.3	0.10	*<0.001*
	As before	73.0	74.3	72.6			68.2	76.8	85.8		
	Higher	21.4	18.8	22.5			26.9	16.9	8.9		
Legumes	Lower	8.6	5.2	9.9	0.08	*<0.001*	9.2	8.4	4.7	0.06	*0.001*
	As before	84.4	88.6	82.7			85.5	83.1	83.4		
	Higher	7.1	6.2	7.3			5.3	8.4	11.8		
Fish	Lower	8.4	6.6	9.1	0.07	*0.003*	7.8	9.5	6.5	0.06	*0.002*
	As before	75.8	80.5	73.9			78.7	73.2	70.4		
	Higher	15.8	12.9	17.0			13.4	17.4	23.1		
Pastries (commercial)	Lower	18.4	15.5	19.5	0.07	*0.001*	16.2	20.5	20.7	0.10	*<0.001*
	As before	60.6	66.1	58.3			57.1	63.7	66.9		
	Higher	21.1	18.4	22.2			26.6	15.8	12.4		
Pastries (homemade)	Lower	8.1	6.9	8.6	0.13	*<0.001*	7.3	8.4	12.4	0.05	*0.007*
	As before	53.8	64.0	49.6			51.8	55.5	58.0		
	Higher	38.1	29.1	41.8			40.9	36.0	29.6		
Fried foods	Lower	17.7	16.5	18.2	0.03	0.291	17.7	18.2	14.8	0.04	0.104
	As before	78.2	78.5	78.1			77.4	78.1	84.0		
	Higher	4.1	4.9	3.8			4.9	3.6	1.2		
Alcohol	Lower	14.1	13.4	14.3	0.05	0.037	13.0	15.1	16.0	0.03	0.178
	As before	55.6	59.5	53.9			57.6	52.9	56.8		
	Higher	30.3	27.1	31.7			29.4	32.0	27.2		
Fast food	Lower	25.4	25.6	25.3	0.01	0.773	24.8	25.9	26.6	0.08	*<0.001*
	As before	59.5	58.6	59.9			56.4	62.1	66.9		
	Higher	15.1	15.8	14.8			18.8	12.0	6.5		

[a] *The four respondents who did not identify as either male or female (cf.* ***Table 1****) are not included in this analysis.*

Differences between gender and MEDAS groups were assessed by Pearson's χ^2 test. Associated effect sizes (Cramer's V) and p-values are reported. Significant p-values (<0.05) are italicized.

this period (7) and, in the case of homemade pastries, with the earlier result that many participants reported cooking more during lockdown. At the same time, a significant percentage of respondents reported a lower intake of commercial pastries (18.4%), fried foods (17.7%) and fast food (25.4%) which can also be attributed to the longer time spent at home and limitations to the foodservice sector.

Other notable changes include a lower intake of fruit and vegetables reported by, respectively, 24.9 and 19.5% of participants. A possible contributor to this is that many companies in Denmark provide fresh fruit for their employees, and therefore it could be expected that for some participants, not being physically at work may have resulted in lower fruit consumption. Similarly, a substantial fraction of the consumption of vegetables is in relation to lunch and dinner, and the patterns for their preparation has been substantially changed during lockdown (see below). Interviews in media and reports from Danish retailers in the lockdown period and following show

some of these large changes as well. The Danish retail chain Coop (market share around one-third of Danish retail sales), briefly reports an analysis of the changes in the sales of different food categories in the first weeks of the lockdown [measured in Week 13 + 14, 23 March to 5 April (15)]. They report a 97 and 83% growth in sales of flour and yeast, respectively, compared to same time in 2019. Across the retail sector, Nielsen Retail analysis reports an increase of 63% in the sales of flour in March and April 2020 (16). The sales of sweetened beverages (carbonated and un-carbonated pooled in the analysis), had an increase of 10% compared to 2019 in weeks 13 and 14 compared to the same weeks in 2019 (15). All this is consistent with the reported changes we observed. Madkulturen (a self-governing knowledge and change agency under Danish Ministry for Environment and Food), regularly carries out and reports food consumption among Danish citizens. In May 2020 they issued a brief special report regarding changes in food culture as a consequence of the lockdown (17). It revealed that 36% of Danes to some, high or very high degree have seen their food habits affected by the lockdown. The most notable changes that correspond to the present results are that 26% report eating more of "unhealthy foods," while 9% report eating less of them. In addition, 16% report increase in drinking alcoholic beverages (wine, beer or other) with their dinner, while 9% report decreases. For many of those, the reported changes are related to increases in the consumption of snacks, other in-between meals and alcohol.

Differences between genders did not appear major, as indicated by the relatively small effect sizes[1] (Cramer's V range: 0.02–0.13), although they were in most cases statistically significant due to the large sample size. The clearest difference between genders pertained to the consumption of pastries (both commercial and homemade) which increased significantly more for women than for men (**Table 3**). This mirrors the findings by Madkulturen, where 32% of women report eating more of unhealthy foods, and of snacks, while 19% of men report this (17). With respect to MEDAS groups, **Table 3** indicates that as for gender, differences between the groups were not very large (Cramer's V range: 0.03–0.10), and overall a majority of participants reported no change in intake for most food categories. However, for those participants that did report changes, the direction of the differences suggests that the participants in the High group increased intake in food categories positively associated with the MEDAS score (e.g., olive oil, fruit, fish) and decreased intake in items negatively associated with it (e.g., red meat, carbonated beverages, commercial pastries), whereas the low MEDAS group showed the exact opposite trend (**Table 3**). Again, this is in correspondence with Madkulturen's findings (17). They report, that among those that report their food habits affected by the lockdown, 40% perceive the changes overall as positive (e.g., eating healthier), whereas 29% report them as negative (e.g., eat less healthily, eat more take-away).

[1]With 3 d.f.—which is the case for all comparisons in **Table 3**—Cohen (13) suggested the following rule of thumb for interpretating Cramer's V values: 0.06 = small effect, 0.17 = medium effect, 0.29 = large effect.

Taken collectively, the results indicate a pattern whereby individuals with less healthy dietary habits (Low MEDAS) were affected negatively (weight gain, lower physical activity, etc.) by the lockdown, whereas individuals with initial healthier eating patterns (High MEDAS) moved in a healthier direction characterized by increased physical activity and an even higher-level adherence to the MedDiet.

This study confirms some, but not all, of the earlier findings reported in the COVIDiet International project concerning the Spanish population (5). Findings that could be replicated in both countries were that individuals with a high MedDiet adherence reported an increased intake of MEDAS related food categories during lockdown, although this was not true for all food categories (for example, intake of pastries generally increased even for high MEDAS Danes whereas in Spain it decreased). The major difference pertains to the MEDAS score, which was lower in the Danish population. This is of course not entirely surprising since the dietary habits in a Mediterranean country should indeed be closer to the MedDiet ideal than in a Nordic country like Denmark. The main conclusion from the Spanish study was that adherence to the MedDiet increased in the Spanish population during the lockdown (5). The results for the Danish cohort suggest that this was the case only for people characterized by a high MEDAS score, whereas participants with a low adherence to MedDiet (over 50% of the sample) were more negatively affected by the lockdown.

Limitations of this study are discussed in depth in Rodríguez-Pérez et al. (5). We briefly acknowledge here the convenience sampling strategy, which resulted in the overrepresentation of certain categories, particularly women and people with higher education. This was also the case in all countries participating in the COVIDiet international project and reflect the fact that these categories are more likely to be interested in food and health topics and therefore more likely to participate in such studies. Moreover, while the results are based on a large sample size and employed empirically supported measures like the MEDAS score, participants' accuracy in reporting their dietary habits before and during the lockdown is uncertain given that the correlation between self-reported and actual intake can be assumed to be positive, but imperfect (18). Future studies, which are strongly advised to assess the *long-term* effects of the lockdown on dietary habits, can productively address both limitations by employing quota-sampling and a more accurate dietary assessment methods such as 3-day dietary recall or diet history interviews.

CONCLUSIONS

This brief paper focused on changes in dietary habits during the COVID-19 lockdown in the Danish population. The data presented in the paper, based on a self-administered web-based questionnaire (N = 2,462), suggest that the lockdown has affected lifestyle and dietary habits of some adult Danes. Main findings include a substantial proportion of participants who reported eating more, snacking more, and exercising less, and consequently gaining weight during the lockdown.

It corresponds to other reports of changes in dietary patterns during the lockdown in Denmark (17), as well as the observed changes in purchase patterns in retail (15). Many of the results presented could be linked to the amount of time spent at home (e.g., a higher cooking frequency), a higher degree of emotional eating during the lockdown (e.g., a higher consumption of pastries and alcohol), and generally showed that women were affected to a higher degree than men. Additionally, dietary changes during the lockdown to a certain degree reflected pre-existing (un)healthy eating habits as measured by adherence to the Mediterranean Diet, where positive health outcomes were observed in participants with a high MEDAS score and negative outcomes (e.g., weight gain and higher intakes of pastries and carbonated beverages) were associated with participants with a low MEDAS score. These changes, if sustained long-term are potentially concerning from a public health perspective, especially given that more than half of the participants were characterized by a low adherence to the MedDiet.

AGR-141 RESEARCH GROUP

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DATA AVAILABILITY STATEMENT

Raw, anonymized data can be obtained upon reasonable request to the corresponding author and after approval by the COVIDiet project coordinator. Requests to access the datasets should be directed to Davide Giacalone, dg@iti.sdu.dk.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Research Ethics Committee of the University of Granada. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

DG: conceptualization, investigation, visualization, formal analysis, writing—original draft, writing—review and editing. MF: conceptualization, investigation, writing—review and editing. CR-P: conceptualization, methodology, data curation, project administration, writing—review and editing. All authors contributed to the article and approved the submitted version.

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frontiers in Nutrition

BRIEF RESEARCH REPORT
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An Evaluation of the COVID-19 Pandemic and Perceived Social Distancing Policies in Relation to Planning, Selecting, and Preparing Healthy Meals: An Observational Study in 38 Countries Worldwide

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Objectives: To examine changes in planning, selecting, and preparing healthy foods in relation to personal factors (time, money, stress) and social distancing policies during the COVID-19 crisis.

Methods: Using cross-sectional online surveys collected in 38 countries worldwide in April-June 2020 (N = 37,207, Mage 36.7 SD 14.8, 77% women), we compared changes in food literacy behaviors to changes in personal factors and social distancing policies, using hierarchical multiple regression analyses controlling for sociodemographic variables.

Results: Increases in planning (4.7 SD 1.3, 4.9 SD 1.3), selecting (3.6 SD 1.7, 3.7 SD 1.7), and preparing (4.6 SD 1.2, 4.7 SD 1.3) healthy foods were found for women and men, and positively related to perceived time availability and stay-at-home policies. Psychological distress was a barrier for women, and an enabler for men. Financial stress was a barrier and enabler depending on various sociodemographic variables (all $p < 0.01$).

Conclusion: Stay-at-home policies and feelings of having more time during COVID-19 seem to have improved food literacy. Stress and other social distancing policies relate to food literacy in more complex ways, highlighting the necessity of a health equity lens.

Keywords: food literacy, food planning, food preparation, food selection, nutrition, COVID-19, psychological distress, time availability

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INTRODUCTION

At the onset of the global COVID-19 crisis, "panic buying" of grocery staples and time-intensive food preparation activities emerged worldwide (1, 2). The crisis and social distancing policies created unique situations worldwide that allow us to study people and their circumstances in relation to food and health, which is needed for future intervention approaches (3). The goal of this study is to evaluate people's experience of and responses to the COVID-19 crisis and social distancing policies in relation to three behavioral food literacy components: planning, selecting, and preparing healthier foods (4, 5) that have a direct impact on of the individual and household? (6).

A lack of time, financial struggles, and stress are well-known personal barriers to food literacy (7–10). Since the onset of the COVID-19 crisis, many people around the world have experienced (partial) unemployment, and experts anticipate long-term economic consequences that will also affect health (11). We hypothesize that due to the COVID-19 crisis, financial stress and, if applicable, loss of income will have had negative associations with food literacy behavior.

The COVID-19 crisis has also distorted many peoples' perception of time (12). Policies to stay home may have given people the perception of having more time than usual, to the degree that initial findings concerning time and COVID-19 even mention boredom (13). The perception of having more hours in the day might also relieve people from the time-related stress of busy schedules, which is known to impede food literacy behaviors (14). We hypothesize that personal perceptions of having more time and contextual factors of being forced to stay home will have related positively to changes in food literacy behavior.

Next, the COVID-19 crisis and social distancing policies have caused considerable social and psychological distress (11). Psychological distress is known to have negative effects on nutrition behaviors (15). Eating behaviors are also part of food literacy behavior (4, 5), and negative effects of COVID-19-induced stress on planning, selecting, and preparing foods can also be expected. However, preparing foods (e.g., baking) potentially functions as a creative activity to relieve stress (16). Psychological distress caused by the COVID-19 crisis may thus relate to food literacy behavior in both positive and negative ways.

Based on these hypotheses, this study aims to investigate how the onset of the COVID-19 crisis and ensuing social distancing policies have influenced individual feelings that ultimately led to changes in planning, selecting, and preparing healthier foods in 38 countries worldwide. Acknowledging social inequities based on gender, age, educational attainment, employment status, income (for food), and the number of (adult) members in the household (3–5, 7, 10, 17), these factors will also be considered in this study as covariates.

MATERIALS AND METHODS

Study Design and Setting

A cross-sectional online survey was launched in 38 countries worldwide[1], using almost all native languages (all details are listed in **Table 1**) between April 17th and June 25th 2020. The survey consisted of multiple information blocks, of which only a few variables are used and reported in this paper. A full overview of the study protocol and survey is accessible via https://osf.io/nz9xf/files/.

The Ethics Committee for the Social Sciences and Humanities of the University of Antwerp approved the study protocol (approval code 20_46).

Participants

Eligible respondents were adults (18+ years old) residing in one of the 38 participating countries during the COVID-19 crisis. Respondents were recruited through convenience sampling; multiple banners were shared on social media, and the survey was advertised via several (inter)national press releases.

Variables

The present study considered planning, selecting, and preparing healthier foods as part of the food literacy construct. Gender, age, educational attainment, employment status, income (for food), and the number of (adult) household members are considered as covariates of food literacy (4, 5, 7, 10, 17).

Outcome Variables

Outcome variables were measured using 11 items from a validated food literacy scale that captures behaviors in the domains of "planning (and managing)," "selecting," and "preparing" healthier foods (18). Answers were given on seven-point frequency scales (1 = never do this, to 7 = do this every time, see **Table 1**). Respondents were asked to answer each item twice, reporting their behavior before the COVID-19 crisis and at that moment (during the COVID-19 crisis). Variables (plan, select, prepare) were calculated following the original factor scores (18), and had high reliability scores in our sample (αFL_plan_before = 0.87, αFL_select_before = 0.84 αFL_prepare_before = 0.84; αFL_plan_during = 0.90, αFL_select_during = 0.89 αFL_prepare_during = 0.85). Change variables were computed by subtracting the before from the during scores. Changes in planning, selecting, and preparing healthier foods ranged from −6 to +6, with negative scores signifying a decline and positive scores indicating an increase.

Predictors

Regarding predictors, psychological distress was measured with the Kessler K6 scale (19). The original scale assesses symptoms

[1]Australia; Austria; Bahrein; Belgium; Brazil; Canada; Chile; China; Denmark; Ecuador; Egypt; Finland; France; Germany; Greece; Ireland; Italy; Japan; Jordan; Kuwait; Lebanon; Mexico; Netherlands; New Zealand; Oman; Palestine; Peru; Poland; Qatar; Romania; Saudi Arabia; Singapore; South Africa; Spain; Uganda; United Arab Emirates; United Kingdom; United States.

TABLE 1 | Detailed descriptive statistics (Means, Standard Deviations, and Valid Percentages) for the entire sample, weighted[a] and subsamples of women and men, used in all analyses.

		Total sample $N = 37,207$		**Weighted sample used in analyses**	**Weighted female subsample**	**Weighted male subsample**	
	Answer option	***M* (*SD*) or *n* (valid %)**	**Missing values *n***	***M* (*SD*) or valid %**	***M* (*SD*) or valid %**	***M* (*SD*) or valid %**	**Significance of sex. differences based on *t*-tests (*M*, *SD*) or Chi-square (%)**
Food literacy scores							
Plan before COVID-19	1–7 Likert	4.70 (1.26)	0	4.57 (1.29)	4.65 (1.27)	4.29 (1.31)	$t_{(234,243.28)} = 94.50$, $p < 0.01$
Plan during COVID-19	1–7 Likert	4.89 (1.34)	0	4.76 (1.38)	4.85 (1.36)	4.42 (1.42)	$t_{(231,778.53)} = 105.76$, $p < 0.01$
Select before COVID-19	1–7 Likert	3.61 (1.66)	0	3.65 (1.65)	3.71 (1.65)	3.46 (1.63)	$t_{(243,395.33)} = 51.16$, $p < 0.01$
Select during COVID-19	1–7 Likert	3.67 (1.71)	0	3.72 (1.71)	3.76 (1.71)	4.56 (1.69)	$t_{(243,754.55)} = 39.75$, $p < 0.01$
Prepare food before COVID-19	1–7 Likert	4.60 (1.24)	0	4.53 (1.29)	4.64 (1.24)	4.16 (1.39)	$t_{(221,592.58)} = 119.03$, $p < 0.01$
Prepare food during COVID-19	1–7 Likert	4.72 (1.29)	0	4.65 (1.35)	4.77 (1.30)	4.25 (1.43)	$t_{(223,802.91)} = 127.19$, $p < 0.01$
COVID-19 induced feelings							
Financial stress	1–7 Likert	2.85 (1.76)	0	2.98 (1.79)	2.95 (1.77)	3.09 (1.84)	$t_{(233,649.35)} = -24.84$, $p < 0.01$
Feel they have more time	1–7 Likert	4.18 (1.74)	0	4.21 (1.74)	4.21 (1.74)	4.22 (1.75)	$t_{(239,256.17)} = -1.34$, $p = 0.18$
KESSLER 6	1–7 Likert	3.06 (1.28)	0	3.14 (1.29)	3.20 (1.28)	2.93 (1.28)	$t_{(240,129.48)} = 71.93$, $p < 0.01$
COVID-19 contextual factors							
Forced to work/stay home	Yes/No	29,558 (79.4%)	0	74.9%	75.6%	72.2%	$X^2_{(1)} = 715.67$, $p < 0.01$
Public gatherings restricted	Yes/No	9,464 (25.4%)	0	27.6%	26.7%	30.9%	$X^2_{(1)} = 1,009.81$, $p < 0.01$
Private gatherings restricted	Yes/No	5,508 (14.8%)	0	15.8%	15.3%	17.6%	$X^2_{(1)} = 430.02$, $p < 0.01$
Restaurants closed	Yes/No	28,309 (76.1%)	0	68.6%	68.9%	67.6%	$X^2_{(1)} = 86.40$, $p < 0.01$
Bars/pubs closed	Yes/No	29,259 (78.6%)	0	71.9%	71.7%	72.4%	$X^2_{(1)} = 25.28$, $p < 0.01$
Schools closed	Yes/No	31,530 (84.7%)	0	84.5%	85.1%	82.2%	$X^2_{(1)} = 715.23$, $p < 0.01$
Socio-demographics							
Gender	Women	28,668 (77.1%)	0	77.8%			
	Men	8,539 (22.9%)		22.2%			
Age	Age given	36.71 (14.79)	0		34.36 (13.90)	37.31 (14.96)	$t_{(227,593.05)} = -68.24$, $p < 0.01$
General financial struggles	1–7 Likert	2.90 (1.73)	0	3.02 (1.71)	3.02 (1.69)	3.03 (1.75)	$t_{(234,807.52)} = -1.06$, $p = 0.29$
Financial struggles for food	1–7 Likert	2.50 (1.82)	0	2.64 (1.86)	2.64 (1.86)	2.65 (1.86)	$t_{(240,796.33)} = -1.36$, $p = 0.18$
Loss of income	Yes/No	12,393 (33.3%)	1	34.8%	33.4%	39.8%	$X^2_{(1)} = 2,078.81$, $p < 0.01$
Highest obtained degree			6				$X^2_{(4)} = 7,688.20$, $p < 0.01$
Under a high school diploma		1,479 (4.0%)		4.3%	3.9%	5.9%	
High school diploma or equivalent		8,666 (23.3%)		23.0%	22.6%	24.3%	
Bachelor's degree		16,722 (45.0%)		48.8%	51.0%	41.0%	
Master's degree		8,040 (21.6%)		17.9%	17.5%	19.2%	
Doctorate		2,294 (6.2%)		6.1%	5.1%	9.6%	
Employment status during COVID-19			0				$X^2_{(2)} = 13,809.26$, $p < 0.01$
Student		8,899 (23.9%)		26.5%	28.2%	20.7%	
Employed		18,096 (48.6%)		45.3%	41.5%	58.6%	
Not employed		10,212 (27.4%)		28.2%	30.4%	20.7%	
Number of cohabiting adults	Min 0 Max 12	2.38 (1.97)	324	2.76 (2.17)	2.84 (2.22)	2.49 (1.98)	$t_{(263,026.22)} = 57.30$, $p < 0.01$
Number of cohabiting children	Min 0 Max 12	1.05 (1.44)	250	1.27 (1.59)	1.30 (1.59)	1.17 (1.57)	$t_{(240,479.25)} = 29.80$, $p < 0.01$
Country of residence during COVID-19			0				

(Continued)

TABLE 1 | Continued

	Answer option	Total sample $N = 37,207$		Weighted sample used in analyses	Weighted female subsample	Weighted male subsample	Significance of sex. differences based on *t*-tests (*M*, *SD*) or Chi-square (%)
		M (*SD*) or *n* (valid %)	Missing values *n*	*M* (*SD*) or valid %	*M* (*SD*) or valid %	*M* (*SD*) or valid %	
Australia		533 (1.4%)		0.1%	0.1%	0.0%	
Austria		362 (1%)		0.1%	0.1%	0.1%	
Bahrein		693 (1.9%)		0.3%	0.3%	0.3%	
Belgium		6,886 (18.4%)		4.1%	4.2%	3.8%	
Brazil		546 (1.5%)		0.4%	0.4%	0.5%	
Canada		844 (2.3%)		0.8%	0.8%	0.7%	
Chile		863 (2.3%)		0.9%	0.8%	1.3%	
China		539 (1.4%)		0.6%	0.3%	1.8%	
Denmark		835 (2.2%)		1.1%	0.7%	2.6%	
Ecuador		775 (2.1%)		1.2%	0.9%	1.9%	
Egypt		734 (2%)		1.2%	1.2%	1.3%	
Finland		791 (2.1%)		1.4%	1.7%	0.5%	
France		232 (0.6%)		0.4%	0.4%	0.6%	
Germany		662 (1.8%)		1.4%	1.0%	2.6%	
Greece		800 (2.1%)		1.8%	1.5%	2.7%	
Ireland		496 (1.3%)		1.3%	1.2%	1.4%	
Italy		315 (0.8%)		0.8%	0.9%	0.7%	
Japan		577 (1.5%)		1.6%	1.1%	3.6%	
Jordan		2,675 (7.2%)		8.0%	8.0%	7.8%	
Kuwait		728 (1.9%)		2.3%	2.3%	2.2%	
Lebanon		2,282 (6.1%)		7.5%	7.8%	6.4%	
Mexico		623 (1.7%)		2.1%	2.0%	2.5%	
Netherlands		778 (2.1%)		2.8%	2.9%	2.2%	
New Zealand		2,982 (8%)		11.1%	12.8%	5.3%	
Oman		186 (0.5%)		0.7%	0.8%	0.6%	
Palestine		859 (2.3%)		3.5%	3.5%	3.2%	
Peru		589 (1.6%)		2.5%	2.4%	2.7%	
Poland		550 (1.5%)		2.4%	1.7%	4.8%	
Qatar		653 (1.7%)		2.9%	3.0%	2.7%	
Romania		325 (0.9%)		1.5%	1.5%	1.4%	
Saudi Arabia		2,999 (8%)		14.3%	15.1%	11.4%	
Singapore		113 (0.3%)		0.6%	0.4%	0.9%	
South Africa		138 (0.4%)		0.7%	0.8%	0.5%	
Spain		730 (2%)		3.8%	3.7%	4.2%	
Uganda		320 (0.9%)		1.7%	1.1%	3.8%	
United Arab Emirates		1,718 (4.6%)		9.5%	10.0%	7.8%	
United Kingdom		205 (0.5%)		1.2%	1.0%	1.6%	
United States		271 (0.7%)		1.6%	1.5%	1.8%	

[a] *Sample sizes off all participating countries differed. To control for over or underreporting from certain countries due to unequal survey collections, a survey weight based on the country variable generated by SPSS for unbalanced samples was applied in all analyses.*
Valid percentage = responses only without considering missing values.

of psychological distress in the past 30 days. In this study, respondents indicated on seven-point frequency scales (1 = never to 7 = all the time) how often they experienced each of the six feelings since the COVID-19 crisis. The internal consistency of this scale in our sample was high ($\alpha = 0.88$), and the mean sum score ranged from 1 (never distressed) to 7 (distressed all the time).

Financial stress was measured with a single item: "Since the COVID-19 crisis, I have experienced financial stress" answered on a seven-point frequency scale (1 = never to 7 = all the time).

For time availability, respondents were asked how often since the COVID-19 crisis they felt they "had more time than usual," using a similar seven-point frequency scale.

For social distancing policies, respondents answered yes (= 1) or no (= 0) to questions inquiring if they were forced to stay at/work from home, if public and private gatherings were forbidden or restricted, and if restaurants, pubs/bars, and schools were closed. We relied on self-report perceptions of social distancing measures rather than official announcements. This is because in many countries social distancing measures differed according to region and changed rapidly according to the situation. Moreover, in the end respondents' thoughts, feelings and behaviors may correspond more to what they believe is restricted rather than what is officially restricted or not.

Control Variables

Modifying sociodemographic variables included gender, age, educational attainment, employment status, number of cohabiting adults and children, and general financial situation. Financial situation was measured with two questions: "In general, how often is it a struggle to make your money last until the end of the month/payday?" and "In general, how often is it a struggle to have enough money to go shopping for food?" using a seven-point frequency scale (1 = never to 7 = always). Loss of income was measured with the question "Have you lost (a part of your) income since the lockdown?" with answer options 1 = yes and 0 = no.

Study Size and Statistical Analysis

Analyses were performed in SPSS version 26. Repeated measures ANOVA was first used to test the significance of changes in self-reported planning, selection, and preparation of healthier foods before vs. during COVID-19. Hierarchical multiple regression analyses were used to test the predicted model for planning, selecting, and preparing healthier foods as outcome measures separately. In all analyses feelings of psychological distress, financial stress, having more time than usual, and sociodemographic modifying variables were entered in the first block, and contextual factors in the second block, both by forced entry. Using G-power for this model with 17 predictors, anticipated small effect sizes of 0.01, and a level of significance set at a conservative $p < 0.0001$, a minimum total sample size of 4,881 was required. Missing values (see **Table 1**) were excluded listwise. A collinearity tolerance of <0.20 and a VIF of five and above were used as criteria to control for multicollinearity. None of the reported regressions contained collinearity levels lower than 0.52 or VIF higher than 1.92, meaning no multicollinearity problems occurred.

Descriptive analyses, independent samples *t*-tests and chi-square tests (see **Table 1**) showed that scores of male and female respondents were different for all variables except for the perception of having more time and general financial struggles. Gender differences in reported lockdown policies correspond to different gender ratios in the participating countries. Based on these results, all further analyses were performed separately for men and women. Sample sizes off all participating countries differed. To control for over or underreporting from certain countries due to unequal survey collections, a survey weight based on the country variable generated by SPSS for unbalanced samples was applied in all analyses.

RESULTS

Participants

Of all 81,486 people that started the survey, 38,666 completed the survey. Cases with invalid values for age (two cases) and gender (one case) were removed. Gender diverse (X-gendered) respondents ($n = 128$) were also omitted from analysis since this answer option was not used in every country, and the resulting subsample was too small for meaningful analyses. Respondents who did not live in one of the participating countries ($n = 479$) or did not provide their country of residence ($n = 849$) were also excluded from the analyses. A final $N = 37{,}207$ (77.8% women, $M_{age} = 36.71$, $SD = 14.79$) were retained for analysis. Further details of the demographic characteristics of our sample are given in **Table 1**.

Descriptive Results

Mean scores for planning, selecting, and preparing healthier foods were average to high before the COVID-19 crisis in both women and men. All three food literacy behavior domains increased during the COVID-19 crisis in both women and men [plan, women, $F_{(1,\ 522{,}232)} = 25594.47$, $p < 0.01$, men $F_{(1,\ 149{,}036)} = 2931.54$, $p < 0.01$; select, women, $F_{(1,\ 522{,}232)} = 1088.85$, $p < 0.01$, men $F_{(1,\ 149{,}036)} = 1153.84$, $p < 0.01$; prepare, women, $F_{(1,\ 522{,}232)} = 9{,}819.70$, $p < 0.01$, men $F_{(1,\ 149{,}036)} = 1054.81$, $p < 0.01$, see **Table 1** for all means and SD]. Furthermore, both men and women scored higher on financial stress when they had lost income due to COVID-19 [for women $t_{(3{,}131{,}242)} = 296.81$, $p < 0.01$ with $M = 2.46$, $SD = 1.56$ for women who did not lose income and $M = 3.94$, $SD = 1.76$ for women who lost income; for men $t_{(3{,}131{,}242)} = 296.81$, $p < 0.01$ with $M = 2.46$, $SD = 1.58$ for men who did not lose income and $M = 4.04$, $SD = 1.79$ for men who lost income].

Hierarchical Multiple Regression Analyses

Results of all hierarchical multiple regression analyses are reported in full detail in **Supplementary Table 2**, and summarized in **Figures 1**, **2** and **3**. To start with the personal responses, the perception of having more time since the COVID-19 crisis was associated with increases in planning, selecting, and preparing healthier foods in both women and men ($p < 0.01$). COVID-19-induced financial stress was associated with decreases in planning and preparing healthier foods in both women and men ($p < 0.01$). Financial stress was further associated with an increased use of food labels and nutrition information among women ($p < 0.01$). COVID-19-induced psychological distress was associated with decreases in planning, selecting, and preparing healthier foods among women ($p < 0.01$). For men, psychological distress was negatively related to selecting–and positively related to preparing–healthier foods ($p < 0.01$).

Concerning contextual factors, positive associations were found between policies to stay at home/work from home and

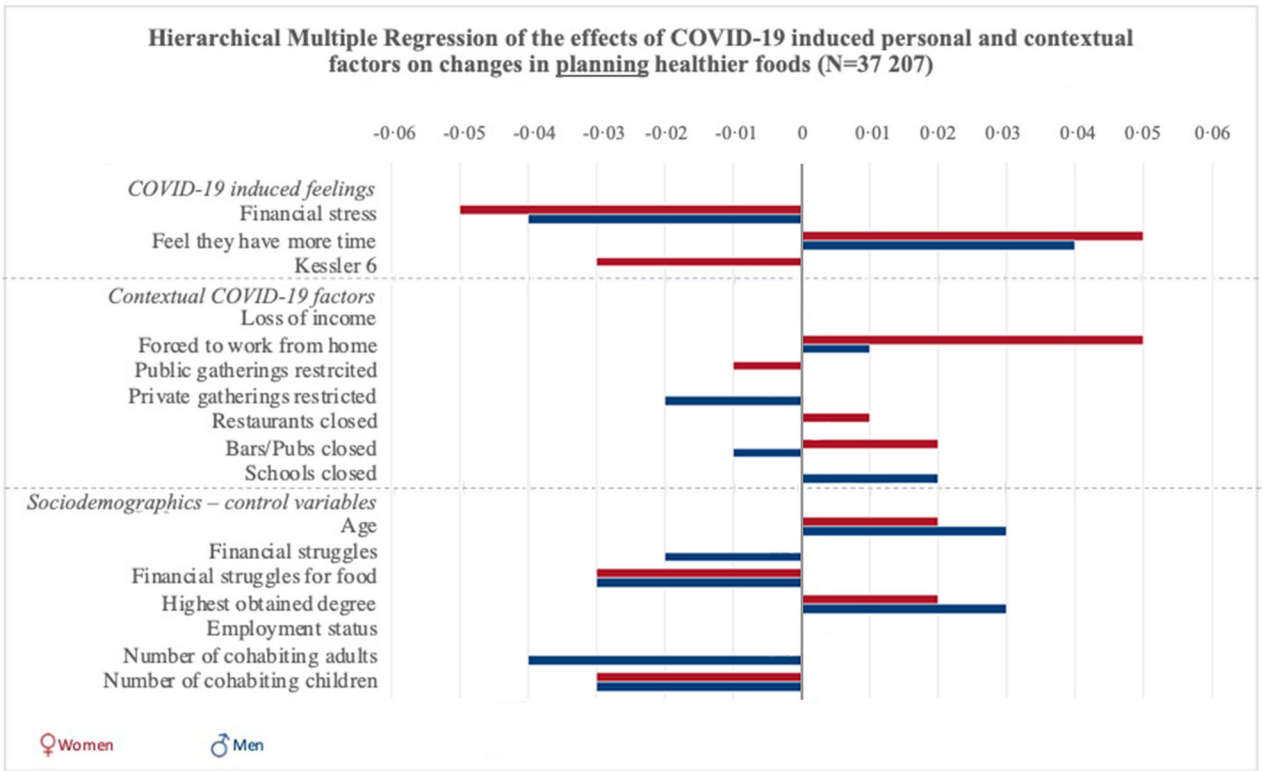

FIGURE 1 | Graphic summary of the significant relations between personal, contextual and sociodemographic variables and changes in planning healthier foods during COVID-19. We report beta-values only for significant relations in models 2 for planning healthier foods. Bars to the right indicate improvement in food planning, bars to the left indicate decreases in planning healthy foods.

changes in planning and preparing healthier foods in both women and men ($p < 0.01$). However, staying home was negatively associated with selecting healthier foods in women and men ($p < 0.01$). Next, policies on public gatherings related to an increase in selecting healthier foods among women, but this association was negative for men ($p < 0.01$). Policies on public gatherings also negatively related to women's planning and preparing of healthier foods. Policies on private gatherings negatively related to men's planning and preparation of healthier foods ($p < 0.01$).

The closure of schools was associated with increased healthier food selection in men and women ($p < 0.01$), but decreased healthier food planning in men and preparation in women ($p < 0.01$). The closure of restaurants and the closure of pubs and bars was associated with decreases in selecting healthier foods in men and women ($p < 0.01$). The closure of restaurants, pubs, and bars further increased women's healthier food planning, while healthier food planning decreased in men when pubs/bars were closed ($p < 0.01$). And while women's preparation of healthier meals increased when restaurants were closed, men reported that their preparation of healthier meals decreased ($p < 0.01$).

Regarding the sociodemographic characteristics associated with changes in food literacy behaviors, educational attainment was negatively related to changes in selecting healthier foods and positively related to changes in planning and preparing healthier foods in men and women ($p < 0.01$). Employment status was negatively related to changes in food preparation in men and women ($p < 0.01$) and positively related to changes in selecting healthier foods in women. Struggling to make money last until the next payday was positively related to changes in women's selecting healthier foods ($p < 0.01$), and negatively related to men's changes in food planning ($p < 0.01$). Struggling to have enough money to go shopping for food was also related to positive changes in women's use of food labels (selecting healthier foods), but related to negative changes in both women and men's planning and preparing healthier foods ($p < 0.01$). Also loss of income was related to an increase in selecting healthier foods among women and men ($p < 0.01$), an increase in preparing healthier meals in women, and a decrease in preparing healthier meals in men ($p < 0.01$). Age was positively related to changes in planning healthier foods for men and women. It was also positively related to changes in men's healthier food selection, while for women it was negatively related to changes in selecting and preparing healthier foods ($p < 0.01$). Finally, the more adult cohabitants women had during the COVID-19 crisis, the more their selection and preparation of healthier foods improved ($p < 0.01$). For men, increases in the number of adult cohabitants related to decreases in planning and preparing healthier foods (p

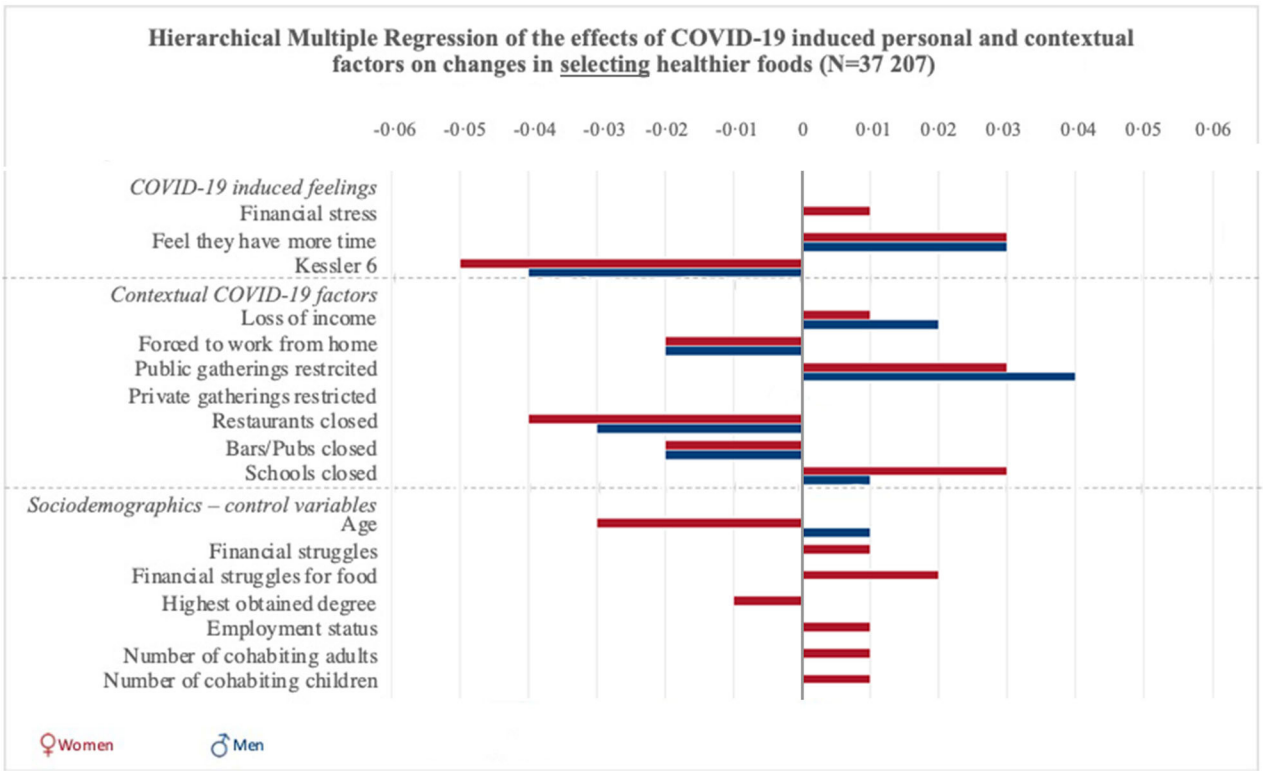

FIGURE 2 | Graphic summary of the significant relations between personal, contextual and sociodemographic variables and changes in selecting healthier foods during COVID-19. We report beta-values only for significant relations in models 2 for selecting healthier foods. Bars to the right indicate improvement in food selection, bars to the left indicate decreases selecting healthy foods.

< 0.01). The number of children in the household was negatively associated with men and women's planning and preparation of healthier foods ($p < 0.01$), and positively associated with women's selection of healthier foods.

DISCUSSION

Observations from this study in 38 countries worldwide during the COVID-19 crisis show that positive changes in food literacy can be achieved, and often depend on combinations of personal characteristics and circumstances. Three key learnings from the available evidence are useful in informing future nutrition interventions.

First, the COVID-19 crisis has taught us that stay-at-home policies, and especially personal perceptions of having more time, can increase the willingness to plan, select, and prepare healthier foods. Stay-at-home policies resulted in distorted perceptions of time and made many people feel bored (12, 13). Yet, stay-at-home policies may be in our favor when it comes to food literacy, if people feel to have more time, because in these cases we observed positive increases in planning, preparing, and selecting healthier foods. A health equity lens is warranted (3), however, since working from home is not beneficial for everyone and can lead to increased stress in some people (20). Results also show that while feeling to have more time relates to increases in planning, selecting and preparing healthier foods, stay-at-home policies corresponded to decreases in selecting healthier foods as well. Moreover, women with young children in particular experience more stress and time constraints when working from home (21). We also observed that an increase in the number of children one lives with relates to a decrease in changes in planning and preparing healthier foods. Thus, health practitioners should find ways of incorporating workplace policies to increase time availability in long-term food literacy interventions, bearing the home situation in mind. The requirement to work from home has been a successful public health initiative to curb the spread of COVID-19, and may be a successful long-term strategy to improve food literacy, other factors considered.

Second, nutrition interventions should also be cognizant of mental health and focus on strategies to deal with psychological distress, especially among women. The COVID-19 crisis caused considerable distress (11); our results show that women experienced more psychological distress compared to men. Furthermore, women's psychological distress was related to decreased planning, selection, and preparation of healthier foods. Idyllic representations of relieving stress in the kitchen during the COVID-19 crisis (2) may not have applied to women in our study. Among men we did observe an increase in preparing healthier meals when psychological distress increased. This could be interpreted as men viewing cooking as a "leisure" activity (22),

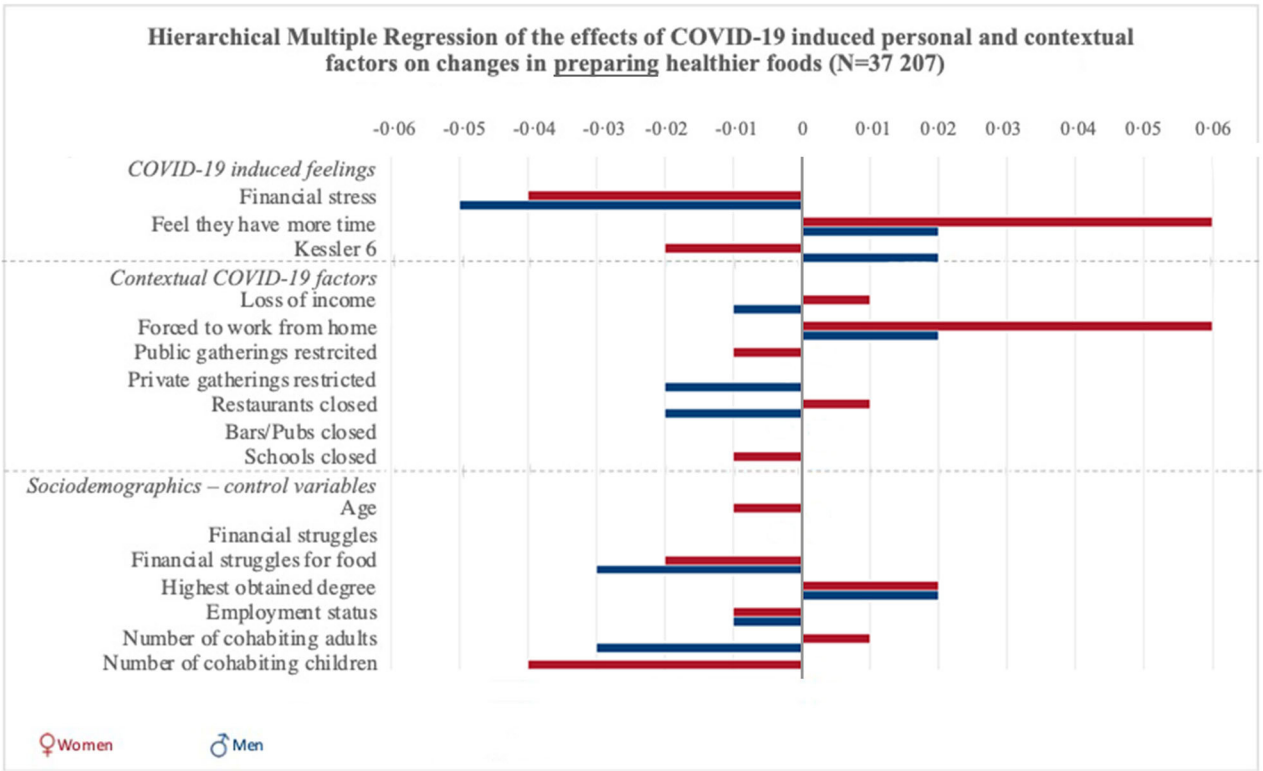

FIGURE 3 | Graphic summary of the significant relations between personal, contextual and sociodemographic variables and changes in preparing healthier foods during COVID-19. We report beta-values only for significant relations in models 2 for preparing healthier foods. Bars to the right indicate improvement in food preparation, bars to the left indicate decreases in preparing healthy foods.

while women take up the "burden" of everyday cooking (23). This may explain why, during the COVID-19 crisis, psychological distress became a barrier to women's everyday cooking but a creative outlet for men as a way to relieve stress (16). Given that women are more likely to be responsible for everyday food preparation in households, the negative impact of psychological distress on their food literacy behaviors may impact the health of many other children and adults.

Third, our results confirm that policymakers must apply a health equity lens, and see both overt and subtle social differences (3). For instance, they should not only focus on income, but on personal feelings of financial stress as well. Our results show that COVID-19 induced loss of income relates to significantly higher levels of financial stress. Both loss of income and feelings of financial stress caused by the COVID-19 crisis, as well as struggling to have enough money for food related to increases in selecting healthier foods for women. When looking at the planning and preparation of healthier meals, however, results show a different pattern: financial stress and struggles to have enough money for food related to decreases in planning and preparing healthier meals. Thus, while financial stress and -constraints do not relate to women's planning and preparation of healthier meals, something did change in their food shopping behavior. A potential explanation for this may be that prices of certain foods became more expensive, especially for foods that were hoarded due to social panic (24). If one needs to switch to more expensive alternatives, increased attention to food labels may occur. Consumers subscribe to a general lay theory that more expensive foods equal to healthier foods (25). This could also explain our other finding, that during the COVID-19 crisis, food labels were mostly read by lower-educated women. However, this may have occurred not necessarily because of an increased knowledge-driven interest, but because of a more critical attitude when having to (relatively) spend more money on food. Previous studies on effects of crisis periods on cooking patterns also demonstrated mixed results (26–28). Our results confirm that the relation between economic constraints and unhealthy food habits is complex (29): a lack of money (for food) and the accompanying stress diversely relate to how people select, plan, and prepare food.

With regard to other sociodemographic characteristics, our results show that increases in food planning were associated with older age in men and women, while for women age was related negatively to changes in selecting and preparing healthier foods. A potential explanation for this is that more women acquire higher levels of food literacy at a younger age than men, leaving less room for improvement as they get older (4, 5, 7, 10).

This study has several strengths. First, we reported changes in planning, selecting, and preparing healthier foods during the COVID-19 crisis in 38 countries worldwide. International

collaborations are important to understand food literacy within the complex context of ecological influences (30). Our results confirm that the COVID-19 crisis is related to changes in food and nutrition, as was expected (11). Second, by inquiring about food literacy behavior both before and during the COVID-19 crisis with short validated instruments (18), we could control for baseline (pre-COVID-19) levels of food literacy behavior, which were generally average too high in our sample. Third, we gathered information on known personal factors and a range of suspected contextual factors that fluctuated. Social distancing policies were enforced in some, but not all, of the participating countries, and even within one country regional differences applied. This yielded sufficient variation to test for the effects of specific lockdown policies. Finally, there is limited empirical research concerning both intrinsic and extrinsic factors related to food literacy in general (4, 5, 7, 8, 10). This is the first empirical study that looked at factors that can facilitate or impede aspects of food literacy in 38 countries worldwide.

We acknowledge several limitations. First, we looked at planning, selecting, and preparing healthier foods as components of food literacy. Food literacy consists of personal skills, knowledge, self-efficacy, beliefs, feelings, and behavior, which interplay with contextual factors (4, 5, 7, 10). These various complex factors make food literacy a difficult concept to measure, and a scale that captures all food literacy aspects does not currently exist. A second limitation was the small effect sizes. Small effect sizes are more likely in large ($N \geq 2{,}000$) and heterogeneous samples, where there is a lot of variation in context that affects how easily the dependent variable can be influenced (31). Changing food literacy is difficult (4, 5, 7, 10), and our sample of $N = 37{,}203$ was very heterogeneous, covering 38 countries worldwide. Finally, our sample was not achieved through a random sampling of populations; there was a clear overrepresentation of women and highly educated people. Our sample size was large enough to achieve valid results for all groups, but in future planned data collections, we will need greater targeted outreach of underrepresented populations.

In conclusion, we reported overall increases in planning, selecting, and preparing healthier foods during the COVID-19 crisis among women and men in 38 countries around the world using self-report data. Perceptions of having more time were most clearly associated with these positive changes, followed by the contextual factor of stay-at-home policies. Psychological distress was related to decreases in women's food literacy, and increases in men's healthy food preparation. Financial stress was not always related to decreases in food literacy; especially among women, financial stress and struggles related to increased healthier food selection behaviors.

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 Ethical Committee for the Social Sciences and Humanities of the University of Antwerp. File number 20_46. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

The study was conceptualized by CD, LT, IC, PD, SP, and KV. Data were collected by all members of the Corona Cooking Survey Study Group. Data analysis was done by CD. The original manuscript was prepared by CD, LT, IC, PD, SP, CM, HA, and KV. Further writing, reviewing and editing was done in multiple rounds by the entire Corona Cooking Survey Study Group. All authors have read and agreed to the final version of the manuscript.

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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.2020.621726/full#supplementary-material

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The Timing, Nature and Extent of Social Media Marketing by Unhealthy Food and Drinks Brands During the COVID-19 Pandemic in New Zealand

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Background: Concerns have been raised that health and societal causes surrounding the COVID-19 pandemic were misappropriated by companies to promote their unhealthy products to vulnerable populations during a time of increased stress and hardship (i.e., COVID-washing). Social media is a common medium for unhealthy foods and beverage marketing due to lack of regulation and low levels of monitoring.

Purpose: This study aimed to investigate the timing, nature and extent of COVID-washing on public social media accounts by New Zealand's major food and drink brands in the initial stage of the pandemic after the first case was detected in New Zealand and when stay-at-home lockdown restrictions (Level 4 and 3 Alert levels) were in place.

Methods: A content analysis of social media posts from February to May 2020 by the twenty largest confectionery, snacks, non-alcoholic beverages, and quick-service restaurant (fast-food) brands was undertaken. COVID-19 related posts were identified and classified to investigate the timing, themes and engagement with social media marketing campaigns, flagging those that may breach New Zealand's Advertising Standards.

Results: 14 of 20 unhealthy food and drink brands referenced COVID-19 in posts during the 4-month period, peaking during nationwide lockdown restrictions. Over a quarter of all posts by the 14 brands (n = 372, 27.2%) were COVID-19 themed. Fast-food brands were most likely to use COVID-19 themed posts (n = 251/550 posts, 46%). Fast-food brands also had the highest number of posts overall during the pandemic and the highest engagement. The most commonly-used theme, present in 36% of all social media posts referring to COVID-19, was to draw on feelings of community support during this challenging time. Suggesting brand-related isolation activities was also common (23%), and the message that "consumption helps with coping" (22%). Six posts were found to potentially breach one of New Zealand's advertising standards codes by promoting excessive consumption or targeting children.

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Conclusion: COVID-washing was used by unhealthy food and drinks brands to increase brand loyalty and encourage consumption. The current Advertising Standards system is ineffective and must be replaced with a government-led approach to effectively regulate social media advertising to protect all New Zealanders, particularly in times of crisis.

Keywords: Coronavirus, COVID-19, food marketing, advertising, food and beverage, social media, New Zealand, commercial determinants of health

INTRODUCTION

The consumption of energy-dense/nutrient-poor food and beverage products–hereafter referred to as "unhealthy food and drinks"–increases the risk of preventable diet-related diseases (1, 2). The marketing of unhealthy food and drinks has been shown to increase preference for unhealthy products, purchasing (requests in the case of children), and consumption and total energy intake in both children (3–7) and adults (8, 9). Adults experiencing "cognitive overload" during times of heightened stress are even more susceptible to advertising (10) and it is clear that the COVID-19 pandemic was a time of unprecedented change in everyday life, which resulted in decreased psychological well-being for many people globally (11–13), including within New Zealand (14). The first case of COVID-19 in New Zealand was detected on 28 February 2020, and from 26 March a national "lockdown" was enacted which restricted movements for all but essential workers from 26 March (15). During the first month of lockdown, fast-food restaurants, takeaways and delivery of cooked food was prohibited, but these restrictions were eased to allow for contact-less delivery and pickup from 28 April under Level 3 lockdown which lasted until 13 May 2020 (16).

Evidence is emerging globally that unhealthy commodity companies (i.e., producers of tobacco, alcohol, and unhealthy foods and drinks, among others) leveraged the COVID-19 pandemic for marketing purposes (17); with some labeling this type of marketing "COVID-washing" (18, 19). The term COVID-washing is a play on the word "whitewashing" and refers to a type of cause marketing, whereby brands or companies align themselves with a social or health issue in order to enhance their own image. Similar to greenwashing (i.e., showing concerns for the climate emergency while contributing to overconsumption and pollution), COVID-washing portrays a company as empathetic and contributing in a meaningful way to the pandemic response. For example, a company shares health promotion messages or publicizes their philanthropic donations, when, in reality, this is just another strategy to promote products and choices that are detrimental to health. In public health, this is considered "a commercial determinant of health" (20, 21).

The marketing of unhealthy food and beverages is pervasive and prolific across multiple platforms, including online platforms (6, 22, 23). Food and beverage companies reportedly use social media to promote their products because of the ability of these platforms to engage consumers in an interactive relationship which increases purchasing intentions, extends reach, and improves brand loyalty (24). A 2019 study of 7–16 year-olds in Canada found that 72% were exposed to food marketing within 5 min of using their two favorite social media apps (10 min in total), and the majority of this content was for unhealthy products (fast-food, sugary drinks, confectionery, snacks, and alcohol) (25). Children who have higher online exposure to unhealthy food brands are more likely to remember and have a positive attitude toward the brands (5, 26), and consume more unhealthy foods and drinks (7).

Globally, the World Health Organization (WHO), public health advocates and academics have called on governments to restrict the marketing practices of unhealthy food and beverage companies, long before the COVID-19 pandemic. The WHO Set of Recommendations on the Marketing of Foods and Non-alcoholic Beverages to Children sets out that comprehensive marketing restrictions are necessary that cover all forms of marketing mediums and techniques and that protect children up to 18 years of age (27). However, there has been limited comprehensive regulation globally, and online advertising is frequently not included in the scope of government regulations or industry self-regulation to restrict unhealthy food and drink marketing, leaving social media marketing largely unregulated (28–30). In New Zealand, an industry-funded organization representing advertisers, agencies, and the media, called the Advertising Standards Authority (ASA), regulates advertising practices. To do this, the ASA has developed a series of codes of practice. Of relevance to this study is the Advertising Standards Code (ASC) and The Children and Young People's Advertising Code (CYPA Code). The ASC states that "Advertisements must be prepared and placed with a due sense of social responsibility to consumers and to society," and specifically relevant to food, "Advertisements must not undermine the health and well-being of individuals." The CYPA Code states "Advertisements (including sponsorship advertisements) for occasional food or beverage products must not target children or be placed in any media where children are likely to be a significant proportion of the expected average audience."

The objective of this study was to identify, quantify and classify the COVID-19 related marketing strategies used on the public social media accounts of the largest confectionery, snacks, non-alcoholic beverages (sugary drinks) and quick-service restaurant (fast-food) brands in New Zealand. By analyzing the date of posting, themes related to the COVID-19 pandemic, and user engagement with the posts, we aimed to investigate the timing, nature and extent of online COVID-washing by New Zealand's major food and drinks brands during the initial stage of the pandemic. A secondary objective of the study was to identify potential breaches of the ASA Codes in the COVID-19 related posts collected.

MATERIALS AND METHODS

A content analysis of the posts on social media sites belonging to the five major brands for market-share in New Zealand in each of the following the categories: confectionery, snacks, non-alcoholic beverages (sugary drinks), and quick-service (fast-food) restaurants was conducted. These were chosen to ensure a wide variety of food and beverage brands were captured but limited to the top five in each category to allow an in-depth analysis of social media posts across time. Brands were identified from the Euromonitor International 2020 database according to the highest retail value within each category in 2019. Brands that did not sell predominantly energy-dense, nutrient-poor food and beverages were excluded from analyses and replaced by the next brand with the largest sales. Food delivery companies were excluded from this study, because the largest and main food delivery company in New Zealand, UberEats, has the same media platforms as Australia [which were the subject of an Australian study analyzing COVID-19 related posts during the same time period (31)]. Ten of the 20 brands shared the same name and therefore social media platforms as the parent company (e.g., McDonald's and Domino's), but in other cases there were separate social media sites for parent companies that were excluded from this study (e.g., Coca-Cola Amatil NZ which also had a brand page for Coca-cola).

Data (individual social media posts) from brand official public accounts were collected from four digital media platforms: Facebook (posts including photos, videos, and events on homepage); Instagram (posts, pinned stories, and hashtag promotions in the bio); YouTube (videos), and Twitter (Tweets and retweets). These platforms were chosen for the Australian study because they are the most used social media platforms (32). Only brand or company accounts that had been in active use for 12 months (since 1 February 2019) were included in analyses. Only official brand and company generated marketing material and re-posted marketing was included.

For each brand, the following information was collected from all four digital media platforms (where applicable): number of followers; number of posts from February to end May 2020; and number of COVID-19 related posts in the same period. Data were extracted retrospectively in August 2020 for a 4-month time period (1 February to 31 May 2020). The following information was recorded for each COVID-19 related post: screen shots of posts and screen captures of videos on a backed-up and secure cloud-based storage; date of post or launch of marketing campaign; description of product marketed; number of likes/views and shares of posts. COVID-19 themed posts were categorized weekly by date of posting and examined with reference to differing levels of New Zealand government COVID-19 alert level restrictions (15, 16).

Content analysis of the COVID-related themes was based on an existing coding framework (31), and posts that may be potential breaches of the Advertising Standards Authority codes were flagged. Two researchers (KL and BK) captured and coded the posts, with every individual post coded by one researcher. Additionally, 20% of posts from each researcher were re-coded by the other researcher to check for consistency in coding, with 89% agreement found in the coding of COVID-related marketing themes. The discrepancies in coding were decided in discussion with a third researcher (SG). Descriptive frequencies of the themes and engagement with posts were conducted in Microsoft Excel. Three authors (SG, AC, and FS) then analyzed the flagged posts to determine whether they constituted a breach of the ASA Codes. Where there were discrepancies, the authors discussed their rationale to reach consensus.

RESULTS

Quantity of COVID-19 Themed Posts on Social Media

Fourteen of the 20 confectionery, snacks, sugary drinks, and fast-food brands included in the study (70%) had referred to the COVID-19 pandemic in social media posts from the start of February to end of May 2020. A total of 1,368 social media posts from these 14 brands were counted in the 4-month period, and nearly one in three posts was COVID-19 themed (n = 372, 27%). Each brand posted multiple times with reference to COVID-19, although Coca-Cola only posted twice very early in the pandemic. **Six** brands included in the study did not post anything on social media during the 4-month time period related to COVID-19: Cadbury, Bluebird, Doritos, Schweppes, Sprite and L&P (**Table 1**).

Domino's Pizza was the brand with the largest number of COVID-19 themed social media posts; 120 individual posts from the 16 March to end May, which was an average of more than 1.5 posts per day. All five fast-food brands had over 100,000 Facebook followers on their New Zealand sites, with McDonald's and KFC having over one million followers each on Facebook (**Table 1**).

The majority of COVID-19 themed posts were on Facebook (n = 195, 52%), followed by Instagram (n = 106, 29%), Twitter (n = 45, 12%) and then YouTube (n = 26, 7%). Lindt and Whittaker's confectionery brands posted mainly on Facebook and Instagram, whereas M&M'S (Mars) and Kit Kat (Nestlé) used Twitter and to a lesser extent YouTube (**Table 1**). Snack brands favored Facebook, with Arnott's biscuits having the largest number of posts and COVID-19-specific marketing. Sugary drinks brands had a low social media presence (**Table 1**), with the exception of a 12 episode video campaign by V (Frucor Suntory drinks brand) on YouTube during May, entitled "Bored in the House" which featured a media celebrity sharing Tik Tok videos of lockdown activities.

Timing of COVID-19 Themed Posts on Social Media

The first COVID-19 themed social media post was on 6 March by Coca-Cola (on both Facebook and Twitter). The fast-food brands all began to post about COVID-19 in the week prior to the national lockdown being announced on 23 March 2020 (**Figure 1**). Confectionery brands and, to a lesser extent, snack food brands then followed, with COVID-19 themed posts peaking for confectionery and snack foods during the Level 4 and 3 lockdown periods. Fast-food brands continued to post on social

TABLE 1 | COVID-19 themed posts, reach and engagement on social media sites of the largest unhealthy food and beverage brands in New Zealand (1 February 2020 to 31 May 2020).

Brand	COVID-19 themed posts as a proportion of all brand posts (%) Stars indicate number of followers of the brand on each social media platform					Average views[b] per COVID-19 themed post, *n* (range)
	Facebook	Instagram	YouTube	Twitter	Total	
Confectionary						
Cadbury[a]	****0/0	*0/0	*0/0	*0/0	0/0	N/A
Whittaker's	***5/34	**0/8	*0/0	**0/10	5/52	45,124 (694–219,000)
Lindt	****11/86	**17/86	*0/2	0/0	28/174	762 (36–7,800)
KitKat (Nestlé)	****0/2	**0/2	*6/23	***11/62	17/89	559 (43–2,600)
M&Ms (Mars)	*0/0	*0/0	***0/18	***29/243	29/261	1,969 (23–39,100)
Total	16/122 (13.1)	17/96 (17.7)	6/43 (14.0)	40/315 (12.7)	79/576 (13.7)	-
Snacks						
Bluebird	**0/5	*0/0	0/0	0/0	0/5	N/A
Eta	**2/5	1/1	0/0	0/0	3/6	54,423 (35–163,000)
Arnott's	**10/48	**8/44	*0/0	*0/0	18/92	18,147 (42–314,000)
Doritos	****0/21	*0/4	*0/0	0/0	0/25	N/A
Griffin's	***6/17	*0/5	0/0	0/0	6/22	29,094 (107–145,000)
Total	18/96 (18.8)	9/54 (16.7)	0	0	27/150 (18.0)	-
Sugary drinks						
Coca-Cola	***1/2	*1/2	0/0	0/2	2/6	45 (29–60)
Schweppes	0/0	0/0	0/0	*0/0	0/0	N/A
Sprite	**0/2	0/9	0/0	***0/45	0/56	N/A
L&P	***0/9	*0/0	0/0	0/0	0/9	N/A
V (Frucor)	***1/6	*0/0	*12/15	*0/0	13/21	223 (9–1051)
Total	2/19 (10.5)	1/11 (9.1)	12/15 (80.0)	0/47 (0.0)	15/92 (16.3)	-
Fast-food						
McDonald's	****19/60	**6/17	**0/3	*0/0	25/80	2,893 (126–22,000)
KFC	****23/44	**11/14	*1/4	**2/5	37/67	40,660 (8–368,000)
Subway	***33/56	*19/30	4/8	*0/0	56/94	262 (8–313,000)
Burger King	***9/26	**4/7	0/9	0/0	13/42	32,645 (55–242,000)
Domino's	***75/163	**39/91	*3/4	*3/9	120/267	2,144 (1–25,000)
Total	159/349 (45.6)	79/159 (49.7)	8/28 (28.6)	5/14 (35.7)	251/550 (45.6)	-

*Stars indicate potential reach of posts: no star<1,000 followers, *1,000–9,999, **10K+-99,999, ***100K−99,9999, ****1 million or more followers.*

[a]*Cadbury includes the sub-brands Cadbury Dairy Milk, Cadbury Moro, and Cadbury Roses.*

[b]*Number of views per post were used to calculate the average views by brand. Where number of views per post was not available, number of likes per post was used instead.*

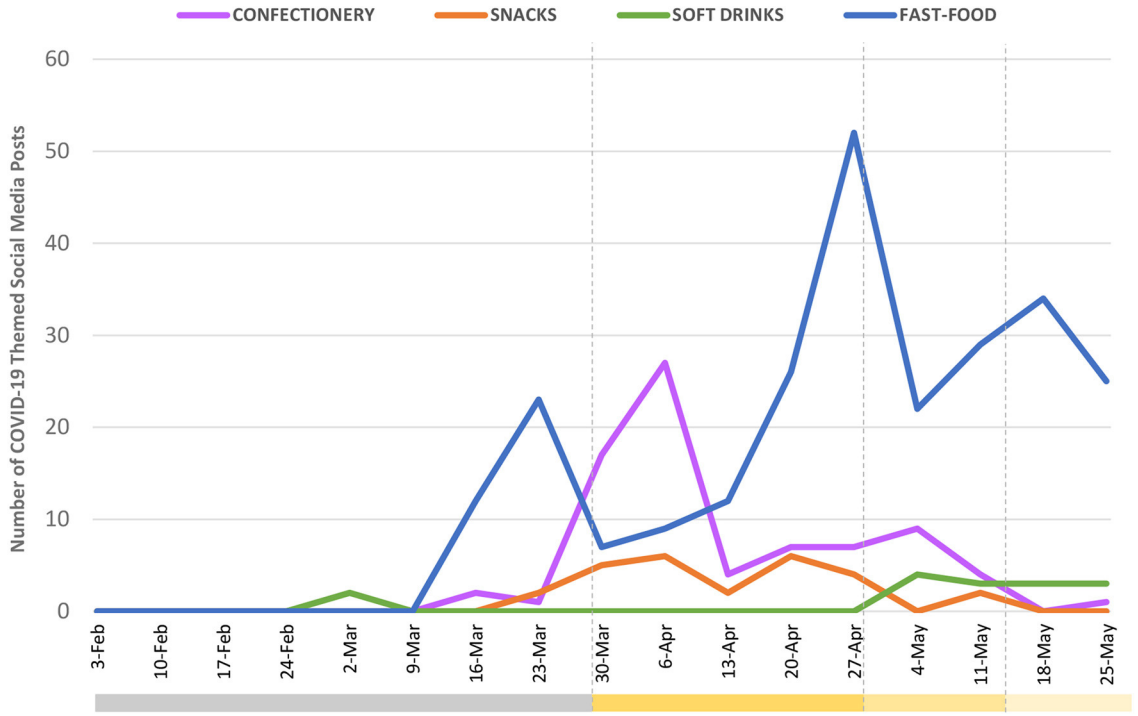
media during the highest level of COVID-19 restrictions (Level 4 lockdown) but with less frequency than before the lockdown, and then toward the end of Level 4 and into the start of Level 3 restrictions the five major fast-food brands reached a height of more than 50 COVID-19 themed posts a week and continued to post until the end of the study period (**Figure 1**).

COVID-19 Related Themes Employed in Social Media Posts

A wide range of COVID-19 themes were used throughout the 4-month period in social media posts from the five major brands in each category (**Tables 2**, **3**). The most commonly used theme, present in 36% of all social media posts about COVID-19, was to draw on feelings of community support during this challenging and unprecedented time with phrases such as *#allinthistogether* (Domino's), "*Kia kaha [Stand strong]*" (McDonald's), "*We know these are challenging times for all of us…*" (Lindt). Domino's had a campaign "*Making ends meet is a struggle, we're here to help!*" whereby the public could have their rent, phone bills or groceries paid by commenting on the post. They also had a Facebook hiring campaign over the lockdown period, stating "*We need 1,000 new team members to safely deliver food to our communities and those on the front-line as we see out this crisis.*"

Home delivery of food (32.3% of COVID-19 themed posts), and the hygiene policies or steps taken by the company to reduce the risk of virus transmission such as contactless payments and physical distancing (32% of COVID-19 themed posts) were the next most common themes (**Table 3**).

The most commonly used COVID-19 theme by snacks and sugary drinks companies in their social media posts was "Isolation Activities" with suggestions for things to do while in lockdown (23% of all posts, but 74% of snack food and



ALERT LEVEL N (ROW %)	N	N/A BEFORE 26 MAR	LEVEL 4 (26 MAR – 27 APR)	LEVEL 3 (28 APR – 13 MAY)	LEVEL 2 (14 MAY – 8 JUN)
Confectionery	79	2 (2.5)	56 (70.9)	17 (21.5)	4 (5.1)
Snacks	27	2 (7.4)	21 (77.8)	2 (7.4)	2 (7.4)
Soft drinks	15	0 (0)	0 (0)	7 (46.7)	8 (53.3)
Fast food	251	6 (2.4)	55 (21.9)	108 (43.0)	82 (32.7)
Total	**372**	**10 (2.7)**	**132 (35.5)**	**134 (36.0)**	**96 (25.8)**

FIGURE 1 | Weekly COVID-19 themed social media posts by the major unhealthy food and drinks brands in New Zealand, during pandemic response alert level periods (February to May 2020).

87% of sugary drinks posts) (**Table 3**). Examples of this are shown in **Figure 2**, and include recipes for home-made versions of their products (Arnott's), coloring sheets, scavenger hunts and quizzes. Some of these types of posts were directed at parents of young children, encouraging them to print out coloring sheets (with branded characters or pictures of product) or to give their products as rewards for isolation activities. Several brands capitalized on the nationwide Teddy Bear Hunt phenomenon (33), where people would put bears in their street facing windows so children could count bears when on neighborhood walks. When Easter coincided with the lockdown, Easter Eggs became a substitute "bear in the window" promoted by confectionery companies.

"Consumption helps with coping" was another reoccurring theme in the social media posts, particularly from snack food and fast-food brands (**Figure 3**). These posts often sympathized with or encouraged followers to share how much they missed the food product during the lockdown Levels 4 and 3 when fast-food businesses were closed. KFC had a competition asking followers to share a photo of their "home-made KFC" and McDonald's shared a Big Mac sauce recipe. As Level 2 approached, the theme in COVID-19 related posts shifted to be about the reopening; "*Tell us which sub you're grabbing first!*" (Subway Facebook), "*When Macca's reopens my first order will be...*" (McDonald's).

Some COVID-19 related social media posts used the opportunity to applaud health care staff or essential workers and publicize donations of food to either front-line workers or foodbanks. Domino's encouraged followers to nominate supermarket, hospital, pharmacy and rest home workers to receive free pizza, and confectionery brands Kit Kat and Whittaker's had "*Thank you*" posts aimed at healthcare workers, produce pickers and street cleaners. Three fast-food brands used social media posts to convey that they had donated food which would have gone to waste when their restaurants shut (Domino's, McDonald's and Subway).

TABLE 2 | Coding categories of themes in COVID-19 related social media posts and example posts.

COVID-19 themes	Definition	Examples
Trading/event updates	Practical updates around trading hours, opening/closing stores, events (excluding delivery)	"… We're opening all drive-thru restaurants this Tuesday for contactless drive-thru, pick-up when ordering via the BK App, and delivery via Uber Eats. And we're taking extra safety measures to make sure you, our team and our community stays safe. We can't wait to see you. At a distance of course" (KFC, Facebook) "Light at the end of the tunnel! Our Drive-Thrus are open now. Check your local Macca's is open at mcdonalds.co.nz #MaccasNZ" (McDonald's, Instagram) "BK is back! We've got contactless pick up through the BK App, Drive Thru and delivery options to give you the flame-grilled flavor you've been yearning for. And we're taking extra safety measures to make sure our guests, our staff and our community stays safe. Check our website for more details: https://www.burgerking.co.nz/reopening and meanwhile, tag someone who needs that flame-grilled fix!" (Burger King, Instagram)
Home delivery/take away in lock down period	Home delivery/take away in lock down period/ no need to leave the house/using Uber eats (should include a specific mention of e.g., unusual times; difficult times/ staying at home etc.)	"…Get contactless takeaway for all your Subway® faves. Pre-order online or via the Subway® App, or get it delivered with Uber Eats." (Subway, Instagram) "After each pizza leaves our 250 degree ovens, the only hands that touch them, are yours. Stay home, stay safe with Zero Contact Delivery." (Domino's, Instagram) "How's this for the ultimate come back? Contactless drive-thru, and delivery is coming very soon, check here regularly for updates" (KFC, Facebook)
Hygiene/zero-contact	Referring to reducing chances of virus spread through hygiene practices when preparing food or handling food/drinks, social distancing by employees and customers (e.g., contactless, zero-contact, keeping community safe)	"Why did Domino's deliver me an empty box?! When you order a Zero Contact Delivery at Domino's, the Delivery Expert will place your order in front of your door before moving back to a safe distance. In the event that a suitable surface is not available, your order will be placed on an empty box to keep it off of the ground. For more information, please visit: http://bit.ly/ZEROCONTACT" (Domino's, Instagram) "The safety of our guests, team, and community is our top priority... We encourage you to use the BK App for your take-away and drive-thru orders to minimize person-to-person contact." *Description of visual: 'YOUR SAFETY IS OUR PRIORITY…'. Burger King paper bag and a burger on a table with blurred background.* (Burger King, Facebook)
Community support/feeling	Mentions something like: Standing together in this challenging/unprecedented/unexpected times/you're not alone/we're in the same boat/we are here to support you	"WE'RE HERE TO HELP Making ends meet is a struggle many Kiwi's are facing at this time, and we're here to help. For the next month, Domino's is helping to pay your bills, starting with RENT! Head to our Facebook page to see how you could get your rent paid by Domino's! Terms: https://bit.ly/BILLSTERMSNZ" *Description of visual: 'PAID BY DOMINO'S' in white text on blue background.*
Applaud health care staff or essential workers	Specifically referencing/thanking essential workers, health workers, front line workers etc.	"Hello Nurses, we just wanted to show our support for all the amazing work you do to keep us safe" *Description of visual: Picture of four Whittaker's bars forming a white cross with a red colored background.* (Whittaker's, Facebook) "As a proud New Zealand food manufacturer, Griffin's is classed as an Essential Service and we are working closely with our suppliers and retailers to ensure we can continue to bake New Zealand's favorite biscuits, helping keep the shelves stocked. We'd also like to take this opportunity to thank our incredible team, supply chain and retail staff, who are working tirelessly to keep up with the increased demand in these uncertain times. Take care, be kind and lets all #shopnormal" *Description of visual: Shape of New Zealand created in assorted cookies, on a white background.* (Griffin's, Facebook) "The world is forever grateful to you for not having a break right now. #ThankYou" *Description of visual: Image with gray text on white background: 'Dear courageous double shift healthcare workers. The world is forever grateful to you for not having a great right now....'* (KitKat, Twitter)
Donations	References to (large scale) product or monetary donation	"Help us uncover the critical organizations near you who are going above & beyond. We're saying thanks by delivering chocolate to essential services in Porirua. Now we want to go wider. Add your Lockdown Legend to our registry." *Description of visual: Picture of medal with a Whittaker's chocolate block that directs to a link for to nominate a 'lockdown legends'.* (Whittaker's, Facebook) "Do you know a frontline team that deserves pizza on us during this time? Tell us what organization you'd like to nominate below and why they are so outstanding as we would love to surprise a few nominations" *Description of visual: 'Nominate A FRONTLINE TEAM WHO DESERVES DINNER ON US' in white text on blue background with an image of a woman holding a stack of pizza boxes.* (Domino's, Facebook)
Isolation Activities	Suggestions for things to do while in isolation/social distancing that relate to or include brand use or promotion: e.g., recipes	"We're hearing from a lot of people who are missing their Macca's fix. The good news is there's no secret to our Big Mac special sauce. So, if you fancy trying your own lockdown version, check out this clip from our friends McDonald's Canada. Give it a go and let us know how you get on! https://youtu.be/rcu4Bj3xEyI" *Description of visual: Close-up shot of a double patty burger with cheese oozing out.* (McDonald's, Facebook)

(Continued)

TABLE 2 | Continued

COVID-19 themes	Definition	Examples
Consumption helps coping with COVID-19	Contains themes around: consumption makes you feel better/"you deserve it"/surviving COVID-19 at home/comfort food	"100% no judgment here…" *Description of visual: @dominos_NZ status: 'Not sure who needs to hear this, but you can order Domino's more than once today. It's OK.'* (Domino's, Facebook) "We'd tell you to choose wisely... But you really can't go wrong" *Description of visual: "WHICH MENU ITEMS WOULD YOU ISOLATE WITH?" on orange background. 'Bubble 1 [BK items]...Bubble 2 [BK items]...Bubble 3 [BK items]....'* (Burger King, Instagram)
Supporting local business/trading partners	Suggestion for consumer to support local businesses or announcements that the brand or company supports local businesses or their trading partners	"We're proud of our amazing teams, who have been doing a great job in tough circumstances, like so many other Kiwis. Many of our teams just want to say thanks—"Huge thank you to Cromwell for sticking by us and supporting us! Simply incredible. We can't thank you enough!"—From Suzy, Elena, Jayne, Courtney and Suzanna from the Cromwell restaurant family. #subwaynz" *Description of visual: Picture of subway staff (x5) in store with 2 wearing Subway green shirts.* (Subway, Instagram)
(Mental) health advice	Posts include health or mental health advice with reference to COVID-19	"We won't let anything get in the way of you and your sub, not even a little <-social distancing–>…" *Description of visual: 'About seven of these'; image of a footlong sub on square tile with yellow background. Subway logo in bottom right corner.* (Subway, Facebook and Instagram) "With even more measures in place at our restaurants, we're able to continue serving you fresh food, conveniently and safely. #subwaysafe" *Description of visual: 'Sanitize before entering' in white letters on green background. Icon of spray bottle disinfectant underneath.* (Subway, Facebook)

Coding framework was developed by Martino et al. (31).

TABLE 3 | COVID-19 related marketing themes and strategies used in social media posts by 20 major unhealthy food and drinks brands in New Zealand (1 February 2020 to 31 May 2020).

COVID-19 related marketing theme	Number of posts containing each theme, by brand categories (column %)				
	Confectionery *N* = 79	Snacks *N* = 27	Sugary drinks *N* = 15	Fast-food *N* = 251	Total *N* = 372
Trading/event updates	4 (5.0)	3 (11.1)	0 (0.0)	68 (27.1)	75 (20.2)
Home delivery/take away in lockdown period	1 (1.3)	0 (0.0)	0 (0.0)	119 (47.4)	120 (32.3)
Hygiene/zero-contact	3 (3.8)	0 (0.0)	2 (13.3)	113 (45.0)	118 (31.7)
Community support/feeling	48 (60.8)	10 (37.0)	0 (0.0)	77 (30.7)	135 (36.3)
Applaud health care staff or essential workers	12 (15.2)	2 (7.4)	0 (0.0)	21 (8.4)	35 (9.4)
Donations	3 (3.8)	0 (0.0)	0 (0.0)	18 (7.2)	21 (5.6)
Isolation activities	36 (45.6)	20 (74.1)	13 (86.7)	18 (7.2)	87 (23.4)
Consumption helps coping with COVID-19	8 (10.1)	10 (37.0)	2 (13.3)	61 (24.3)	81 (21.7)
Supporting local business/trading partners	4 (5.0)	1 (3.7)	0 (0.0)	15 (6.0)	20 (5.4)
Other, hiring and financial hardship campaigns	0 (0.0)	4 (14.8)	0 (0.0)	11 (4.4)	15 (4.0)

N = Total number of posts. Posts could be coded for multiple themes so the columns do not add up to 100%.

Reach and Engagement of COVID-19 Related Social Media Posts

The potential reach of social media posts from unhealthy food and drink brands is large, given that on Facebook six of the 20 brands had more than 1 million followers each, and a further 8 brands had between 100,000 and 999,999 followers each (**Table 1**). Follower engagement (views and likes) with posts on the brand's social media accounts varied widely, with some posts receiving single-digit views/likes while other posts had received over 300,000 views/likes. The COVID-19 themed post with the largest number of views/likes was from KFC, repeated on Facebook, Instagram and YouTube, with a video of a person in a life-size branded character doing a dance routine. The posts stated *"Cutting shapes in lockdown - can you move like the Colonel? A 2-minute routine designed to help you move those wicked wings and dip low like you would those chips in gravy. Are you ready to take on the #ColonelsChallenge?*" Across the three platforms this post was seen by 487,847 viewers.

Potential Breaches of the Advertising Standards Authority Codes

Six COVID-19 related posts were identified that potentially constitute a breach of a specific clause in one of New Zealand's ASA Codes (detailed in **Table 4**). Four advertisements may have breached the CYPA Code by targeting children with unhealthy food and beverage marketing, and two others may have breached

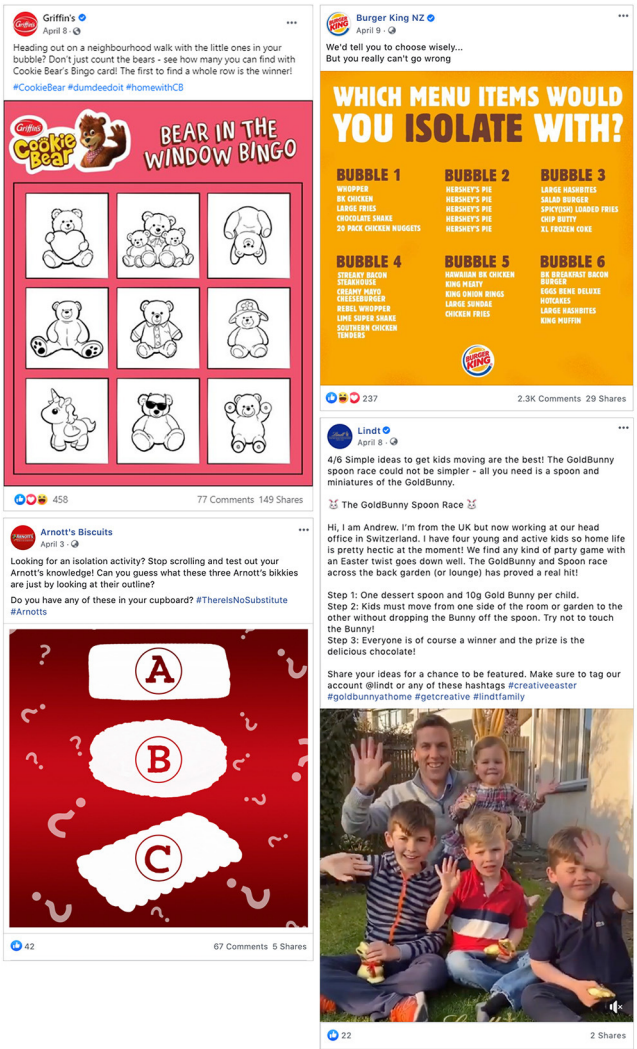


FIGURE 2 | Examples of "Isolation activity" COVID-19 themed social media posts.

FIGURE 3 | Examples of "Consumption helps with coping" COVID-19 themed social media posts.

the ASC Code by encouraging excessive consumption in the general population. Because of the vague language of the Principle in the ASC that states "Advertisements must be prepared and placed with a due sense of social responsibility to consumers and to society," and "Advertisements must not undermine the health and well-being of individuals" it is arguable that all unhealthy food and beverage brands promoting consumption of their products with COVID-washing techniques were undermining the ASC.

DISCUSSION

COVID-Washing by New Zealand's Major Food and Drinks Brands

This study provided an empirical examination of the marketing practices and "corporate social responsibility" strategies employed by New Zealand's major food and drinks brands during the COVID-19 pandemic, finding that the majority used COVID-washing to promote their brands and products, attaining significant reach and engagement through this tactic. Fast-food companies were the worst offenders, with a rapid increase in the number of social media posts just prior to the end of Level 4 restrictions. This is arguably when many viewers would be most vulnerable to "comfort" or binge eating due to the jubilation of being out of lockdown and relief at the end of a prolonged period of heightened stress caused by the pandemic (36–38). The COVID-related themes commonly used by unhealthy food and drink brands in social media posts were analogous to those found in studies globally (17, 31), with "community support," positioning themselves as "in this together" with consumers, and "applauding health staff and front-line workers" common narratives. A similar study in Australia found the same level of COVID-washing in social media posts, whereby one-third of all posts by the "Big Food and Drinks" brands during the same 4-month period were COVID-19 related, and fast-food companies were also the largest proponents of COVID-washing (31).

TABLE 4 | Possible breaches of the Advertising Standards Code and the CYPA Code on social media, February to May 2020.

Brand (Platform)	Explanation	Relevant ASC or CYPA Code principles, rules, and guidelines.	ASC (34) or CYPA Code (35) principles, rules, and guidelines.
Whittaker's (Facebook)	Video of a child coloring in a easter egg on a piece of paper with the title 'The Big New Zealand Easter Egg Hunt'	**ASC** Principle 1: Rule 1(h) **CYPA** Principle 1: Rule 1(i)	**ASC Principle 1:** Advertisements must be prepared and placed with a due sense of social responsibility to consumers and to society **Rule 1(h):** Advertisements must not undermine the health and well-being of individuals **Guideline:** Advertisements for food or beverages must not condone or encourage excessive consumption **CYPA Principle 1:** Advertisements targeted at children or young people must not contain anything that is likely to result in their physical, mental or moral harm and must observe a high standard of social responsibility. **Rule 1(i):** Advertisements (including sponsorship advertisements) for occasional food or beverage products must not target children or be placed in any media where children are likely to be a significant proportion of the expected average audience **CYPA Principle 3**: A special duty of care must be exercised for Occasional Food and Beverage Product sponsorship advertising targeted to young people. **Rule 3(a):** Sponsorship advertisements must not show an occasional food or beverage product, or such product's packaging, or depict the consumption of an occasional food or beverage product.
McDonald's (Facebook)	"Maccas...Survived 5 weeks without Nuggies....Achievement Sticker"; graphic on yellow background.	**ASC** Principle 1: Rule 1(h) **CYPA** Principle 1: Rule 1(i)	
Griffin's (Facebook)	"BUBBLING LAVA CHALLENGE"; "CAN YOUR FAMILY AVOID THE LAVA TO EARN A BIKKIE" in white text on red background; CookieBear logo in bottom right corner.	**ASC** Principle 1: Rule 1(h) **CYPA** Principle 1: Rule 1(i)	
Domino's (Facebook, Instagram, Twitter)	"Not sure who needs to hear this, but you can order Domino's more than once today. It's OK."	**ASC** Principle 1: 1(h) **CYPA** Rule 1(i)	
Domino's (Facebook, Instagram)	2 hands pulling apart a cheesy slice of pizza in front of a white brick wall. "The only stretching I'll be doing in ISO ☺"	**ASC** Principle 1: Rule 1(h)	
V (YouTube)	Video series titled "The Vibe" and these episodes are titled "Bored in the House"	**ASC** Principle 1: Rule 1(h) **CYPA** Principle 3: Rule 3(a)	

The COVID-19 pandemic provided an opportunity for food and beverage companies to market themselves as caring and contributing members of a society during a time of unprecedented crisis, and thereby increase the desirability of their brands and the products they sell. Social media posting was a way to rapidly share advertising content and reach a wide audience, as most of the population was following stay-at-home orders and spending more time than ever before online (39). This type of corporate activity sits squarely within the understanding of the commercial determinants of health. Kickbusch et al. (20) outline four ways in which commercial determinants of health occur, two of which were demonstrated in our study: first, marketing practices which enhance the desirability and acceptability of unhealthy commodities, and second, "corporate social responsibility" strategies to "whitewash" or, in this case "COVID-wash" in order to maintain a good reputation (20).

Potential Breaches and Issues of the Advertising Standards Authority Codes

Relatively few posts were considered to breach the CYPA Code, and it was hard to interpret whether COVID-washing advertisements breached the broader ASC Principle as the wording in the ASC is too vague. If the CYPA Code was broader in scope, and in line with the WHO Recommendations, then more brand advertising would have been considered to be in breach as many advertisements targeting children only contained the brand rather than the actual product. For the ASC, the only clear breaches were those that "encouraged excessive consumption" as outlined in the Guidance of the ASC for Rule 1(h), such as Domino's Pizza stating *"Not sure who needs to hear this, but you can order Domino's more than once today. It's OK."*

The findings of this study query whether unhealthy food and beverage companies were showing a "due sense of social responsibility to consumers and to society" as required under the New Zealand ASC, and whether their COVID-19 related postings "undermine the health and well-being of individuals" (34). The encouragement by social media posts to consume foods and drinks which are known to increase the risk of overweight and obesity (36) seems particularly unconscionable, given that people with obesity have a higher risk of COVID-19 complications and intensive treatments (40, 41). New Zealand research (42) echoes studies internationally (43–46) that adult diets were adversely impacted during the Level 4 and 3 lockdowns, with an overall shift toward an unhealthy dietary pattern characterized by increased sweet and salty snacks, sugary drinks and alcohol. Adults experiencing the most stress, for instance those who had lost income or were juggling working from home with childcare, were the most likely to have a detrimental change in their diet (42). The findings suggest that there is a significant proportion of the population–indeed around 30–50%–that are susceptible to "comfort eating" during times of increased stress, and this group may have been even more vulnerable to marketing of unhealthy food products (9, 10, 47). Unless the ASC is extended to include this type of marketing in its scope, vulnerable populations are left unprotected against such advertising tactics.

In addition to vulnerable adults, the ASA self-regulatory system is also ineffective at protecting children from the exposure to, and power of, unhealthy food and beverage marketing, with only one complaint being upheld since the introduction of the CYPA Code in 2017 (48). Specifically, when considering the COVID-washed advertisements, the CYPA Code falls short in protecting children against three reasons. First, the ASA Complaints Board does not consider any social media marketing

to "target children" as children under 13 cannot legally access social media platforms. Most social media platforms (Facebook, Twitter, and Instagram) require the viewer to be at least 13 years of age to set up an account and access content. However, it is clear that these restrictions can be circumvented by children who may use their parents or other adults details or misrepresent their age (49–51). A representative survey of New Zealand children aged 6–14 years in March 2020 found that 19% used Instagram and 9% used Facebook, mostly daily or weekly, and only 1% used Twitter (52). YouTube was the most common place for children to watch programs and shows; half of New Zealand children aged 6–14 years old watched YouTube daily and most of them were by themselves when looking at this content (52). The United Kingdom (UK) has recently announced a policy proposal to ban all online marketing of unhealthy food and beverages due to the complexities of the digital environment and the realities of the amount of online advertising children are exposed to that can go unregulated. The UK Government considers a full online marketing ban is required because of the absence of any independent, comprehensive, industry-recognized, gold-standard and publicly available means of measuring who the final audience is of any online content and its associated advertising (50).

Second, many of the advertisements on social media promote a brand, not a product, and unless a food or beverage product or packaging is shown or mentioned in the advert in a way i.e., appealing to children, it is not in scope of the CYPA Code. For example, Griffin's used the Cookie Bear brand icon to promote children's isolation activities like bear hunts or scavenger hunts, but they did not always mention or show a biscuit. Four COVID-19 themed social media posts were identified that used a brand to employ techniques which would appeal to children, but have not been included in **Table 4** as under the current CYPA Code these would not be upheld. Whilst brand marketing is not explicitly included in the WHO recommendations (27) it is now widely recognized that branding is an important element of marketing and should be included in the regulatory design of marketing policies (30).

Third, the COVID-19 themed advertisements often targeted children through their parents, consequently circumnavigating the Code. For example, posts encouraged parents to give their children a branded product as a "treat" or a "reward," or created competitions like Easter egg hunts and coloring competitions using branded material, which ultimately were designed to reach children and increase their brand awareness and engagement (6). For example, Lindt encouraged parents to give the gift of a Lindt Easter bunny to their children using images of children enjoying Lindt chocolate bunnies. These posts would not be considered breaches because the audience is parents rather than children.

Strengths and Limitations of the Study

This paper adds to an emerging literature base on the commercial determinants of health, specifically related to corporate marketing. Measuring and evaluating unhealthy commodities' corporate practices, such as the extent of advertising and corporate social responsibility strategies, can be difficult as there is limited publicly available data, but it is a requirement of the public health community to counter the barriers to monitoring these practices. This study, along with other studies monitoring corporate practices during the COVID-19 pandemic (17, 31) provide methods for future studies. The study highlights the important role that public health civil society organizations play in holding the food and beverage industry to account for their role in diet-related diseases (53, 54). In New Zealand, groups such as the INFORMAS Network (55), Healthy Auckland Together (56) and Health Coalition Aotearoa (57) play an important role in advocating for NCD prevention.

The main limitation of the research is due to the scope of which social media platforms and postings were included in the study. Only five major brands from each unhealthy food and drinks category were included, which would have missed other brands and companies that also used COVID-washing techniques during the same time period. This study only looked at the promotion of unhealthy brands and was focused on those with the largest market share, which may not have been the most prolific users of social media marketing. Further, corporate social responsibility activity is usually advertised through parent company websites and social media accounts (31) and because this study focused on brands, the extent of COVID-washing by "Big Food" is likely to be under-reported. Additionally, only four social media platforms were consequently the extent of COVID-washing would be under-reported in this study. Additionally, only four social media platforms were included in the study and food and beverage advertising on other social media platforms was not captured (e.g., TikTok, Snapchat, and others). While popular with young people, Snapchat and TikTok were excluded from analysis because Snapchat use private messaging only, and TikTok private accounts are not yet widely and effectively utilized by the selected brands. Also television, radio and other mediums such as billboards were not included. The study did not include paid (sponsored) advertisements, which target consumers specifically as these are difficult to obtain these retrospectively. Finally, user generated content was not included in the research, such as tagged posts or comments.

Recommendations and Conclusion

The current study adds further evidence that more comprehensive regulatory mechanisms are required to adequately protect New Zealanders from the marketing practices of the unhealthy food and beverage industry (23, 48, 58), particularly on Facebook where the COVID-washing posts were most prolific and had the most engagement. Social media platforms often have policies that prohibit or restrict the advertising of products and/or services relating to alcohol, tobacco, gambling, and/or weight loss to under 18 year-olds but unhealthy food and drinks marketing appears to have escaped scrutiny to date (59). This study highlights the inadequacy of the industry-led ASA self-regulatory system and demonstrates the need for a government-led approach, which is free from conflicts of interest, to effectively protect children from economic exploitation by these large trans-national brands and companies. Comprehensive legislation protecting children up to 18 years old from all forms of unhealthy food and beverage marketing is urgently required to address New Zealand's child obesity rates

and to uphold the United Nation's Convention on the Rights of the Child (48), similar to current policy proposals for a blanket ban on online food marketing in the UK (50). Additionally, a more robust government-led code of practice is needed to ensure the general population is protected from unhealthy commodity industries misappropriating a time of crisis to promote their products that directly contribute to poor population health. While, the principles and guidelines of the ASA Codes are commendable, in reality they are not as effective or enforceable when part of a self-regulatory scheme.

Future regulation must reconsider the way we determine whether marketing is "targeted" or "directed" at children. The definition to date has not been fit for purpose as children are exposed to multiple forms of marketing in the food environments they live in, and in the online space, and so it is particularly difficult to identify marketing i.e., specifically targeted at children. Much of the social media posts found in this study could be said to be aimed at parents, even though the call to action in the posts was ultimately aimed at children, for example branded coloring in sheets for parents to print out for their children. The definition of marketing must also include "brand marketing" to ensure those brands with a high percentage of unhealthy products are also prohibited from marketing their brand and brand icons to build brand loyalty.

In conclusion, many of the social media posts from New Zealand's unhealthy food and drinks brands during the first half of 2020 could be termed "COVID-washing," that is, the misappropriation of social concern about the pandemic in order to promote unhealthy products and build brand loyalty. The COVID-19 epidemic left many people feeling isolated or stressed, which increased their vulnerability to "comfort eating" or binge eating, and led to increased unhealthy food and beverage purchasing and intake. Additionally, some social media posts were targeted at children. Given the circumstances, COVID-washed social media posts by unhealthy food and drinks brands were irresponsible and undermined public health.

DATA AVAILABILITY STATEMENT

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found at: Center for Open Science Framework (OSF) https://osf.io/nbj4q/.

AUTHOR CONTRIBUTIONS

SM, AC, and SG conceived the study. FM and KB designed the analysis. KL collected and coded the data. SG and KL undertook the analyses. SG and FS wrote the draft manuscript. All authors contributed to the interpretation of findings, writing the manuscript, and approved the final version.

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Changes in Food Consumption During the COVID-19 Pandemic: Analysis of Consumer Survey Data From the First Lockdown Period in Denmark, Germany, and Slovenia

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This paper focuses on changes in food consumption that occurred during the COVID-19 pandemic. Its objective is to map changes at individual consumer level and identify the influence of different factors related to the COVID-19 pandemic on changes in individual food consumption. We conducted a cross-sectional online survey among 2,680 residents of Denmark (DK), Germany (DE), and Slovenia (SI) using quota sampling for gender, age and regional distribution. Data on consumption frequencies before and during the pandemic were collected with a food frequency questionnaire in the spring of 2020 (during the first lockdown period) for important types of fresh food and non-perishable food. Our results showed that, depending on the type of food, 15–42% of study participants changed their consumption frequency during the pandemic, compared to before. In all the study countries, the food categories with the highest rates of change were frozen food, canned food, and cake and biscuits; among the food categories with lower rates of change were bread, alcoholic drinks, and dairy products. People across all three countries shopped less frequently during lockdown and there was an overall reduction in the consumption of fresh foods, but an increase in the consumption of food with a longer shelf life in Denmark and Germany. Interestingly though, we observed diverging trends in all food categories analyzed, with some people decreasing and others increasing their consumption frequencies, demonstrating that the pandemic had different impacts on people's lifestyles and food consumption patterns. Using the method of multinomial regression analysis, we identified factors significantly ($p < 0.01$, $p < 0.05$, $p < 0.1$) related to increases and decrease in individuals' consumption frequencies in different food categories. The factors include restrictions put in place in response to the pandemic (i.e., closure of physical workplaces, canteens, cafés and restaurants, schools, and childcare institutions), changes in households' grocery shopping frequency, individuals' perceived risk of COVID-19, income losses due to the

pandemic, and socio-demographic factors. Interesting differences between the countries were detected, allowing insights into the different food cultures. Conclusions include implications for policy-makers and actors in the food supply chain on the issues of healthy diets, food system resilience, and behavior change.

Keywords: COVID-19, food choice, food consumption, behavior change, lockdown measures, food cultures, online survey

INTRODUCTION

Food is key to personal health [e.g., (1)], as well as to the health of the planet given that current patterns of food production and consumption have considerable environmental impacts (2). Conversely, disasters such as the COVID-19 pandemic can disrupt our food system (3) and change our relationship with food. For instance, in an effort to reduce the spread of infection, border and other logistic restrictions limiting the flow of goods and people increased the risk of food shortages due to impaired supply chains, including those related to labor shortages [as can be seen in the US and Europe, (4, 5)]. Furthermore, the partial or complete lockdown measures introduced at regional and national levels, such as the closure of schools, universities, workplaces, non-essential shops and restaurants, banned events, and travel and mobility restrictions, likely changed the way people accessed their food, where they ate, and how their food was prepared. Some of these measures have served as a further obstacle to the distribution of food to vulnerable populations. For example, some programmes that provide main meals for school children were not operational during confinement. Additionally, quarantine due to illness or coming into contact with infected people may have further restricted people's access to food.

A variety of COVID-19 related psychological changes might have also affected food-related behaviors. Even in areas with relatively low disease risks, people were exposed to extensive communication about the risks of COVID-19, which was likely to have caused some of them stress. Such people may try to cope through stress-related eating, in which they attempt to make themselves feel better by eating or drinking when under stress [e.g., (6, 7)]. For example, during lockdown in Italy, people increased their consumption of processed "comfort foods," such as chocolate, chips, and snacks (8, 9), and in some cases this was due to anxiety about their eating habits during COVID-19 (10). A study from Denmark also observed a higher degree of emotional eating during the lockdown, e.g., increased consumption of pastries and alcohol (11). In Norway, it was found that consumption of high sugar food and beverages was greater for those with increased COVID-19 related worries and general psychological distress than the overall population (12).

Risk perception associated with COVID-19 may influence people's food purchase and consumption behaviors. For example, people may try to minimize the risk of being infected by increasing their use of delivery services, purchasing more packaged food, which is seen as being more hygienic (8), buying food with a longer shelf-life (and thus purchasing less fresh food), in order to limit their shopping trips, or eating more healthy food in an attempt to boost their immune system [e.g., (13)]. Additionally, people's concern about possible food shortages may have influenced purchasing behavior, e.g., stocking up on certain foods [e.g., (8)].

It has been shown recently that COVID-19 might present additional health risks due to the metabolic impact of overeating under conditions of home confinement (14). Ammar et al. (44) reported an increase in unhealthy eating patterns based on their international survey on physical activity and eating behavior (N = 1,047, April 2020), something that was also observed during lockdown in a Polish national cross-sectional study (N = 1,097) by Sidor and Rzymski (15). About half of the participants reported more eating and snacking, while these tendencies were more pronounced in overweight individuals (15).

In Italy, which was affected much earlier and more seriously by COVID-19 than most other European countries in the first wave of the virus, a total lockdown was introduced at the national level in March 2020. A study by Scarmozzino and Visioli (9) was conducted on 1,939 participants (using a snowballing sampling approach) in April 2020 and showed that about 20% of them gained weight. This study also found and highlighted the increased consumption of processed "comfort foods," such as chocolate, desserts, and snacks. These observations were partially confirmed by a food consumption study which investigated changes in the sale of food in over 10,000 Italian stores (8), showing an increase in the consumption of pasta, flour, eggs, long-life milk and frozen foods, alongside a reduction of fresh food purchases. This study also reported a drop in the sale of snacks, particularly sweet ones, in relation to homemade desserts, although there was an increase in savory snacks. Interestingly, the results of a COVIDiet Study, conducted on a very large sample (N = 7,514; snowball sampling approach) in Spain (a country also severely affected by COVID-19) showed that confinement in general led to the adoption of healthier dietary behaviors, measured as adherence to the Mediterranean diet (13).

While the above-mentioned studies focused on the general population, some studies specifically targeted younger people. A study of 820 adolescents (aged 10 to 19 years) from Italy, Spain, Chile, Colombia, and Brazil showed that COVID-19 confinement notably influenced dietary habits and modified consumption of both processed foods and fruits and vegetables (16). Gallo et al. (45) investigated the impact of COVID-19 isolation measures on Australian university students and observed increased snacking frequency and the energy density of consumed snacks. Increased energy intake was observed in females (but not males), while physical activity was impacted for both sexes – the proportion of students with "sufficient" physical activity levels was about

30% lower, in comparison with data collected in the years 2018 and 2019.

Studies by consulting companies – addressing changes in shopping behavior during COVID-19 across different product categories (food and others) – reported a marked shift across all categories to "mindful" shopping, "trading-down" to less expensive items (17), and in particular a strong focus on "essentials" (17–19). Groceries was the only product category in which consumers across all countries consistently anticipated spending more (17, 19).

The above literature regarding changes in food purchase/consumption patterns during COVID-19 documents general trends, but does not relate them to specific changes in people's circumstances due to the pandemic and resulting lockdown. Making such linkages is important in order to be able to identify the mechanisms underlying such changes, so that more accurate projections of the effects of COVID-19 can be forecast, and measures can be effectively targeted toward minimizing their negative effects on food consumption. Therefore, the main aim of our research was to understand the changes in food consumption behavior and identify the factors influencing individual changes in the food consumption frequencies of different food categories, such as fresh food, preserved food, sweet snacks, and alcoholic drinks.

To do this, we examined three countries that were similarly affected by COVID-19 infection rates in the first wave, but which varied in the extent of their lockdown measures: namely, Denmark, Germany, and Slovenia. The specific examples of government measures in the three study countries (**Supplementary Table 1**) illustrate how different households were affected by restrictions in different ways, e.g., not everybody was required to work from home.

To avoid some confounding factors, the study was conducted simultaneously using online panel surveys in late April and early May 2020 in three European Union countries – Denmark, Germany, and Slovenia. The three countries are comparable in terms of all having prompt and extensive government restrictions imposed at the beginning of the pandemic. On the one hand, these lockdown measures considerably limited the spread of the disease at a very early stage of the first wave of the pandemic, but on the other hand, they seriously affected people's lives. Although this paper is focused on changes in food consumption, given the scale of the pandemic and its effects on the food supply system, changes in people's food-related behavior are also likely to have implications for the resilience of food systems.

CONCEPTUAL FRAMEWORK

We developed a conceptual framework of factors that potentially caused changes in food consumption at the level of the individual consumer during the pandemic (**Figure 1**), building on two strands of literature: food choice process, and behavior change.

The interplay between food-related behaviors forms the core of our framework (**Figure 1**), i.e., the processes of consuming (what, where, with whom, how often), obtaining (where, how, how often), and preparing food (what, how). Food-related behaviors are influenced by the personal food system, i.e., food-related values and strategies, which in turn are influenced by personal factors, resources, and ideals (20, 21). We introduced a dynamic perspective by recognizing that food consumption *during* the pandemic is related to food consumption *before* the pandemic.

The framework further recognizes that individual-level (changes in) food consumption patterns are embedded in a complex system of multilevel factors (22), including the household level and the broader micro- and macro-context (23). We further drew upon dynamic behavior change models (24) based on Bandura's (25) social cognitive theory and concept of reciprocal determinism, postulating that personal, contextual, and behavioral factors create a feedback loop and influence each other. We thus suggest that personal experiences with changes in food-related behaviors during the pandemic potentially influence future behavior after the pandemic and might also lead to changes in personal food-related values and strategies.

Figure 1 maps the most important changes the pandemic (potentially) brought about in the study countries. This illustrates that government restrictions and lockdown measures (along with restrictions imposed by the private sector) had profound impacts on the micro- and macro-contexts of food choice. For instance, the closure of physical workplaces and the closure of schools and day care institutions interrupted people's daily life and potentially changed how, where and with whom individuals ate meals and snacks. The same applies to the closure of work canteens, cafés and restaurants, and the restrictions on private gatherings. Government recommendations to stay at home are likely to have affected how often (and where) people went food shopping.

At the personal level, we expected that the individual risk perception of COVID-19 might have caused changes in food consumption. One proposition is that people concerned about the disease would eat more healthily in order to strengthen their immune system [e.g., (13)]. An alternative proposition is that people anxious about COVID-19 might drink more alcohol and eat more comfort foods, such as snacks and cake, in order to better cope with the situation [e.g., (6, 7, 11). The pandemic also had potential impacts on households' food-related resources, i.e., money and time. Some people faced income losses, e.g., due to reduced working hours. In terms of time, households were affected by the pandemic in very different ways; some people faced severe time constraints while others had more time available for food preparation and consumption than before. In our empirical analysis, we tested the effects that pandemic-related changes at a personal level and contextual changes had on food consumption.

MATERIALS AND METHODS

Data Collection

The online survey (compatible for both computer and hand-held devices) was conducted in the spring of 2020 (DK: April 22 to May 6; DE: April 22-27; SI: April 23-30), during the (partial) lockdown period in the selected countries. The sample contains 2,680 valid cases in total: 1,105 from Denmark, 973 from

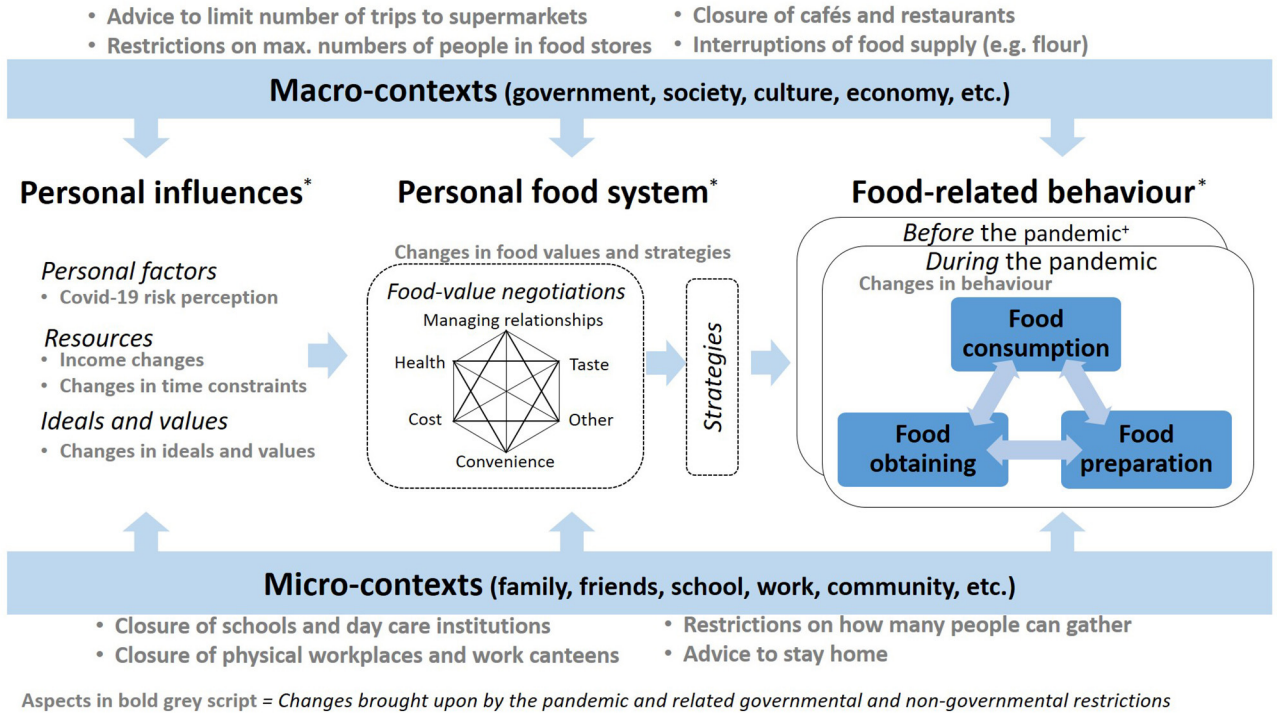

FIGURE 1 | Conceptual framework of potential factors related to changes in food consumption during the pandemic [adapted from (20, 21, 23)]. *Not depicted in the figure due to space limitations: feedback loops over time between behavior, personal influences and the personal food system, as suggested by social cognitive theory [adapted from (24)]. +The box on food-related behavior before the pandemic contains the same three conceptual elements as the box "during the pandemic".

Germany, and 602 from Slovenia. Participants were recruited via consumer panel agencies with quota sampling for the age group 18+ years, gender, and region. Participants completed the online survey upon invitation. Out of 4,171 participants who had completed the survey, 1,491 were excluded (36% of initial sample) because they had not correctly responded to the two attention-check questions in the survey. The survey length, i.e., the time participants needed to complete the survey, ranged between 5 min 28 s to 38 min 56 s; the mean interview duration was 14 min 31 s.

The survey was developed in English and then translated to Danish, German and Slovenian (the complete survey can be retrieved from the **Supplementary Material**). The survey was pre-tested with a minimum of 10 participants in each country, including experts in food science and consumer research as well as lay people. The questionnaire contained 34 questions. To determine changes in food consumption, participants were asked to report how often they personally consumed 11 categories of fresh food, non-fresh food, convenience food, and snack food during and before the pandemic. The food frequency questionnaire contained a six-point scale ranging from *less than once a fortnight or never* to *daily*:

- fresh food (fruit & vegetables, meat, fish, dairy, bread),
- non-perishable food (frozen food and canned food),
- ready-made meals,
- sweet snacks (cake & biscuits, sweets & chocolate), and
- alcoholic drinks.

Moreover, participants reported their behavior *before* and *during* the COVID-19 pandemic in terms of:

a) from which channels (e.g., supermarkets, farm markets, home delivery) they obtained various foods (answer format: check all that apply from a list of channels),
b) the frequency of purchasing four food types: fresh vegetables and fruits, fresh fish and meat, other fresh products, and non-fresh food (answer format: six-point scale ranging from *less than once a fortnight or never* to *daily*),
c) which meals were typically prepared and consumed at home (answer format: check all that apply from a list of meals),
d) the main ways household food was prepared, e.g., from take away, from a supermarket, ready to heat/cook meals, home-made meals using either processed and raw ingredients (answer format: check all that apply from a list of food preparation ways),
e) the frequency of consuming from various eateries away from home, e.g., work canteens, cafés and restaurants, street vendors, free food in hostels (answer format: six-point scale ranging from *less than once a fortnight or never* to *daily*), and
f) whether meals in the household had been missed due to lack of food and anxiety about obtaining enough food (answer format: three-point answer scale from *never* to *frequently*).

Participants were further asked whether they had experienced certain changes due to COVID-19, including changes in household income and closure of their physical workplace.

Questions were also asked about the extent to which their household had been afflicted with COVID-19, and their own perceived risk of the disease based on three items (with a five-point answer scale from *very low* to *very high*). Finally, they reported on the demographic details of their household and themselves.

Data Analysis

The data was analyzed at country level. The first step included paired-samples *t*-tests to detect significant differences in the mean food consumption and shopping frequencies of different food categories during the pandemic compared to before. In addition, we identified individual changes in food consumption by comparing consumption frequencies during the pandemic and before. For each of the 11 food categories, we determined whether an individual had increased, decreased or not changed their personal consumption frequency. These descriptive analyses served the aim of mapping changes in food-related behaviors during the pandemic.

The second step addressed the aim of identifying factors with a significant effect on changes in individuals' food consumption during the pandemic. We estimated multinomial logistic (MNL) regression models (maximum likelihood estimation) using STATA version 15.1 (StataCorp LLC, TX, USA). The dependent variable was the individual change in consumption frequency with the three possible outcomes "increase," "decrease," and "no change" in consumption frequency.

MNL regression models are designed for a nominal outcome variable with more than two levels (26). These models simultaneously estimate binary logits (i.e., the logarithm of odds of the different outcomes) for all possible outcomes, while one of the outcomes is the base category (or comparison group). In our case, the outcome "no change" served as the base category. We estimated separate models for the 11 food categories and the three countries.

The MNL regression models predict the probability P that a respondent increased/decreased consumption frequency subject to a set of independent variables (listed in **Table 1**):

$$P\left\{y_i = t\right\} = \frac{\exp(X'_{it-1}\,\beta_l)}{1 + \sum_{k=1}^{J}\exp\left(X_{it-1}\beta_k\right)}, \tag{1}$$

with X being a vector of independent (or predictor) variables for consumer i, t, and j representing choice alternatives from choice set J, and β being the parameters estimated by the model.

The relative probability of an "increase"/"decrease" of consumption frequency compared to the base outcome "no change" is calculated as follows:

$$\frac{\Pr(y_{(increase)})}{\Pr(y_{(no\ change)})} = \exp\left(X\beta^{increase}\right) \tag{2}$$

$$\frac{\Pr(y_{(decrease)})}{\Pr(y_{(no\ change)})} = \exp\left(X\beta^{decrease}\right) \tag{3}$$

The coefficients reported in the **Supplementary Material** are odds ratios (OR):

$$OR = \frac{\frac{\Pr\left(y{=}increase \mid x{+}1\right)}{\Pr\left(y{=}no\ change \mid x{+}1\right)}}{\frac{\Pr\left(y{=}increase \mid x\right)}{\Pr\left(y{=}no\ change \mid x\right)}} \tag{4}$$

The models were estimated as "full models," i.e., each model contained the whole set of independent variables listed in **Table 1**. The choice of independent variables predicting changes in food consumption frequency was guided by our conceptual framework (**Figure 1**). The models included food-related behaviors, personal factors and resources, and contextual factors. The latter were operationalised as respondent-specific variables: based on our questionnaire, we could determine whether a respondent was directly affected by a change in the macro- or micro contexts due to the pandemic, e.g., whether the respondent's physical workplace had been closed or whether the respondent had frequently eaten out-of-home before but not during the pandemic.

Most of the independent variables were direct measures from the questionnaire, two variables were sum scales (see **Table 1**). The variable "changes in food shopping frequency" is the sum scale of changes in food shopping frequency in four food categories (fresh fruit & vegetables, fresh meat & fish, other fresh food, non-fresh food), measured on a six-point frequency scale before and during the pandemic. The variable "COVID-19 risk perception" is the sum scale of three items measured on a five-point rating scale ("The likelihood of any member of your household to become infected by the virus," "The likely severity of the virus for any member of your household," "The level of your anxiety concerning the potential impact of the virus on your household") adapted from Kwok et al. (46). The scale was tested for reliability and displayed good Cronbach's alpha values of 0.77 (DK), 0.82 (DE), and 0.74 (SI).

RESULTS

The results chapter starts with a description of the socio-demographic composition of the sample (section Socio-demographic characteristics of the sample) and the main COVID-19 impacts (section Main COVID-19 impacts), before presenting the observed changes in food-related behaviors (section Changes in food-related behaviors), and the analysis of factors significantly related to increases and decreases of food consumption frequencies (section Factors related to changes in food consumption frequencies).

Socio-Demographic Characteristics of the Sample

In terms of gender, the samples in all three countries are close to the distribution in the national populations, i.e., ∼50–50 (**Table 2**). The age distribution in the samples is also generally reflective of the national population, with the following observations:

- The 19–49 age groups in Denmark are a little under-represented, and in Slovenia somewhat over-represented.

TABLE 1 | Variables included in the multinomial logistic regression models.

Variable	Definition	Measurement	Link to conceptual framework
Yi	Change in consumption frequency	(1) "increase"	Food-related
		(0) "no change"	behavior
		(−1)"decrease"	
x1i	Changes in food shopping frequency	Continuous variable: sum scale of changes in shopping frequency in four food categories (fresh fruit & vegetables, fresh meat & fish, other fresh food, non-fresh food)	Food-related behavior
x2i	COVID-19 risk perception	Continuous variable: Sum scale of three items measured on a 5-point interval scale	Personal factor
x3i	Closure of physical workplace	(1) "not affected"	Micro-context
		(2) "affected": respondent's physical workplace was closed during the first lockdown	
x4i	Closure of work canteens	(1) "not affected"	Micro-context
		(2) "affected": respondent had eaten there at least once a week before the pandemic but not during the first lockdown	
x5i	Closure of cafés and restaurants	(1) "not affected"	Macro-context
		(2) "affected": respondent had eaten there at least once a week before the pandemic but not during the first lockdown	
x6i	Income loss due to pandemic	(1) "not affected"	Personal resources
		(2) "affected": Respondent had lost income due to the pandemic	
x7i	Household composition	(1) "household with children"	Micro-context
		(2) "single-person household"	
		(3) "household with 2+ adults, no children living in the household"	
x8i	Gender	(1) "female"	Personal factor
		(2) "male"	
x9i	Education	(1) "lower secondary or equivalent"	Personal factor
		(2) "upper secondary or equivalent"	
		(3) "university or higher degree"	
x10i	Age group	(1) "19–35 years of age"	Personal factor
		(2) "36–49 years of age"	
		(3) "50–65 years of age"	
		(4) "66+"	
x11i	Eating frequency before pandemic	Continuous variable: 6-point interval-scale	Food-related behavior

- The 50–65 age group is somewhat over-represented in all three countries.
- The 66+ age group is somewhat over-represented in Denmark and under-represented in both Germany and Slovenia.

Denmark's sample of educational level is very similar to the country average, whilst in Germany and Slovenia the sample is somewhat skewed toward tertiary education and in Slovenia the lower secondary group is under-represented.

The household composition in the sample also slightly deviates from the population. In Denmark's sample, households with children are somewhat under-represented and households with two or more adults are over-represented. In Slovenia's sample, households with children are over-represented and single-person households are under-represented.

Main COVID-19 Impacts

Table 3 presents important changes brought by the pandemic on the sample population, where relevant compared with national and EU28 data. When related to the changes in food-related behavior reported by respondents discussed below, this enables international comparisons to be made with potentially important lessons for food behavior and culture, food systems, food policy, and crisis management.

COVID-19 Impacts and Risk Perception

In terms of nationally reported COVID-19 cases and deaths, all three countries do much better than the EU28 average up until the end of April 2020, and all three have a lower urbanization rate than EU28 (although Germany is only just below). One explanation for this is the evidence that cities constitute the epicenter of the pandemic, particularly because of their high levels of connectivity and air pollution, both of which are strongly correlated with COVID-19 infection rates, although there is no evidence to suggest that density *per se* correlates to higher virus transmission (27). This is loosely shown in our three countries, but other factors clearly also play important roles, probably including policy and regulatory interventions, as well as culture and attitudes to behavior more generally.

In terms of COVID-19 impacts on the sample households, the questionnaire contained three separate questions asking

TABLE 2 | Socio-demographic composition of the sample.

		Denmark (*N* = 1,105)	Germany (*N* = 973)	Slovenia (*N* = 602)
			Sample %	
Gender	Female	53.3	57.3	50.2
	Male	46.6	42.5	49.8
	Other	0.2	0.1	0.0
Age	*Mean age in years (SD)*	*54.9 (14.1)*	*48.9 (16.0)*	*44.1 (13.5)*
	19–35 years of age	14.3	23.0	29.7
	36–49 years of age	12.2	25.3	33.6
	50–65 years of age	46.6	34.7	30.9
	66+	26.9	17.0	5.8
Education	Lower secondary or equivalent	21.5	10.5	4.0
	Upper secondary or equivalent	45.9	54.1	62.4
	University or higher degree	32.6	35.5	33.4
Household composition	Households with children	17.3	23.3	41.0
	Single-person households	27.0	29.4	8.8
	Households with 2+ adults without children living in the household	55.7	47.3	50.2

whether any household member had been (a) infected with COVID-19 or had symptoms consistent with COVID-19, (b) in isolation or quarantine because of COVID-19, and (c) in hospital because of COVID-19. Denmark's sample experienced significantly more infected household members and household members in isolation/quarantine than Germany (*Z*-tests for comparison of proportions, $p < 0.001$). The number of infected household members in Slovenia was higher than in Germany and lower than in Denmark but the differences were not significant. Slovenia's sample also experienced significantly more household members in isolation/quarantine than Germany (*Z*-tests for comparison of proportions, $p < 0.01$). All three countries had relatively low hospitalization rates. The sample data tend to align with the three countries' overall population case and death rates and with urbanization rates. Interestingly, not all participants who indicated that a household member had been infected with COVID-19 or had symptoms consistent with COVID-19 also reported that a household member had been in isolation or quarantine. A possible explanation is that in the early phase of the pandemic in the study countries (i.e., until the beginning of March), people with symptoms consistent with COVID-19 were often not tested for COVID-19 and not necessarily asked to self-isolate or go into quarantine.

COVID-19 risk perception in the sample households was, on average, low to medium in the overall sample (**Table 3**, topic C.), with some statistically significant differences between the countries (comparison of mean values with ANOVA). Regarding the likely severity of the virus for any member of the household (item 2), we observed no significant differences between the countries. Regarding the likelihood of any member of the household to become infected by the virus (item 1), a significantly ($p < 0.001$) higher mean value was observed in Germany, followed by Denmark and Slovenia, perhaps reflecting the higher overall COVID-19 impact in Germany and Denmark, and the relatively strict lockdown measures in Slovenia. At the same time, the level of anxiety concerning the potential impact of the virus on the household (item 3) was significantly ($p < 0.01$) higher in Slovenia and Germany compared to Denmark, perhaps because of the closer geographical proximity to early COVID-19 hotspots in Northern Italy and Austria.

Changes in Macro- and Micro-Contexts and Income

One of the most pronounced changes in the macro- and micro-contexts beyond the household's direct control was the closure of physical workplaces. In Germany, about 30% of respondents were affected by it, in Denmark more than 40%, and in Slovenia more than 70% of the respondents were impacted. This significant difference among the three countries (*Z*-test for comparison of proportions, $p<0.001$) is also mirrored in the number of households who experienced an income loss due to the pandemic. Overall, only 9% of Denmark's sample households experienced income loss, 23% in Germany, but more than 50% in Slovenia (*Z*-test for comparison of proportions, $p < 0.001$). Although German households reported relatively higher income gain than the other two countries, all three countries experienced substantially more income loss than income gain. In terms of national poverty data, all three countries are well below average EU28 poverty levels with only small differences between them.

Food Poverty and Anxiety

Table 3 also shows the changes between before and during COVID-19 reported by the sample households in terms of missed meals and anxiety about acquiring food. Regarding missed meals, there was little change between before and during in all three countries.

Regarding anxiety about acquiring food, there was significant increase from before to during (*Z*-test for comparison of proportions, $p < 0.001$), to some extent in Denmark, somewhat more in Germany and quite a lot in Slovenia.

TABLE 3 | Changes brought by the COVID-19 pandemic.

	Denmark (N = 1,105)	Germany (N = 973)	Slovenia (N = 602)
A. COVID-19 impacts on sample households	**Sample %**	**Sample %**	**Sample %**
Infected members	6.5	2.6	3.8
Isolation or quarantine	6.1	2.6	6.2
Hospitalization	0.2	0.3	0.2
B. National COVID-19 impacts until end April 2020[a]			
Cumulative cases/100,000	*155.5*$^{+}$	*189.9*$^{+}$	*68.2*$^{+}$
Cumulative deaths/100,000	*7.6*$^{+}$	*7.5*$^{+}$	*4.3*$^{+}$
C. Risk perception of COVID-19 reported by sample households (5-point scale from "1 = very low" to "5 = very high")	**Mean**	**Mean**	**Mean**
1. The likelihood of any member of your household to become infected by the virus.	2.4	2.6	2.2
2. The likely severity of the virus for any member of your household.	2.6	2.7	2.6
3. The level of your anxiety concerning the potential impact of the virus on your household.	2.5	2.8	2.7
D. Changes in micro- and macro-context of sample households	**Sample %**	**Sample %**	**Sample %**
Closure of your (physical) workplace	43.3	29.2	73.6
Eating at work canteens before but not during the pandemic[c]	17.1	14.8	17.2
Eating at cafés or restaurants before but not during the pandemic[c]	7.8	22.0	22.8
E. Income change during COVID-19 reported by sample households	**Sample %**	**Sample %**	**Sample %**
Income loss	9.1	23.4	53.2
Income gain	1.4	2.7	1.0
F. Food poverty & anxiety reported by sample households (measured on 3-point scale "never," "occasionally," "frequently"; sample % refer to proportion who answered "occasionally" and "frequently")	**Sample %**	**Sample %**	**Sample %**
Missed meals before pandemic	9.9	6.4	11.8
Missed meals during pandemic	10.2	5.2	12.8
Anxiety about acquiring food before pandemic	11.2	2.9	7.8
Anxiety about acquiring food during pandemic	17.6	17.8	31.6
National poverty data[b]			
At risk of poverty (national data)	*16*$^{+}$	*17*$^{+}$	*14*$^{+}$

[a] *The respective EU28 values (per 100,000) are 206.8 cumulative cases and 23.9 cumulative deaths (47).* [b] *The EU28 value (for 2019) is 22% (43).*
[c] *These percentages refer to the share of participants who had indicated in the questionnaire that they had eaten at work canteens and cafés/restaurants, respectively, before but not during the pandemic.*
$^{+}$ *This data refers to national data and not to our sample data.*

Changes in Food-Related Behaviors

Frequency of Food Shopping

Our data clearly shows that the mean frequency of food shopping significantly decreased during the pandemic compared to before (paired-samples t-tests, $p < 0.001$; see **Supplementary Figure 1**). This effect was more pronounced for fresh food compared to non-fresh food (**Supplementary Figure 1**). Depending on the food category, 42–58% of respondents in Slovenia reported a decrease in shopping frequency of fresh food, while 35% reported a decrease for non-fresh food. Interestingly, these numbers were significantly lower in Denmark and Germany (Z-tests for comparison of proportions, $p < 0.05$), where only 27–30% (DK) and 20–28% (DE) of respondents reported a decrease in shopping frequency of fresh food, and 23% (DK) and 16% (DE) for non-fresh food. In other words, the majority of respondents from Denmark and Germany did not reduce their shopping frequency.

Food Consumption Frequencies

The comparison of food consumption frequencies during the pandemic and before with paired-samples t-tests (see **Supplementary Figure 2**) revealed that the *mean* consumption frequencies of fresh food significantly *decreased* in the three countries, with slight variations regarding the types of food affected: fruit & vegetables—all countries; meat—all countries; fish—DE, SI; dairy—DE, DK; bread—DE, SI (all effects significant at the level $p < 0.01$ except for dairy in DK with $p < 0.05$ and dairy in DE $p < 0.1$). The consumption frequencies of non-fresh food, by contrast, significantly *increased* in Denmark and Germany in the categories of ready-made meals, sweet snacks (cake & biscuits, sweets & chocolate), and alcoholic drinks, and in Germany, the mean consumption frequency of canned food also increased (all effects significant at the level $p < 0.01$ except for sweets in DK with $p < 0.05$). In Slovenia, the mean consumption frequencies of non-fresh food did not significantly change except for ready-made meals where a significant decrease ($p < 0.01$) was observed.

However, the comparison of *mean* consumption frequencies does not allow insights into the proportions of people who changed their consumption frequencies during the pandemic compared to before, and it masks

TABLE 4 | Rates of change in food consumption frequency by food category.

Rates of change[+]	Denmark	Germany	Slovenia
High rates of change: >30–42% of respondents	Frozen food, canned food, cake & biscuits	Frozen food, canned food, cake & biscuits	Frozen food, canned food, cake & biscuits, ready-made meals, fruit & vegetables, sweets & chocolate
Medium rates of change: >20–30% of respondents	Fruit & vegetables, meat, fish, ready-made meals, sweets & chocolate	Fruit & vegetables, meat, fish, ready-made meals, sweets & chocolate, dairy products, alcoholic drinks	Meat, fish, bread, dairy products, alcoholic drinks
Low rates of change: 15–20% of respondents	Bread, dairy products, alcoholic drinks	Bread	

[+] *Percent of respondents who had changed consumption frequencies, i.e., increased or decreased consumption frequencies during the pandemic compared to before.*

the following interesting observations. When analyzing changes in consumption frequency at the individual consumer level, we observed diverging trends in all food categories. Some people decreased, others increased, and yet others did not change their consumption frequency (see **Figure 2**). In some categories, these diverging trends "canceled out" each other so that the mean consumption frequency did not significantly change. Our observation of diverging trends in food consumption changes are novel insights which cannot be detected by looking at aggregated data like trends in retail sales or changes in *mean* consumption frequencies.

Depending on the food category, between 15 and 42% of consumers changed their consumption frequency during the pandemic compared to before (**Figure 2**). **Table 4** maps the changes in food consumption by category. Overall, the significantly highest proportions of people who changed consumption frequencies were observed in Slovenia (*Z*-tests for comparison of proportions, $p < 0.05$); the only exceptions were the categories frozen food and ready-made meals where the country differences were not significant (and the categories meat and cake & biscuits where the difference between Slovenia and Denmark was significant but not the difference between Slovenia and Germany).

Interestingly, there are great similarities between the three countries regarding the food categories with the highest and lowest rates of change (by rate of change we mean the combined proportions of people who increased or decreased their consumption). In all three countries, the highest rates of change were observed in the categories of frozen food, canned food, and cake & biscuits, while bread, dairy products, and alcoholic drinks were among the categories with the lowest rates of change (**Table 4**).

We also analyzed changes in consumption frequency across the 11 product categories at the individual consumer level. Interestingly, only a small proportion of respondents did not report any changes in eating frequency (15% in DK; 14% in DE; 8% in SI). About half of the respondents in Denmark and Germany and two-thirds in Slovenia reported changes in three or more product categories. Changes in five or more product categories were reported by 17% of the respondents in Denmark, 24% in Germany and 35% in Slovenia.

Factors Related to Changes in Food Consumption Frequencies

We estimated multinomial logistic (MNL) regression models to identify factors significantly related to the observed decreases and increases in consumption frequencies in the different food categories, as outlined in **Figure 2**. The outcome reference category was the group of people who did not change their consumption frequency (in **Figure 2** displayed in gray color). The model fit varied considerably across the different food categories (**Table 5**) and was generally "moderate" or "good" for fresh food, and rather "low" for non-fresh food (apart from a few exceptions). The models focused on pandemic-related factors as predictors of behavior change. It is therefore not surprising that the model fit was low in some food categories. The variance not explained by the models can be attributed to factors not controlled for, foremost differences in personal food values and strategies (such as health or convenience orientation, which were not included as predictors in the models in order to limit the predictors to a manageable number).

The model results are summarized in **Tables 6–8** (the full model results are provided in the **Supplementary Tables 2–4**). The remainder of the section is organized according to the independent variables analyzed in the MNL regression models. The effects mentioned in the text are significant at the level $p < 0.01$, $p < 0.05$, or $p < 0.1$ (see **Tables 6–8** for level of significance).

Changes in Shopping Frequency

Across the three study countries, a decrease in shopping frequency was significantly related to a decrease in fresh food consumption, with slight variations between the study countries regarding the types of fresh food affected: fruit and vegetables (all countries), meat (DE, DK), fish (DE, DK), and dairy (DK, SI). Furthermore, a decrease in shopping frequency was significantly related to an increase in frozen food and canned food consumption in Germany and Denmark, suggesting some people partly substituted fresh food with frozen food and canned food. Interestingly, a decrease in shopping frequency was also significantly related to an increase in sweet snacks in all three countries (sweets & chocolate: all countries; cake & biscuits: DE, DK).

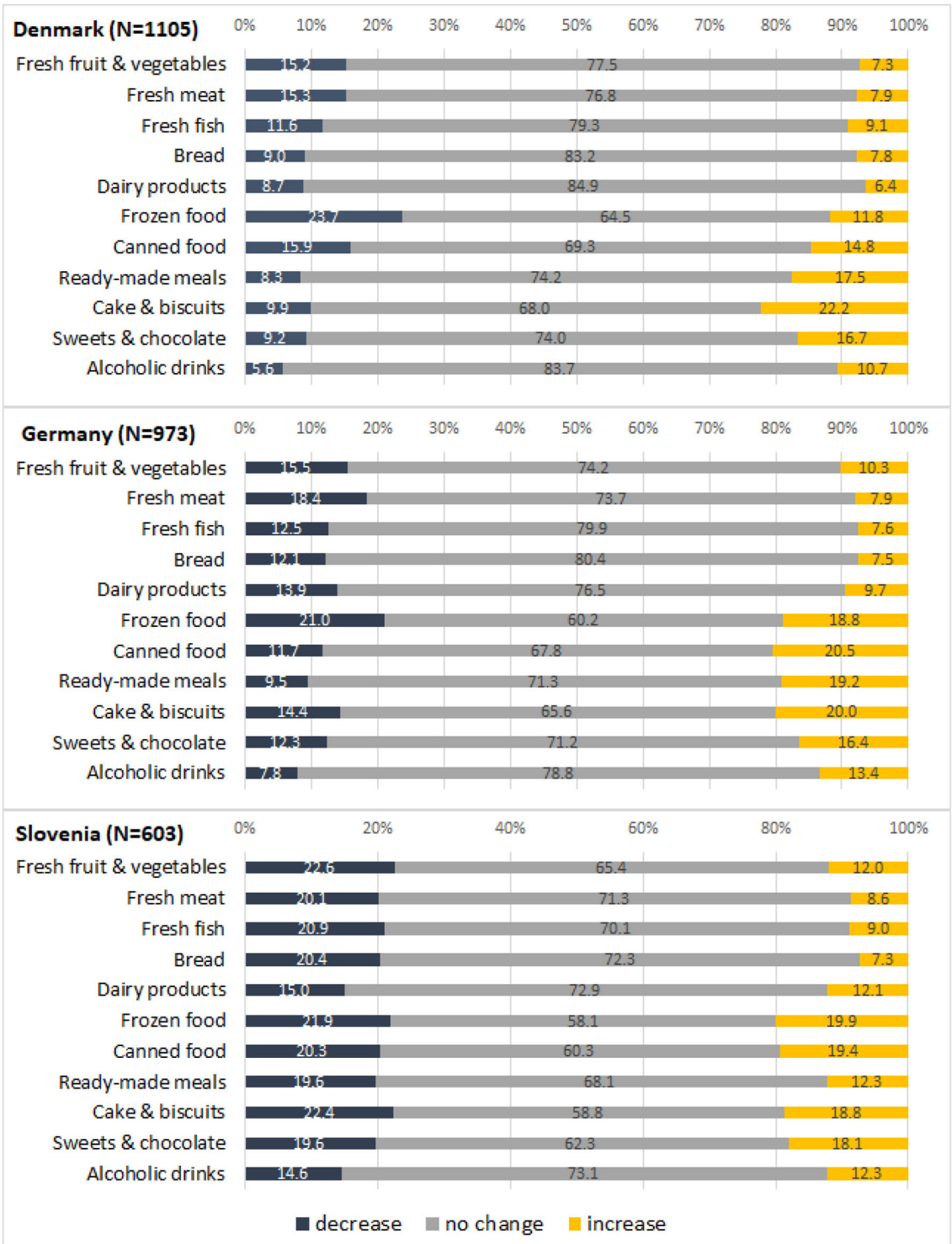

FIGURE 2 | Changes in individuals' food consumption frequencies.

Regarding the consumption of bread and alcohol, we observed opposite effects between the study countries. While a decrease in shopping frequency was significantly related to a decrease in bread consumption in Slovenia, it was significantly related to an increase in bread consumption in Germany. With a decrease in shopping frequency, the consumption of alcoholic drinks

TABLE 5 | Nagelkerke's Pseudo R-Square of the MNL regression models.

	Denmark	Germany	Slovenia
Fresh fruit & vegetables	0.193	0.202	0.227
Fresh meat	0.143	0.109	0.163
Fresh fish	0.159	0.209	0.174
Bread	0.321	0.223	0.249
Dairy products	0.237	0.195	0.188
Frozen food	0.120	0.174	0.098
Canned food	0.079	0.163	0.166
Ready-made meals	0.131	0.159	0.223
Cake & biscuits	0.107	0.137	0.107
Sweets & chocolate	0.067	0.113	0.092
Alcoholic drinks	0.102	0.107	0.107

tended to decrease in Denmark, whereas it tended to increase in Germany.

COVID-19 Risk Perception

The level of perceived risk and anxiety of COVID-19 (hereafter referred to as "COVID-19 risk perception") had significant effects on food consumption in all of the three countries, but with interesting differences between Denmark and Germany on the one hand, and Slovenia on the other hand.

In Denmark and Germany, the consumption of fresh fruit and vegetables was significantly related to COVID-19 risk perception. Higher levels of COVID-19 risk perception were associated with a decrease in the consumption of fruit and vegetables and bread in Denmark. Similarly, lower levels of COVID-19 risk perception were associated with a higher probability of increasing fruit and vegetable consumption in Germany. These trends are in contradiction to our initial assumption, according to which people who are anxious about the COVID-19 virus might try to strengthen their immune system through increased levels of fruit and vegetable consumption. We checked whether the level of perceived risk was significantly related to a change in shopping frequency and found significant correlations with small to medium effect sizes in Germany ($r = -0.19$, $p < 0.001$) and Denmark ($r = -0.24$, $p < 0.001$), but no significant correlation in Slovenia. Thus, it seems that in Germany and Denmark, people who were more anxious about the virus tended to decrease their shopping frequency even more than others did.

In Slovenia, higher levels of COVID-19 risk perception were associated with a decrease in the consumption of fresh meat, while lower levels of COVID-19 risk perception had a significant effect on the probability of increasing bread consumption.

To summarize the key results, it was *not* the case that people who were more anxious about the virus were trying to eat more healthily. On the contrary, higher levels of COVID-19 risk perception were significantly related to a decrease in fruit and vegetable consumption in Germany and Denmark. Neither was it the case that people who were more anxious about the virus increased their consumption of alcohol and sweet snacks as a means to cope with increased levels of stress. On the contrary, an increase of alcohol consumption was significantly related to *lower* levels of COVID-19 risk perception in Denmark.

Closure of Workplaces and Work Canteens

The proportion of respondents affected by the physical closure of their workplace differed significantly across the countries, ranging from 29% in Germany to 43% in Denmark and 74% in Slovenia. Despite this difference, the proportion of people affected by the closure of work canteens was similar across the countries: 15% (DE) respectively 17% (DK, SI) of the respondents used to eat at work canteens at least once a week before the pandemic but stopped eating there during the first lockdown. Both, the physical closure of workplaces as well as canteens had significant - and partly opposite - effects on food consumption in all of the three countries.

In Denmark, people affected by a closure of their physical workplace were more likely to decrease their consumption of bread and dairy products compared to other people. Interestingly, these people were also more likely to decrease the consumption of cake and biscuits. Another interesting phenomenon was observed regarding ready-made meals. While the consumption of ready-made meals had generally increased in Denmark during the pandemic, this effect was not seen among people affected by a lockdown of their workplace.

The closure of work canteens also had interesting effects in Denmark. People who stopped eating in canteens during the pandemic were more likely to decrease their fresh fish consumption compared to other people. Moreover, these people were more likely to increase their consumption of cake and biscuits, suggesting they substituted their canteen lunch (partly) with cake and biscuits.

Similar to the observation in Denmark, people affected by a closure of their physical workplace in Germany were also more likely to decrease their bread consumption and their consumption of fresh fish. Regarding the consumption of cake and biscuits, the effect in Germany was opposite compared to Denmark. In Germany, the consumption of cake and biscuits tended to *increase* among people affected by the lockdown of their physical workplace. Another observation was that these people were more likely to increase the consumption of alcoholic drinks.

The closure of work canteens in Germany had partly opposite effects to the closure of physical workplaces. People who had stopped eating at work canteens were more likely to *increase* fish consumption. Fish is typically served only once a week in German canteens. Furthermore, the closure of work canteens led to an increase in the consumption of frozen food, suggesting these people used frozen ingredients for preparing meals instead of going to the canteen. Moreover, people who had stopped eating at work canteens during the pandemic were likely to change their consumption of fresh meat and sweets and chocolate. Interestingly, the change could go in both directions, an increase as well as a decrease, highlighting the strong influence of contextual factors on eating patterns, however with partly opposite effects. Apparently, some people are nudged at their work canteen to eat less meat and less sweets and chocolate than they would do if they did not eat there, while other people are

TABLE 6 | Factors significantly related to changes in food consumption frequency – DENMARK.

		Fresh fruit & vegetables	Fresh meat	Fresh fish	Bread	Dairy products	Frozen food	Canned food	Ready-made meals	Cake & biscuits	Sweets & chocolate	Alcoholic drinks
Food shopping frequency	*The lower*	↓ ***	↓ ***	↓ ***		↓ **	↑ ***	↑ **		↑ **	↑ **	↓ *
	The higher											
COVID-19 anxiety	*The lower*											↑ *
	The higher	↓ ***			↓ ***							
Closure of workplace	*Affected*				↓ **	↓ **				↓ ***		
	Not affected								↑ **			
Closure of work canteens	*Affected*			↓ **						↑ *		
	Not affected				↓ *					↓ **		
Closure of cafés & restaurants	*Affected*					↑ *						↓ **
	Not affected											
Income loss due to pandemic	*Affected*									↑ *	↑ **	↑ *
	Not affected											
Household composition	*(1) with children*	↑ *2			↑ *3						↑ **3	↑ **
	(2) Single-person	↓ *	↓ ***		↓ **3						↓ **3	
	(3) 2+ adults		↑ *									
Gender	*Women*	↑ *								↑ *	↑ **	
	Men		↓ *		↓ **			↑ *		↓ *		
Education	*(1) Lower sec.*											
	(2) Upper sec.											↓ *1
	(3) University								↑ *1			
Age	*(1) 19–35*				↓ **4			↑ ***4				↓ *4
	(2) 36–49							↑ **4	↑ **4			
	(3) 50–65											
	(4) 66+			↑ **3	↑ *3	↑ *2,3	↓ **1	↓ *1,3				↑ *3
Eating frequency before pandemic	*The lower*	↑ ***	↑ ***		↓ ***	↓ ***	↑ ***	↑ ***		↑ ***	↑ ***	↑ **
	The higher		↓ ***	↓ ***	↓ ***	↓ ***	↓ ***	↓ ***	↓ ***	↓ ***		

*Significant effects based on MNL regression models (see **Supplementary Tables 2–4** for model results).*
↑ / ↓ indicate that the variable level is significantly related to an increase / a decrease of consumption frequency.
**p < 0.1, **p < 0.05, ***p < 0.01 significance level.*
*1, 2, 3, 4 next to an arrow: indicates that the coefficient is significant only compared to the category with the respective number (if no number is indicated, the coefficient is significant compared to all other categories). For example *2 in column "Fresh fruit and vegetables" in line "Household composition – with children" means that households with children were more likely to increase the consumption of fresh fruit and vegetables compared to single-person households.*

affected by eating at the work canteen in the opposite direction – more meat, sweets and chocolate.

In Slovenia, people affected by a lockdown of their physical workplace were more likely to reduce their consumption of ready-made meals. A decrease in the consumption of frozen food and canned food, however, was more likely among people *not* affected by a closure of their physical workplace. The closure of work canteens in Slovenia was significantly related to a decrease in alcohol consumption, but an increase in the consumption of sweets and chocolate.

Closure of Cafés and Restaurants

Interesting changes in food consumption were observed related to the closure of cafés and restaurants. In Germany and Slovenia,

TABLE 7 | Factors significantly related to changes in food consumption frequency – GERMANY.

		Fresh fruit & vegetables	Fresh meat	Fresh fish	Bread	Dairy products	Frozen food	Canned food	Ready-made meals	Cake & biscuits	Sweets & chocolate	Alcoholic drinks
Food shopping frequency	*The lower*	↓ ***	↓ ***	↓ ***	↑ ***		↑ **	↑ ***		↑ ***	↑ *	↑ **
	The higher									↓ **		
COVID-19 anxiety	*The lower*	↑ **										
	The higher											
Closure of workplace	*Affected*			↓ *	↓ *					↑ **		↑ *
	Not affected											
Closure of work canteens	*Affected*		↑ ***	↑ **			↑ *				↑ ***	↑ ***
	Not affected		↓ **								↓ *	
Closure of cafés & restaurants	*Affected*			↓ *		↓ **		↑ ***	↑ ***	↑ ***		
	Not affected											
Income loss due to pandemic	*Affected*						↑ *		↑ **			
	Not affected											
Household composition	*(1) With children*	↑ **		↑ **				↓ *2		↑ **2		
	(2) Single-person											
	(3) 2+ adults							↓ *2	↓ *	↑ *2		
Gender	*Women*	↑ **			↓ *							
	Men					↓ *						
Education	*(1) Lower sec.*					↑ *						
	(2) Upper sec.						↑ *					
	(3) University									↓ *2		
Age	*(1) 19–35*				↓ **4				↓ *4	↓ *4	↑ *4	↑ ***4 ↓ **4
	(2) 36–49				↓ **4							
	(3) 50–65					↓ *4						
	(4) 66+	↑ **2,3	↓ *3 ↑ **2,3	↑ **2		↑ *3		↓ ***2				
Eating frequency before pandemic	*The lower*	↑ ***	↑ ***		↓ *** ↑ ***	↑ ***	↑ ***	↑ ***	↑ ***	↑ ***	↑ ***	
	The higher		↓ ***	↓ ***			↓ ***	↓ ***	↓ ***	↓ ***		

*Significant effects based on MNL regression models (see **Supplementary Tables 2–4** for model results).*
↑ / ↓ indicate that the variable level is significantly related to an increase / a decrease of consumption frequency.
**p < 0.1, **p < 0.05, ***p < 0.01 significance level.*
*1, 2, 3, 4 next to an arrow: indicates that the coefficient is significant only compared to the category with the respective number (if no number is indicated, the coefficient is significant compared to all other categories). For example *2,3 in column "Fresh fruit and vegetables" in line "Age – 66+" means that respondents in the age category 66+ were more likely to increase the consumption of fresh fruit and vegetables compared to respondents in the age categories 36–49 years and 50–65 years.*

22% of the respondents used to eat at cafés and restaurants at least once a week before (but not during) the lockdown, while in Denmark only 8% of the respondents fell into this group.

In Germany, these people were more likely to increase their consumption of ready-made meals, canned food, and cake and biscuits, and decrease their consumption of fish and dairy products, suggesting that "eating out" was substituted with convenience food and sweet snacks instead of cooking a meal from scratch. In Slovenia, a partly similar trend was observed. Here, these people were more likely to increase their consumption of ready-made meals and frozen food, while the consumption of fresh meat was more likely to decrease.

In Denmark, by contrast, people who used to eat at cafés and restaurants before the pandemic were more likely to decrease

TABLE 8 | Factors significantly related to changes in food consumption frequency – SLOVENIA.

		Fresh fruit & vegetables	Fresh meat	Fresh fish	Bread	Dairy products	Frozen food	Canned food	Ready-made meals	Cake & biscuits	Sweets & chocolate	Alcoholic drinks
Slovenia												
Food shopping frequency	*The lower*	↓ *			↓ **	↓ *					↑ **	
	The higher		↑ *			↑ *						
COVID-19 anxiety	*The lower*				↑ **							
	The higher		↓ *									
Closure of workplace	*Affected*								↓ *			
	Not affected						↓ *	↓ *				
Closure of work canteens	*Affected*										↑ *	↓ ***
	Not affected											
Closure of cafés & restaurants	*Affected*		↓ **				↑ **		↑ ***			
	Not affected											
Income loss due to pandemic	*Affected*	↓ **			↑ ***				↓ *			↓ **
	Not affected											
Household composition	*(1) With children*		↑ *						↓ **2			
	(2) Single-person											
	(3) 2+ adults			↓ *1					↓ *2		↑ *1	↑ **
Gender	*Women*	↑ ***	↓ ***	↓ ***	↑ *			↑ *				
	Men				↓ ***							
Education	*(1) Lower sec.*				↑ *		↓ *3	↑ *3				
	(2) Upper sec.						↓ **3		↑ **3			
	(3) University											
Age	*(1) 19–35*	↓ *4								↑ *4		
	(2) 36–49				↓ *4					↑ *4		
	(3) 50–65											
	(4) 66+						↓ *					
Eating frequency before pandemic	*The lower*	↑ ***	↑ ***		↑ ***	↑ ***	↑ ***	↑ ***		↑ **	↑ **	
	The higher		↓ ***	↓ ***			↓ ***	↓ **	↓ ***	↓ ***	↓ ***	↓ ***

*Significant effects based on MNL regression models (see **Supplementary Tables 2–4** for model results).*
↑ / ↓ indicate that the variable level is significantly related to an increase / a decrease of consumption frequency.
**p < 0.1, **p < 0.05, ***p < 0.01 significance level.*
*1, 2, 3, 4 next to an arrow: indicates that the coefficient is significant only compared to the category with the respective number (if no number is indicated, the coefficient is significant compared to all other categories). For example *4 in column "Fresh fruit and vegetables" in line "Age – 20–35" means that respondents in the age category.*

their alcohol consumption, suggesting that these people drink less alcohol when they are at home. Interestingly, such people were more likely to increase their consumption of dairy products.

Income Loss due to the Pandemic

The incidence of income loss due to the pandemic was very different across the three study countries (SI: 53%, DE: 23%, DK: 9%). Interestingly, the effects on changes in food consumption were also very different.

In Slovenia, a loss of income was significantly related to a decrease in the consumption of fruit and vegetables, ready-made meals, and alcoholic drinks, and an increase in the consumption of bread. Opposite trends were observed in the other two countries. In Denmark, people who had

lost parts of their income were more likely to increase their consumption of sweet snacks and alcoholic drinks; in Germany, a loss of income was significantly related to an increase in the consumption of frozen food and ready-made meals.

Household Composition

We distinguished between three types of households: households with children, single-person households, and households with 2+ adults without children living in the household. Each of these types of households were affected by pandemic-related restrictions in different ways: households with children were affected by the lockdown of schools and day care institutions; single-person households were particularly challenged by social distancing restrictions, reduced human contact and potential feelings of loneliness; while households with 2+ adults were potentially not affected to the same extent.

We found significant effects of household composition on changes in food consumption in each country, again noting interesting differences between the countries. In Denmark, respondents living in households with children were more likely to *increase* their consumption of alcoholic drinks (compared to both other groups); sweets and chocolate, and bread (compared to households with 2+ adults); and fruit and vegetables (compared to single-person households). In Germany, households with children were more likely to *increase* the consumption of fruit and vegetables, and fish (compared to both other groups); and cake and biscuits (compared to single-person households). They were also more likely to decrease the consumption of canned food (compared to single-person households). In Slovenia, respondents from households with children were more likely to increase their consumption of fresh meat (compared to both other groups) and decrease the consumption of ready-made meals (compared to single-person households).

Respondents from households with two or more adults in Denmark were more likely to increase the consumption of fresh meat (compared to both other groups). In Germany, this group was more likely to decrease the consumption of ready-made meals (compared to both other groups); and decrease the consumption of canned food and increase the consumption of cake and biscuits (compared to single-person households). In Slovenia, respondents from households with two or more adults were more likely to *increase* the consumption of alcoholic drinks (compared to other two groups); sweets and chocolate, and fish (compared to households with children), and ready-made meals (compared to single-person households).

Respondents from single-person households in Denmark were more likely to decrease the consumption of fruit and vegetables, and fresh meat (compared to both other groups), as well as decrease the consumption of bread, and sweets and chocolate (compared to households with 2+ adults). In Germany and Slovenia, by contrast, respondents from single-person households were generally less likely to have changed their consumption frequencies compared to respondents from other types of households, indicating their food consumption patterns were less affected by the pandemic.

Gender

Interestingly, women were more likely to increase the consumption of fruit and vegetables than men in all three study countries. In Denmark, women were also more likely to increase the consumption of sweet snacks (sweets and chocolate, cake and biscuits), while men were more likely to decrease the consumption of cake and biscuits, fresh meat, and bread, but increase the consumption of canned food compared to women. In Germany, a decrease in the consumption of bread was more likely to occur among women than among men, while the opposite effect was found for a decrease in the consumption of dairy products. In Slovenia, women were more likely to increase the consumption of canned food and decrease the consumption of fresh meat and fish compared to men, and they were more likely to change the consumption of bread (both a decrease and an increase in bread consumption were more likely to happen among women than among men).

Education

We differentiated between three educational groups: lower secondary, upper secondary and equivalents, and university degree. Overall, we observed only a few significant effects. In Denmark, people with a university degree were more likely to increase the consumption of ready-made meals compared to people with a lower secondary degree. People with an upper secondary education were likely to decrease their alcohol consumption compared to people with a lower education. In Germany, people with a university degree were more likely to decrease the consumption of cake and biscuits compared to people with an upper secondary education, while the latter were more likely to increase the consumption of frozen food compared to both other population groups. People with a lower secondary degree were more likely to increase the consumption of dairy products. In Slovenia, people with a lower level of education were more likely to increase the consumption of bread compared to both other groups, and increase the consumption of canned food but decrease the consumption of frozen food compared to people with a university degree. The middle group was more likely to increase the consumption of ready-made meals and decrease the consumption of frozen food compared to people with a university degree.

Age

To capture non-linear relationships between the age of the respondents and changes in food consumption, we distinguished between four age groups (18–35, 36–49, 50–65, and 66+ years), and found a number of significant effects. However, it is difficult to identify patterns within and across product categories.

Consumption Frequencies Before the Pandemic

For each type of food, we controlled for the influence of consumption levels *before* the pandemic on the likelihood of decreasing or increasing consumption. For almost all types of food it was the case that an *increase* of consumption was more likely to happen the *lower* the consumption frequency of this type of food before the pandemic (exceptions are ready-made meals in DK and SI, alcohol in DE and SI, and fish in DK). That is, the

lower the baseline consumption, the greater the probability of a reported increase during COVID-19.

For most types of food, we also observed that a *decrease* in consumption was more likely to happen when the consumption frequency was *higher* before the pandemic. That is, higher levels of baseline consumption were associated with greater probabilities of reported decreases in consumption during COVID-19. An exception was fruit and vegetables, in that a decrease in fruit and vegetable consumption was not significantly linked to the consumption level before the pandemic in any of the three countries (other exceptions are dairy products in DE and SI, sweets and chocolate in DK and DE, and alcoholic drinks in DK and DE).

Overall, these observations suggest that people's consumption levels tended to become more similar during the pandemic compared to before.

DISCUSSION

The main objective of the present research was to map changes in the consumption and purchase of food before and during lockdown of the COVID-19 pandemic in Denmark, Germany, and Slovenia. Broadly speaking, people across the three countries shopped less frequently during lockdown and there was an overall reduction in the consumption of fresh foods, but an increase in the consumption of food with a longer shelf life in Denmark and Germany. However, it is worth noting that within these overall trends, in all food categories there were subgroups of people that exhibited an opposite pattern of behavior, e.g., an increase in the consumption of fresh food. It is interesting that we observed changes in food consumption frequency in all food categories during the pandemic. Depending on the food category, 15 to 42% of respondents reported a change. The findings are in line with another study from Denmark (11). Only a small proportion of respondents (15% in DK; 14% in DE; 8% in SI) reported *no* change across the eleven food categories investigated. About half of the participants in Denmark and Germany and two-thirds in Slovenia reported changes in consumption frequency of three or more food categories, which represents a shift in food choice patterns. The higher rates of change in consumption frequencies in Slovenia were perhaps due to the fact that Slovenia had stricter restrictions in place compared to Germany and Denmark, and is likely to be related to the fact that greater reductions in grocery shopping frequency were reported in Slovenia than in the other two countries.

What is interesting is that differences in individual consumption levels before the pandemic tended to even out during the pandemic, perhaps because many people were facing similar conditions during the lockdown period, leading to a convergence of eating patterns, and so individual differences in macro- and micro- contexts that exerted a greater influence pre-pandemic had less of an effect during lockdown. While it is widely recognized in the literature that food choices are dynamic and evolve over the life course (28), they are also considered to be fairly stable and largely driven by habit when looking at shorter time spans. Significant shifts or turning points in food choice patterns are usually initiated by major life events such as leaving school, changing employment, or entering/leaving personal relationships (29). Our findings suggest that the COVID-19 pandemic and the related restrictions impacting on people's daily lives caused – at least temporary – shifts in food choice patterns for a large part of the population. This is an interesting finding suggesting that the COVID-19 pandemic potentially had similarly large effects on food transitions as major life events.

The question then becomes: are the observed changes a temporary phenomenon limited to the lockdown period in spring 2020, or will the changes last and become new habits? Theories on behavior change suggest that positive experiences with the behavior in question are strong drivers of enduring behavior change; negative experiences, however, are likely to have an opposite effect (24). For example, people who try a new vegetarian dish, and happen to like the taste of it, are likely to eat this food again and change their eating patterns toward more vegetarian dishes, in contrast to people who try the same dish but do not like its taste. In our study, it remains open as to what extent the respondents perceived the changes in food consumption they underwent as positive or negative experiences. It is also worth noting that *repeated exposure* to food has been proven to be a powerful driver of food choice in the literature on food choice trajectories (30). We therefore expect that food shifts experienced in the spring of 2020 will partly lead to new food habits, in particular since the COVID-19 pandemic and related restrictions will continue beyond the year 2020 in many countries around the world.

It is thus worthwhile looking at the observed changes in the different food categories in more detail. Interestingly, we were able to identify factors driving changes in individual food consumption frequency at food category level by analyzing pandemic-related contextual and personal factors as well as socio-demographic variables. The conceptual framework we developed proved very useful. The factors that were found to be associated with changes in food consumption in a more consistent pattern were decreased shopping frequency, loss of income due to the pandemic, COVID-19 risk perception, closure of physical workplaces, cafés and restaurants, having a household with children, and gender. Consumption levels before the pandemic constitute an important control variable. Overall, our findings illustrate how food choice is largely influenced by contextual factors, i.e., where and with whom people eat, and by food shopping frequency.

People tended to reduce their intake of fresh food during lockdown, particularly fruits, vegetables and meat, which is consistent with the findings of Bracale and Vaccaro (8) based on the sales data of Italian food stores. This was related to a reduction in shopping frequency in all three countries, with the greatest decrease occurring in Slovenia compared with Denmark and Germany. This could be because a government recommendation to reduce shopping frequency was in place in Slovenia but not in the other countries, together with travel restrictions (people were only allowed to travel within their municipality of residence). Moreover, it should be noted that Slovenia shares a border with Northern Italy, which was very strongly affected

by COVID-19 in the spring of 2020, and this affected policy measures and, presumably, also people's behaviors. With fewer government restrictions in Germany and Denmark, we see that the reduction in shopping frequency appeared to be at least partly attributable to people's anxiety about COVID-19. That is, the greater they perceived the risk of COVID-19 to be, the less frequently they shopped (perhaps to minimize risk of infection), and thus they tended to consume less fresh produce given its perishable nature.

In Slovenia, respondents from households that had lost income due to the pandemic were more likely to decrease their fruit and vegetable intake, perhaps because income loss was much more pronounced in this country (53%) than the others (DK: 9%, DE: 23%). This household income loss in Slovenia was also associated with an increased intake of bread, and a decrease in ready-made meals and alcohol, suggesting that those who had reduced income may have shifted toward buying more affordable food.

The observed reduction in the consumption of fresh food is in contrast to the results of a study showing an increase in healthier dietary patterns (including increased intake of fruit and vegetables) in Spain during the COVID-19 confinement (13). However, it is important to note that the sample of the Spanish study comprised over 70% women (compared to the current study that was more or less representative in terms of gender) and our results show that women in all three countries were more likely to increase their intake of fruit and vegetables during lockdown. Although women generally consume more of these types of foods than do men [e.g., (31, 32)], it is interesting that this difference was further emphasized during the lockdown. This may be because women feel more strongly that eating fruit and vegetables is good for health, and they feel that they have more control over this behavior, which in turn causes them to consume more fruit and vegetables (33). Given that the pandemic likely highlighted people's health concerns, this could be why the gender difference in fruit and vegetable intake increased even more during lockdown. It remains to be seen to what extent such dietary differences may contribute to the greater severity of clinical outcomes of COVID-19 in men compared to women [e.g., (34, 35)].

Against the trend of an overall reduction in fresh foods, households with children tended to increase their intake of fresh produce in Germany during lockdown, and to a lesser extent in the other two countries. This may be due to households having to replace school lunches during lockdown.

Although people consumed more ready-made meals, sweet snacks and alcohol in Denmark and Germany during lockdown, there was no such increase in Slovenia, with even a decrease in ready-made meals. Other data from this study suggests two possible reasons for this. Firstly, because there appears to be greater anxiety in Slovenia about acquiring food than in the other two countries, and so consumers in Slovenia were less likely to increase spending on less essential food products. Consistent with this, loss of income was related to a decrease in non-essential food in Slovenia but not in Denmark nor Germany. Secondly, because households in Slovenia suffered greater income loss due to the pandemic (and so presumably had less work), participants may have had more time to prepare meals than those in Germany and Denmark.

Unsurprisingly, the closure of cafes and restaurants was associated with increased consumption of ready-made meals in Germany and Slovenia among those who had eaten out at least once a week before lockdown. Inversely, the consumption of such meals actually decreased in Germany, Slovenia, and to some extent Denmark, for those whose physical workplaces had closed. This might suggest these people had more time for meal preparation since they spent more time at home compared to their daily routine before the pandemic. However, given that there was no consistent increase in the consumption of fresh food amongst this segment, this suggests that they were not using more fresh ingredients when eating from home.

There was an overall increase in the consumption of sweet snacks in Denmark and Germany, although not in Slovenia. The rise in snack consumption is consistent with a study of Canadian middle to high income families with young children who also commonly reported consuming more snacks during the COVID-19 pandemic (36). Further, and as noted above, it is likely that the large income loss experienced in Slovenia mitigated against purchasing and eating snacks given that they tend to be a relatively expensive food item.

However, it is also worth noting that the relationship between lockdown and snacking is not always consistent – with for example, one Italian study showing an increase in the consumption of sweet snacks (9), whereas another Italian study showed a decrease in the sales of sweet snacks (8). This may partly be because people's snacking behavior may change over time the longer lockdown continues (37). Furthermore, what is considered to be a snack may not always be clear to consumers, as the same food may be a snack or part of a meal depending on when and how it is consumed.

A major strength of this study is its controlled sampling conducted over a short duration and at the same time in the three case countries. In contrast to most other studies where convenience or snowball sampling was used, the use of online panels enabled the collection of national samples which are more comparable with census data in terms of gender, age, and geography than other samples. However, our samples also exhibit deviations from census data in terms of age and education. It should be noted that strict lockdown measures were in place during data collection, so that an online study was, in practice, the only possible method. Quota sampling secured valid responses geographically across all three countries. Such an approach is, however, also subject to some limitations. For example, there was ready access to populations with internet connections but this probably mitigated against the inclusion of participants with lower socio-economic status. On the other hand, the compatibility of the survey with handheld devices should have reduced this problem to a good extent, and all three countries have relatively good internet infrastructures and digitally literate populations compared with the European average. Even so, it is likely this explains the difficulties in achieving representativeness of the study samples in terms of educational level. While in Denmark's sample the educational level is very similar to the country average, we observed slightly

over-representation of higher education levels in the German and Slovenian datasets.

POLICY AND RESEARCH RECOMMENDATIONS

The current findings suggest that it is more difficult for people to eat healthily during a COVID-19 confinement in terms of fresh fruit and vegetables. However, the fact that their reduced consumption is linked to reduced shopping frequency, and to some extent, greater risk perception of COVID-19, suggests that increasing the accessibility of such produce, such as through deliveries or pick-up points, may be a way of increasing their consumption. Although online delivery systems may be overburdened by individual orders in many cases, measures could be implemented to prioritize the more frequent delivery of more essential foods. This might include having a standard care package of food that could be produced/prepared in bulk, which could also increase the affordability of such produce. Furthermore, the delivery of such items could be prioritized by banning the delivery of non-essentials. For example, by temporarily banning the sales of bottled water, the online British supermarket chain Ocado was able to deliver to 6,000 additional homes during the pandemic (38).

The reduction in the intake of fresh fruit and vegetables during lockdown was also related to gender and loss of income. One factor that has been shown to increase fruit and vegetable intake in previous studies is the use of food banks, which provide such food at a nominal price (39, 40). Relatedly, providing fruit and vegetables for free increases their uptake among socially disadvantaged men (39) and families (41). Although our data show overall only small increases in the use of food banks and anxiety about acquiring food especially amongst participants with a lower education, such changes are significant and might be expected to be higher over a longer timeframe than the initial 5–6 weeks of the pandemic covered by this study. Differences between the three countries also show that as more households have experienced income loss, this has gone hand-in-hand with an increase in food anxiety and a greater reduction in the purchase and consumption of fresh fruit and vegetables. This suggests that those suffering from the greatest income loss shift to more affordable food and away from fresh foods, whilst those with much lower income loss instead tend to seek compensation for the huge inconveniences of lockdowns and changing routines by shifting to greater consumption of ready-made meals, sweets and alcohol, echoing the findings of a US American study among low-income adults (42). This has important policy implications, for example through the provision of greater income support for those who cannot work because of the pandemic and/or for vulnerable households that have the largest squeezes on their incomes. In terms of research, it is clear these issues also require further detailed examination.

Because women were more likely than men to increase their consumption of fruit and vegetables during lockdown, further research could examine whether such increases are due to the fact that women more strongly perceive the health benefits of these foods, and thus may increase their intake in order to support their immunity. If this is indeed the case, then perhaps increasing the awareness of the benefits of fruit and vegetables in helping to protect against COVID-19, particularly among men, may also help to increase the consumption of fruit and vegetables.

Other issues with important policy implications and that require further research include the composition of households which show important differences, for example in terms of whether or not younger children are present. Our study shows that many such households simultaneously tend to both increase their consumption of fruit and vegetables and of sweets and chocolate. These households are likely to require even more focused support than other groups, both in terms of income and of food advice, especially when they fall into the more vulnerable population categories.

Many aspects of this study have shown the importance of local and national food cultures in determining both before- and during-pandemic patterns of food purchasing, preparation and consumption and thus how people change their food behavior. Policies need to be more nuanced in taking account of these differences, working with them where they help shift people to more healthy and sustainable food, as well as attempting to mitigate their influence when they work the other way. Much more research is needed on this issue.

Finally, the results reported in this paper have revealed, as expected, the critical importance of how lockdown measures, as well as the response of the numerous actors along the food value chain, alongside food culture, have impacted moves toward or away from more healthy and sustainable diets. The paper has thrown up many unanswered questions, as well as relevant insights, so it is clear that much more research is required on these issues if policy makers are to be more successful in improving food wellbeing and reducing the negative environmental effects of the food system.

CONCLUSIONS

Across Denmark, Germany and Slovenia people tended to reduce their consumption of fresh food, except for households with children. This change is related to reduced shopping frequency during the pandemic in all countries, and increased risk perceptions of COVID-19 in Denmark and Germany. In Denmark and Germany, people also increased their intake of non-perishable foods, but not in Slovenia, which may have been due to more people in Slovenia being affected by loss of income. Those who ate out once a week before the pandemic increased their intake of convenience foods in Germany and Slovenia during the first lockdown. Women were more likely than men to increase their intake of fresh fruit and vegetables.

The results presented here suggest that changes in eating behavior during the first wave of the pandemic were driven by

contextual factors such as lockdown conditions, and personal factors such as anxiety related to COVID-19, loss of income, household composition, and gender. These results help to identify populations that are particularly vulnerable to nutritional changes during the pandemic, and potential avenues that could be explored to minimize the negative effects of the pandemic on food intake in consumers.

DATA AVAILABILITY STATEMENT

Requests to access the datasets should be directed to Jeremy Millard, jeremy.millard@3mg.org.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Research ethics officer, Danish Technological Institute, Aarhus, Denmark; Research ethics officer, Copenhagen Business School, Department of Management, Society and Communication, Frederiksberg, Denmark; Bioethical committee at the Higher School of Applied Sciences, Ljubljana, Slovenia. The participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

MJ and HH analyzed the data with assistance from JM. All authors contributed to early drafts which were then collated, rewritten and substantially updated by MJ. All authors read and approved the final manuscript, interpreted the data, and made final revisions.

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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.2021.635859/full#supplementary-material

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The Impact of COVID-19 Outbreak in Italy on the Sustainable Food Consumption Intention From a "One Health" Perspective

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Coronavirus disease (COVID-19) is a transmissible illness that was recognized in December 2019 and World Health Organization (WHO) stated a pandemic on 11 March 2020. As no cure has been developed for COVID-19 disease yet, Italy has adopted restrictive measures to avoid the spread of the virus, causing different psychological reactions (e.g., stress, anxiety) that lead people to change lifestyle and in particular the consumer orientation toward food. In addition, the COVID-19 emergency had also affected the Italian economy, causing an 11.3% decrease in GDP (gross domestic product). All these changes gave rise to a sense of instability, but it is known that new possibilities may arise in these situations. In particular, the pandemic could be the turning point to make consumers aware of the close link between human health and the ecosystems, supporting the "One Health" perspective and enhancing the orientation to consumer sustainable food products. However, little is known about how the psychological reactions to COVID-19 emergency have affected the consumers' intention to purchase sustainable food products. In order to answer these questions, a representative sample of 1,004 Italian citizens, extracted by stratified sampling, answered an online survey between May the 12th and 18th 2020. The data were analyzed using ANOVA and contingency tables. The results show that during phase one of COVID-19 disease about 30% of the sample reported that have frequently (often and always) consumed the certified sustainable food products and about 20% of the sample have intention to increase the consumption of them in the next 6 months, percentages that increase among those who feel more vulnerable regarding the risk contagion. Moreover, the psychological impact of the COVID-19 emergency has led to a change in consumers' attitudes, increasing the interest in animal and environmental issues and in human health. These aspects seem to drive the future intention of purchasing sustainable food products. This research highlights how the psychological reactions to the health emergency have changed the consumers' attitudes toward sustainability issues, leading them to follow a more sustainable diet that is recognized as a way to preserve human health, environmental preservation, and animal welfare for present and future generations.

Keywords: COVID-19, sustainability, food consumption, food habits, risk perception, food psychology, one health, consumer orientation

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INTRODUCTION

In January 2020, the coronavirus disease 2019 (COVID-19) caused by *severe acute respiratory syndrome coronavirus-2* (SARS-CoV-2) started to spread in Italy and profoundly changed people's habits. As no cure or vaccine has been developed for COVID-19 disease yet, since March 8th the Italian government have adopted restrictive measures to avoid the spread of the virus and the consequent worsening of the health emergency. These measures to prevent and control the spread of COVID-19 disease affected not only the global economic system, causing a drop in the Italian GDP (1), but they also had a profound psychological impact on people, resulting in an increase of stress, depression, anxiety and frustration (2). These psychological reactions to COVID-19 pandemic have changed people's lifestyle and the perception of the Italian economy, defining it as worrying, and at risk of crisis (3). In response to that, the Italian population has greatly changed food consumption and their food purchase patterns (4–6). Indeed, the stress caused by the pandemic and the risk susceptibility levels of contagion led to increase the consumption of comfort food and to raise food intake to feel better, limiting the purchase of fresh vegetables, and fruits (7). In particular, a study carried out during the COVID-19 lockdown on Tunisian consumers (8) has shown that the stress felt during the COVID-19 pandemic and the risk susceptibility levels of contagion have determined a change in the consumers' sustainability attitudes and in particular toward the food wastage. Most people, indeed, declared that nothing of the foods purchased were discarded, setting up a strategy of saving, storing, and eating leftovers. This first study seems to confirm the thinking of some scholars who argued that this pandemic could be a window of opportunity for recognizing the importance of sustainability issues and in particular the close link between human health and the ecosystems (9–12), supporting the "One Health" perspective. In particular, the "One Health" perspective is defined as an approach that identifies the health of people as closely connected to the health of animals and the environmental themes (13). Understanding the importance of these different facets of health could have changed the attitudes and perceptions of Italian consumers toward sustainability issues, leading people to give more importance to sustainable diet (14, 15). Indeed, many studies that dealt with the topic of sustainable food consumption in "One Health" perspective have shown that the importance given to environmental issues, animal welfare, human health and to the individual responsibility in society are the main aspects in influencing the sustainable food consumption and the implementation of sustainable diet (16, 17). Moreover, some studies argued that the change in the consumers' attitudes toward sustainable food products and the consequent implementation of a sustainable diet could be considered as ways to preserve the ecosystem and the human well-being, decreasing the chances of a new pandemic (18, 19). In particular, research conducted in Italy has suggested that to solve the current pandemic and to prevent the future ones is not enough to carry out studies in the field of medicine, immunology and microbiology, but it is necessary to implement a preventive strategy for sustainable development (10, 11) that supports a higher level of clean production in order to reduce the exploitation of the environment and, as result, the factors that cause the spread of COVID-19 disease and other infections in society (20).

Given these premises, it seems clear that researchers and scientific literature have long recognized the importance of interconnection between human health, environmental preservation, and animal welfare, supporting the "One Health" perspective. On the contrary, the Italian consumers seem to have recognized and given importance to these aspects as a reaction to the COVID-19 emergency, leading them to change their orientation toward a more sustainable food consumption. In light of this, it appears necessary to explore changes in consumers' attitudes toward human health, environmental preservation and animal welfare (16, 17), during the COVID-19 crisis. In this way, it is possible to interpret potential future consumption trends and to orient educational strategies devoted to enable better sustainable food consumption (21, 22).

Although there are many studies that have investigated how the emergency situation caused by COVID-19 disease has impacted on food consumption (4, 7, 23), little is known about how the psychological reaction to COVID-19 pandemic affected the current and future intention to change consumption in the direction of choosing food product with a certification of sustainability and more respectful of human health, environmental preservation, animal welfare. In particular, this study focuses on consumer intentions and attitudes as they, as claimed by the Theory of Planned Behavior (24, 25), are the most important predictors of behavior and have been used to forecast a wide range of behaviors including consumer purchase (26, 27). Furthermore, it has been shown that studying intentions and attitudes allows to investigate the actual predisposition that people have toward food consumption. On the contrary, studying food consumption behavior does not allow to understand the real predisposition that the subject has toward a food product or a type of food consumption since it can be influenced by various psychological, situational, and contextual variables that can compromise the realization of an intention (28, 29).

In particular, the aims of this study are: (1) understand how COVID-19 emergency has changed consumer attitudes toward human health, environmental preservation, animal welfare, and the individual responsibility in society (2) understand the association between perceived vulnerability to the contagion risk and the intention to consume certified sustainable food products (3) association between the intention to consume certified sustainable food products and the consumers' attitudes toward human health, environmental preservation, animal welfare, and the individual responsibility in society.

MATERIALS AND METHODS

Participants

Research data were collected via questionnaire that was filled out by a representative sample of the Italian population with sex, age, profession, size of the center, and geographical area extracted by stratified sampling. The percentages relating to the Italian population were taken from the website of ISTAT (30) (https://www.istat.it/it/) and reported in **Table 1**. The survey was

conducted using a CAWI (Computer Assisted Web Interviewing) methodology between May the 12th and 18th 2020. In particular, the data collection period focused on collecting information regarding consumers' orientation toward sustainable food consumption in relation to the evolving health and economic situation of the country. In particular, in the questionnaire there were 2 questions about the self-reported consumption of certified sustainable food products that referred to different phases of COVID-19 in Italy: phase 1, (started in early March), and phase 2, (started in early May). The two questions allow us to portray two different historical-epidemiological periods characterized by distinct attitudes and behavioral reactions, in particular toward sustainable consumption orientations.

The sample is made up of 1,004 subjects of which 495 are male and 509 are female, aged between 18 and 70 years (Mean = 44.45, Standard Deviation = ±13.9). The demographic profile is presented in detail in **Table 1**. The subjects were randomly selected from the consumers' panel managed by Norstat SRL, a company specialized in collecting data (https://norstat.it/). This study is a part of a broader project (entitled: "Italian citizens' food habits monitoring from a consumer psychology perspective") aimed at monitoring consumption habits of Italian citizens, to which questions are added based on the most interesting contingent events. This study has been performed in accordance with the Declaration of Helsinki and has been approved by an independent ethics committee of Università Cattolica del Sacro Cuore in Milan (CERPS).

TABLE 1 | Demographic profiles of the sample ($N = 1,004$).

	n	%	% population
1. Gender			
Male	495	49.3	49.3
Female	509	50.7	50.7
2. Age			
18–24	101	10.1	10.0
25–34	163	16.3	16.3
35–44	215	21.4	21.5
45–54	228	22.7	22.7
55–59	109	10.8	10.8
60–70	188	18.7	18.8
3. Education			
Elementary	3	0.3	–
Junior high	123	12.2	–
Senior high	602	60.0	–
College or university	276	27.5	–
4. Geographic area			
North-West	264	23.6	26.3
North-East	187	18.6	18.6
Centre	198	19.7	19.7
South and Islands	355	35.4	35.5
5. Inhabited center size			
Until 10,000 inhabitants	314	31.3	32.1
10/100.000 inhabitants	443	44.1	44.0
100/500.000 inhabitants	109	10.9	10.9
More than 500.000	130	12.9	12.9
Missing	8	0.8	
6. Profession			
Entrepreneur/freelancer	124	12.4	12.4
Manager/middle manager	38	3.8	3.8
Employee/teacher/military	193	19.2	19.2
Worker/shop assistant/apprentice	211	21.0	21.0
Housewife	151	15.0	15.0
Student	53	5.3	5.3
Retired	79	7.9	7.9
Unoccupied	155	15.4	15.4
7. Household income level			
Until 600 €	63	6.2	–
601–900 €	66	6.5	–
901–1,200 €	106	10.5	–
1,201–1,500 €	152	15.1	–
1,501–1,800 €	116	11.6	–
1,801–2,500 €	143	14.3	–
2,501–3,500 €	105	10.4	–
More than 3,501 €	103	10.3	–
Missing	150	15.0	–

Measures and Procedure

In particular, in order to answer the research questions, the survey was focused on measuring the following variables (see **Supplementary Materials_A**):

Risk Susceptibility

Participants were asked their perceived risk of being infected by the new COVID-19 virus using a 5-point Likert scale from 1 (very little) to 5 (a lot).

Changes of Attitudes After COVID-19

Participants were asked how the emergency situation caused by COVID-19 could possibly have led them to re-evaluate the importance given to environmental issues, animal welfare, human health and responsibility of individuals in society, intended as aspects of "One Health" approach (13). We created 4 *ad hoc* items to assess these aspects starting from the definition of the concept of "One Health." In particular, the most commonly used definition shared by the US Centers for Disease Control (31) and Prevention and the One Health Commission (32) is: "*One Health is defined as a collaborative, multisectoral, and transdisciplinary approach—working at the local, regional, national, and global levels—with the goal of achieving optimal health outcomes recognizing the interconnection between people, animals, plants, and their shared environment.*" From this definition it is clear that the concept of "One Health" is composed by three specific aspects interconnected with each other: human, animal, and environmental health. To measure these facets, we have created three *ad hoc* items that investigated the importance that people give to environmental issues, animal welfare and human health. Furthermore, the definition talks about "*collaborative approach*" to achieve optimal outcomes referring to the participation and the personal responsibility, paramount aspects to meet the "One Health" principles. In line

with this aspect, we have also added a question that measures this issue related to individual responsibility, investigating the importance that people give to the responsibility of individuals in society. These four items were measured using a 5-point Likert scale from 1 (strongly disagree) to 5 (strongly agree).

The Orientation Toward the Consumption of Certified Sustainable Food Products

The orientation toward the consumption of certified sustainable food products [identified with the following labels: Sustainable cleaning, Ecocert, Ecolabel, Cruelty free, FSC, Fairtrade, Friends of sea, Dolphin safe, MSC which are, according to the observatory carried out by Nielsen (33), the most used to identify the sustainable food products in Italy] was measured considering the self-reported consumption in the last month (corresponding to phase 1 of COVID-19), starting from phase 2 of COVID-19 and future purchase intentions in the next 6 months. All these items concern the reported sustainable food consumption by people and not data regarding sales. The self-reported consumption in phase 1 of COVID-19 was measured by a 5-point Likert scale from 1 (never purchased) to 5 (always purchased). The self-reported consumption of sustainable food products during phase 2 and the future purchase intentions were assessed surveying whether the perceived buying of these food products had diminished, remained the same or increased. All these questions about the orientation toward food consumption had "I do not know" as an option of answer. The subjects who chose this answer were considered as "missing data" and therefore not reported within the different distributions in order to obtain more readable results.

Data Analysis

The data analysis is divided into three main parts. In the first section was used a descriptive statistic and in particular frequencies, percentages, means and standard deviations were carried out in order to understand the distribution of different answers relating to the changes of attitudes, after COVID-19, toward the issues of sustainability, the orientation toward the consumption of certified sustainable food products and the different risk susceptibility levels. The second part of analysis focused on assessing the association between the orientation toward the purchase of certified sustainable food products and the different risk susceptibility levels using a series of contingency tables and one-way ANOVA. In particular the one-way ANOVA was used to analyze the effect of the different risk susceptibility levels (independent variable) on the last month's (corresponding to phase 1 of COVID-19 crisis) self-reported purchase of certified sustainable food products (dependent variable) followed by Bonferroni *post-hoc*. Given the categorical nature of the variables and the unbalanced distributions regarding the measure of phase 2 self-reported purchase and the intention to purchase the sustainable food products in the next 6 months we carried out a series of contingency tables inspecting the Pearson's Chi-square and the standardized residuals. The standardized residuals are calculated as the difference between observed and expected counts of a cell divided by an estimate of its standard deviation. Since they are asymptotically normally distributed with a mean of 0 and standard deviation of 1 under the null hypothesis of independence, as a general rule of thumb cells with an absolute value of standard residuals equal or above 2 can be considered to significantly contribute to the general chi-square value (34). The contingency tables were also used in the third and final part of the analysis which is aimed at exploring the association between the future intentions to purchase the sustainable food products and the importance given to environmental issues, animal welfare, human health and the role of individuals in society after COVID-19 emergency. Moreover, we have analyzed the socio-demographic differences between those who have intention to maintain, increase or decrease the consumption of certified sustainable food products in the next 6 months considering the age (18–38 years old; 39–52 years old; >53 years old), gender, income level (low = 600–1,800€; medium = 1,801–3,500; high >3,501), education level (low = elementary and junior high; medium = senior high; high = college or university) and the geographical area of residence (North-West; North-East; Centre; South and Islands). These analyses were carried out using Pearson's χ^2 to test the hypothesis that the distributions are equal across groups. Whenever the χ^2 resulted significant, column percentages were confronted as *post-hoc* with a *z*-test (corrected with Bonferroni method), as suggested by Sharpe (35) and were graphed.

To simplify the reading of the variables and to allow comparisons among consumer groups, the continuous variables that measure the risk susceptibility and the change of attitudes toward human health, environmental issues, animal welfare and individual responsibility was divided in bands. In particular, the risk susceptibility was divided into three bands: "low risk susceptibility" in which those who responded that they felt not at risk or at little risk (1 and 2 likert scale points) were grouped together; "medium risk susceptibility" represented by those who answered that they felt neither very nor very at risk (3 likert scale point) and "high risk susceptibility" composed by those who answered that they felt quit or very at risk (4 and 5 likert scale points). As regards questions relating to the attitudes toward environmental issues, animal welfare, human health, and the role of individuals in society the medians of each distribution were calculated and these variables were divided into two bands: "low importance" which includes those who strongly agree, agree or neither agree nor disagree with the proposed statements (1, 2, and 3 likert scale points) and "high importance" which includes those who strongly disagree or disagree with the statements (4 and 5 likert scale points). All analyses have been carried out with IBM SPSS 20.

RESULTS

The frequency distributions of the items are presented in **Table 2**. In particular, the results show that most of sample perceives a medium risk susceptibility (42.3%) and only a quarter of the sample has a low risk susceptibility (24.6). Moreover, the results display that this sanitary crisis seems to have shred a light on Italians' awareness toward the sustainability themes. In particular, most of Italians declared

TABLE 2 | Frequency distribution of items.

	n	%	Mean (SD)	Md	A	K
Risk susceptibility (*N* = 1,004)			3.08 (±0.96)	3	−0.19	−0.23
Low *(1–2)*	247	24.6				
Medium *(3)*	424	42.3				
High *(4–5)*	333	33.2				
Importance of animal welfare (*N* = 1,004)			3.63 (±0.91)	4	−0.36	0.10
Low *(1–2)*	81	8				
Neutral *(3)*	364	36.3				
High *(4–5)*	559	55.7				
Importance of environmental issues (*N* = 1,004)			3.78 (±0.87)	4	−0.41	0.20
Low *(1–2)*	48	4.8				
Neutral *(3)*	321	32				
High *(4–5)*	635	63.2				
Importance of human health (*N* = 1,004)			3.91 (±0.80)	4	−0.36	−0.07
Low *(1–2)*	31	3.1				
Neutral *(3)*	267	26.6				
High *(4–5)*	706	70.4				
Importance of individual responsibility in society (*N* = 1,004)			3.71 (±0.88)	4	−0.40	0.17
Low *(1–2)*	64	6.5				
Neutral *(3)*	337	33.5				
High *(4–5)*	603	60				
Self-Reported **Consumption of certified sustainable food products in the last month (Phase 1 of COVID-19 pandemic) (*N* = 930)**			2.69 (±1.31)	3	0.09	−1.17
Never	253	27.3				
Rarely	143	15.3				
Sometimes	252	27.1				
Often	199	21.4				
Always	83	8.9				
Self-Reported **Consumption of certified sustainable food products in phase 2 of COVID-19 pandemic (*N* = 770)**						
Decreased	46	5.9				
Remained stable	618	80.2				
Increased	106	13.8				
Consumption of certified sustainable food products in the next 6 months (*N* = 857)						
Will decrease	36	4.1				
Will remain stable	648	75.6				
Will increase	173	20.2				

(1) SD, Standard Deviation; Md, median; A, asymmetry; K, kurtosis; (2) the numbers in bracket and written in italics represent the points of the Likert scale that were grouped in order to simplify the reading of the table.

that they will increase the importance given to human health (70.4%) followed by the relevance given to environmental issues (63.2%), individual responsibility in society (60%), and animal welfare (55.7%). If we consider the orientation toward the consumption of certified sustainable food products in phase 1 of COVID-19, 30.3% of the Italian population has reported to consume these foods very frequently (often or always). With regard to the orientation toward these products starting from phase 2 and in the next 6 months we note that most people perceived to have kept stable and intend to keep stable the consumption of certified sustainable food products in the next 6 months even if the percentage of those who perceived to have increased or intent to increase this food consumption is greater than those who have perceived to decreased or have intention to decrease them in the next 6 months.

In order to assess the association between the self-reported frequency of purchase certified sustainable food products (in phase 1 of COVID-19, starting from phase 2 of COVID-19 and in the next 6 months) and the different risk susceptibility levels some contingency tables and one-way ANOVA were carried out. In particular the one-way ANOVA was carried out after checking the normality of distribution. How it is possible to see in **Table 2** the kurtosis and asymmetry show a normal

distribution. The ANOVA's results showed a main effect of risk susceptibility levels on the consumption of certified sustainable food products in phase 1 of COVID-19 [$F_{(2, 926)} = 14.381$; $p < 0.001$, $\eta 2 = 0.03$]. In particular, people who have a higher risk susceptibility level perceived to have purchased, in phase 1 of COVID-19, more certified sustainable food products than those who have a medium or low risk susceptibility level (see **Table 3**).

TABLE 3 | Main results from risk susceptibility levels comparison.

	Risk susceptibility levels		
	Low (*n* = 226) *Mean (SD)*	**Medium (*n* = 386) *Mean (SD)***	**High (*n* = 318) *Mean (SD)***
Self-Reported Consumption of certified sustainable food products in the last month (phase 1 of COVID-19 pandemic)	2.42 (±1.29)	2.61 (±1.27)	2.99 (±1.32)
	Risk susceptibility levels comparison		
	Low/medium *Diff. mean (SE)*	**Low/high *Diff. mean (SE)***	**Medium/high *Diff. mean (SE)***
Self-Reported Consumption of certified sustainable food products in the last month (phase 1 of COVID-19 pandemic)	−0.185 (0.108)	−0.572 (0.113)***	−0.387 (0.098)***

*(1) SD, Standard Deviations; (2) Diff mean, differences in means; (3) SE, Standard Errors; (4) Significance in marked with asterisks (*** sig. at $p < 0.001$).*

Considering the orientation toward the consumption of certified sustainable food products in phase 2 of COVID-19 emergency and in the next 6 months, contingency tables show that among those who perceived to have increased in phase 2 the purchase of sustainable food products there is a significantly higher presence of consumers with a high perceived risk of contagion and the same consideration can be used to describe the future intention of consuming certified sustainable food products (see **Table 4**).

Considering the socio-demographic differences of those who intend to increase, not change or decrease the purchase of certified sustainable food products in the next 6 months, we can say that they differ by level of education [*Chi-square = 11.967 (df = 4), p < 0.05)* and by age (*Chi-square = 10.134(df = 4), p < 0.05]*. In particular, among younger subjects there is a higher percentage of people that said that will diminish the consumption of certified sustainable food products in the next 6 months, compared to the oldest individuals (7 vs. 2%, $p < 0.05$; **Figure 1**). As regards the level of education, we note that those who had a high educational level are less likely to keep stable their sustainable food consumption than people with low level of

TABLE 4 | Results of contingency tables.

Variables	**Answers**	**Cell**	**Risk susceptibility levels**			**Row total**
			Low	**Medium**	**High**	
Self-Reported Consumption of certified sustainable food products in phase 2 of COVID-19 pandemic *Chi-square = 18.238 (df = 4), p < 0.01*	Diminished	Observed	14	20	12	46
		Expected	10.7	19.1	16.2	
		Std res.	1.0	0.2	−1.0	
	Unchanged	Observed	152	261	204	617
		Expected	143.6	255.9	217.4	
		Std res.	0.7	0.3	−0.9	
	Increased	Observed	13	38	55	106
		Expected	24.7	44.0	37.4	
		Std res.	**−2.4**	−0.9	**2.9**	
		CT	179	319	271	
Self-Reported Consumption of certified sustainable food products in the next 6 months *Chi-square = 24.396 (df = 4), p < 0.001*	Will Diminish	Observed	4	17	14	35
		Expected	8.2	14.9	11.8	
		Std res.	−1.5	0.5	0.6	
	Will Unchanged	Observed	175	278	196	649
		Expected	153.0	276.4	219.6	
		Std res.	1.8	0.1	−1.6	
	Will Increase	Observed	23	70	80	173
		Expected	40.8	73.7	58.5	
		Std res.	**−2.8**	−0.4	**2.8**	
		CT	202	365	290	

(1) CT, Column Total; Std res, standard residues; df, degrees of freedom; (2) Cells with an absolute value of std. res ≥ 2 are marked in bold.

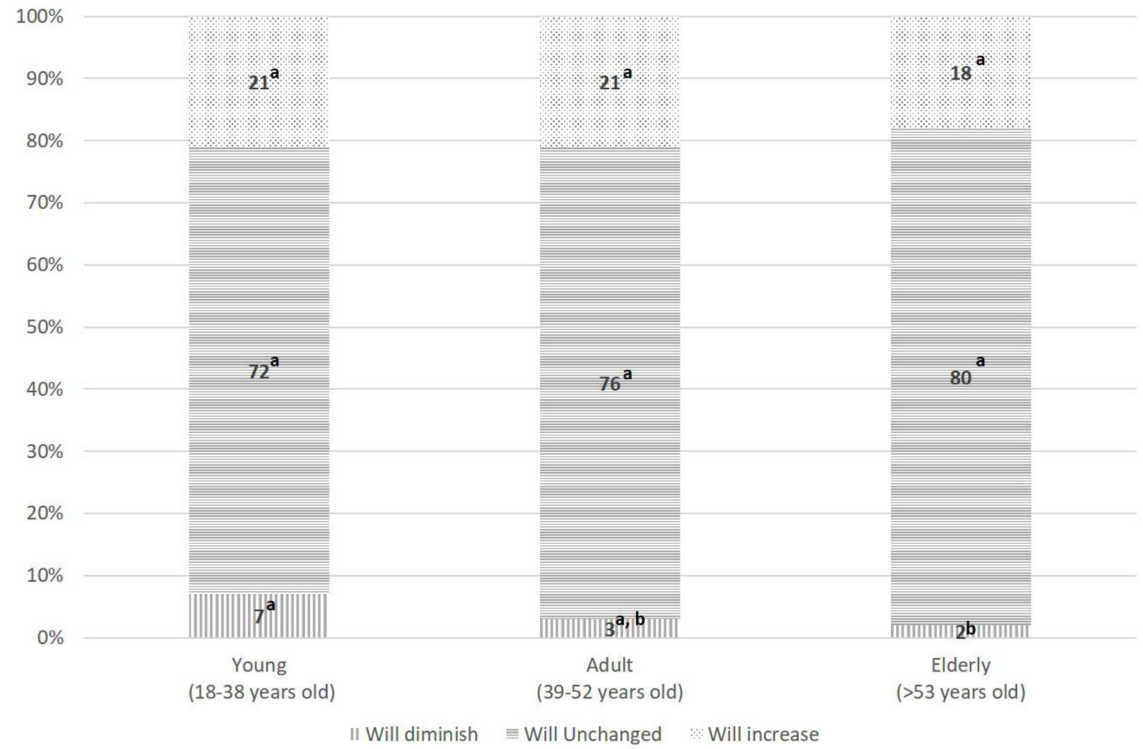

FIGURE 1 | The classification of the consumption of certified sustainable food products in the next 6 months by age. Percentages with the same superscript letter do not differ significantly from each other (*z*-test with Bonferroni correction, $p > 0.05$).

education (70 vs. 85%, $p < 0.05$; **Figure 2**) and in particular they are more prone to increase the certified sustainable food consumption in the future. On the contrary, there are no differences for gender ($p = 0.170$), geographical area of residence ($p = 0.197$), and net monthly household income ($p = 0.073$).

Regarding the relationship between changes in attitude toward human health, animal welfare, environmental issues and individual responsibility, after the emergency from COVID-19, and the future orientation toward certified sustainable food, the contingency tables show that among those who intend to increase the consumption of certified sustainable food products in the next 6 months there is a higher presence of consumers who have acquired, during COVID-19 emergency, a greater awareness of the importance about environmental issues, animal welfare and the responsibility of individual in society (see **Table 5**). With regard to the importance given to human health, it is possible to note that the significance of the chi-square is not so high and also there are not strong significant residual values to comment. This data is difficult to evaluate in terms of significance. However, it is possible to say that among those who intend to increase the consumption of certified sustainable food products in the next 6 months there is a higher presence of consumers who have acquired, during COVID-19 emergency, a greater awareness of the importance of human health even if this presence is not so strongly significant as the other values.

DISCUSSION

This study highlighted how the sanitary emergency caused by COVID-19 disease is raising Italians' attention toward the issue of food consumption sustainability, who are re-evaluating the importance of respecting the environmental, animal welfare, human health and who are reappraising the role of individuals' responsibility in society. This changes in Italians' attitudes appear in line with the scientific principles enshrined in the "One Health" perspective. In particular, the COVID-19 emergency had led Italians to attribute an enhanced importance to the promotion of human health, considering this strongly connected with environmental issues and animal welfare and dependent from the level of individuals' social responsibility. Regarding the perception of vulnerability, most of the Italian population perceive a medium risk of contagion of COVID-19 and just a quarter of them stated that they perceive themselves to be at low risk of contagion. Considering the self-reported consumption of certified sustainable food products, this study shows that in phase 1 of COVID-19 almost a third of the Italian population declared to consume these products frequently (often or always) while in phase 2 of COVID-19 and in the next 6 months most of the sample declared to have kept and to will keep them stable even if those who reported that they have increased or want to increase sustainable consumption are much greater than those who reported to have decreased or intend to decrease them. These results are in line with previous studies which showed

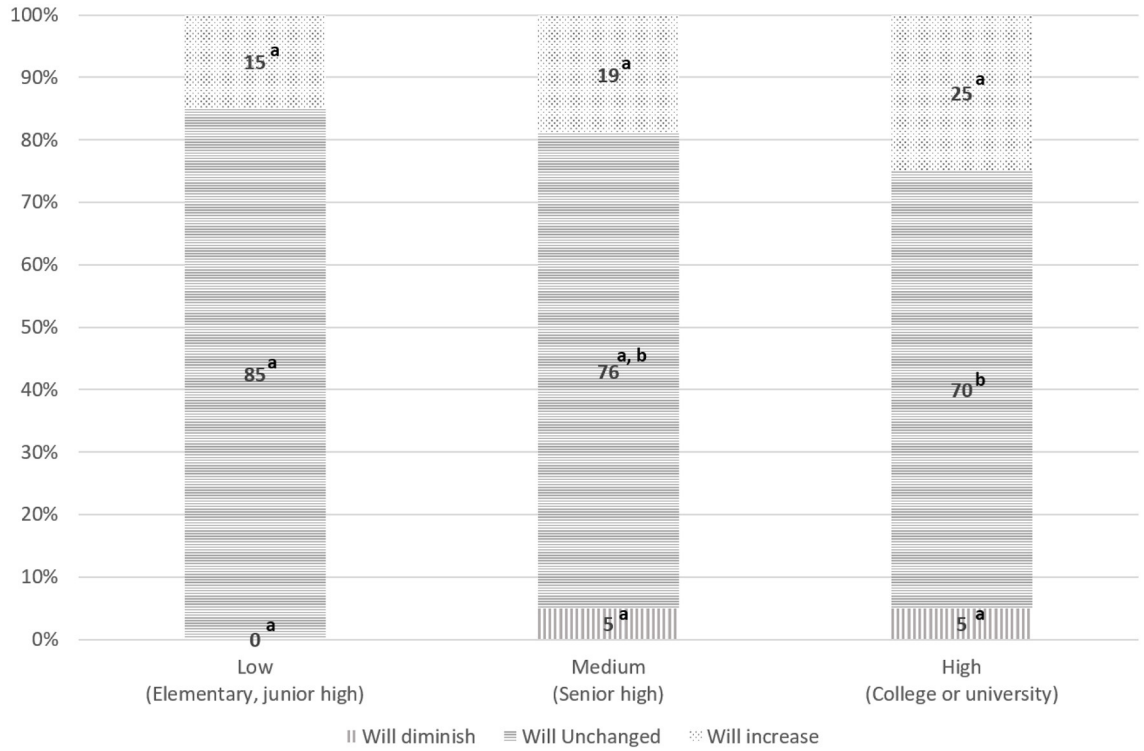

FIGURE 2 | The classification of the consumption of certified sustainable food products in the next 6 months by level of education. Percentages with the same superscript letter do not differ significantly from each other (*z*-test with Bonferroni correction, $p > 0.05$).

how the COVID-19 pandemic raised citizens' concerns about the potential consequences of the intensive exploitation of natural resources on the ecosystem and on the well-being of the world population (9–11). This appears to lead people toward the choice of certified sustainable food product (14, 15). A study carried out in China (36) observed that consumers, due to the COVID-19 crisis, increased the consumption of food products considered healthy, natural and environmentally friendly (37, 38). However, these data are controversial. Other studies conducted in Spain (39, 40) showed that the COVID-19 and containment measures determined by lockdown led to less sustainable nutritional habit of consumers with higher values of Global Warming Potential, Blue Water Footprint and Land Use in respect to the average diets of April and March 2019. The variable results of the available literature on the topic may be interpreted as the potential discrepancy between the consumers psychological attitudes and intention toward a sustainable diet (particularly in a period of sanitary crisis) and actual nutritional behaviors. Many studies have explored the intention-behavior relation in the field of food, demonstrating that it is often moderated by several variables such as actual behavioral control, situational context and psychological variables (41–43). In particular, a recent study carried out in China (44) aiming at understanding the gap between intention to buy and actual consumption of sustainable food during COVID-19 crisis, has showed that high prices of green food, unavailability issues, mistrust issues, and limited knowledge moderated the relationship between intentions to consume sustainable food products and the real purchase. In line with this research, could be assumable that the discrepancy between the studies on intentions toward the consumption of sustainable food products and those based on real behavioral data could be explained by the presence of some moderators related to COVID-19 crisis such as the unavailability of sustainable food products given by the scarcity of food resources during the pandemic. Considering the relationship between the orientation toward the consumption of certified sustainable food products in phase 1 of COVID-19 pandemic and the perceived risk of infection, the study shows that those who perceived to have most frequently purchased the sustainable food products have a higher level of risk susceptibility. Moreover, our study shows that among those who perceived to have increased in phase 2 of COVID-19 disease the consumption of sustainable food products there is a significantly higher presence of consumers with a high perceived risk of contagion, underlining how this psychological emotional aspect affects the orientation toward the consumption of certified sustainable food products. the same results are observable if we consider future purchases. This evidence confirms previous studies that have highlighted how the psychological reaction—for example in terms of stress and fear of contagion—determined a change in food consumption intentions (45, 46). For instance, a research on Tunisian consumers (8) has shown that the stress felt during the COVID-19 lockdown has raised citizens attention toward the importance of opting for a better sustainable diet, with a particular focus on reducing food waste. Another

TABLE 5 | Results of contingency tables.

Variables	Levels	Cell	Consumption of certified sustainable food products in the next 6 months			Row Total
			Will diminish	Will unchanged	Will increase	
Importance of animal welfare *Chi-square = 13.181 (df = 2), p < 0.01*	Low *(1–2–3)*	Observed	19	279	51	349
		Expected	14.3	264.2	70.5	
		Std res.	1.3	0.9	**−2.3**	
	High *(4–5)*	Observed	16	369	122	507
		Expected	20.7	383.8	102.5	
		Std res.	−1.0	−0.8	1.9	
		CT	35	648	173	
Importance of environmental issues *Chi-square = 10.814 (df = 2), p < 0.01*	Low *(1–2–3)*	Observed	18	228	44	290
		Expected	11.9	219.5	58.6	
		Std res.	1.8	0.6	**−2.0**	
	High *(4–5)*	Observed	17	420	129	566
		Expected	23.1	428.5	114.4	
		Std res.	−1.3	−0.4	1.4	
		CT	35	648	173	
Importance of human health *Chi-square = 6.486 (df = 2), p < 0.05*	Low *(1–2–3)*	Observed	13	200	38	251
		Expected	10.3	189.8	51.0	
		Std res.	0.9	0.7	−1.8	
	High *(4–5)*	Observed	22	448	136	606
		Expected	24.7	458.2	123.0	
		Std res.	−0.6	−0.5	1.2	
		CT	35	648	174	
Importance of individual responsibility in society *Chi-square = 15.888 (df = 2), p < 0.001*	Low *(1–2–3)*	Observed	22	259	49	330
		Expected	13.8	249.6	66.5	
		Std res.	**2.2**	0.6	**−2.2**	
	High *(4–5)*	Observed	14	390	124	528
		Expected	22.2	399.4	106.5	
		Std res.	−1.7	−0.5	1.7	
		CT	36	649	173	

(1) CT, Column Total; Std res, standard residues; df, degrees of freedom; (2) Cells with an absolute value of std. res ≥ 2 are marked in bold; (3) the numbers in bracket and written in italics represent the points of the Likert scale that were grouped in order to simplify the reading of the results.

longitudinal research carried out by the International Food Information Council (IFIC) (47) on American consumers has shown that, although the perception of importance of achieving an environmental sustainability was stable compared to past years, the COVID-19 pandemic has led American consumers to becoming better aware about the impact of individuals' decisions in achieving the sustainable goals. Furthermore, an Italian study (48) has analyzed how the fear of reduced food availability during the COVID-19 pandemic has led consumers to better preserve and manage purchased food products, by reducing the extent of food waste. Very similar results were achieved in Qatar where the COVID-19 pandemic has not only greatly reduced food waste but has also drastically changed the consumption behavior of people who have purchased more healthier and sustainable products (49).

Focusing on the future orientation toward the consumption of certified sustainable food products, this study underlines how this orientation is also influenced by socio-demographic characteristics such as age and level of education while income, geographical area of residence and gender do not influence this predisposition. In particular, the study showed that young people (18–35 years old), compared to older ones (>53 years old), had a less predisposition to increase the consumption of sustainable food products. This result is controversial in the current literature. Some studies carried out both in Italy (50) and in other foreign countries (51) confirmed that older people seemed to be more prone than the younger ones to purchase sustainable food products. However, other research conducted in Italy and in Serbia, achieved an opposite result, namely that young people were more predisposed toward the sustainable food products than the older ones (52, 53). From this results we may conclude that the socio-demographic characteristics impact on the intention to buy of sustainable food consumption is not clear. Other situational factors may influence this phenomenon, such as the psychological alarm caused by a sanitary crisis. Furthermore, people with a high level of education (college or university) were more likely to change the consumption of sustainable food products in the future by increasing them, than those with a

lower education level. This data seems to be strongly consolidated and supported by previous studies which underlined how people with a higher level of education were more orientated toward the consumption of sustainable food products than those with a lower level of instruction (54, 55).

Finally, it is possible to note that the change in attitude toward sustainable issues during the COVID-19 pandemic affects the future intention to consume certified sustainable food products. In particular, the study shows that the consumers attitudes toward the environmental issues, animal welfare and their appraisal of the individual responsibility in the process affect their intentions to consume sustainable food products in the Italian population. These results are in line with other studies that highlight how the consumption of sustainable products is not only influenced by personal ethic values but also by a social component (16, 56). In particular, some studied demonstrated that those who consider their sustainable food choices as a way to contribute to specific sustainable development-related outcomes are more prone to consume sustainable food products (57, 58). Although it is clear that the crisis caused by COVID-19 has increased people's interest in environmental issues, animal welfare and in individual responsibility, which positively influence the future orientation toward the consumption of certified sustainable food products, the role of health is uncertain. Our results clearly show that among those who intend to increase the consumption of certified food products there are more people who have re-evaluated the importance of human health but it is difficult to describe it as a strong significant result. Furthermore, from the results it can be observed that the importance given to human health seems to have a lower association with the consumption of certified sustainable foods than the other variables considered (animals welfare, environmental issues and individual responsibility). The latter result is confirmed by some previous studies (59, 60) that have noted how the egoistic motivations (i.e., health consciousness and food safety) have a significant effect on the intention to purchase products that support sustainable consumption patterns (e.g., consumption of local products, consumption of organic products) but to a lesser extent than altruistic motivations related to respect for the environment and animals. Nonetheless, this evidence suggests that Italians perceive an association between sustainable consumption and the protection of their health even if this awareness should be reinforced.

In conclusion, this study showed that the COVID-19 sanitary emergency has not only increased citizens' awareness toward the issue of sustainability but the sense of vulnerability to the risk of contagion has also led Italians to a greater intention to consume certified sustainable food products during phase 1 and phase 2 of COVID-19 pandemic. This appears also influencing their future consumption intentions. This research, therefore, points out how the crisis caused by COVID-19 can represent an unrepeatable opportunity to educate and involve the consumer toward sustainable diets, exploiting the positive attitudes of consumers toward sustainability issues. For these reasons, this is the moment in which policy makers and food companies should create opportunities for discussion with the consumer, creating workshops or dedicated web platforms. They have the opportunity to take advantage of this "teachable moment" (61), that if properly exploited can push people toward significant change in consumption behavior. In particular, it would be advisable to exploit the openness that older people with a high level of education have toward the consumption of sustainable food products, making them informed citizens who in turn can positively influence the attitudes and orientations of younger people who are less inclined to this type of consumption. Furthermore, these educational moments could be an opportunity to emphasize the concept of "One Health" by highlighting how the safeguarding of our health is closely linked to animal and environmental well-being by promoting sustainable diet as a means of preserving the natural resources and human health (21, 22). Now all the stakeholders of food supply chain have the opportunity -but also the necessity- to rethink on holistic approaches for improving the relationship with the environment that will lead people toward sustainable consumption as a way to preserve the ecosystem and the personal health of present and future generations.

Although this research produced interesting results, it has some limitations. The frequency of consumption of certified sustainable food products is based on self-reported items, which allows the researchers to grasps individual elaboration of this phenomenon and real people's perceived intentions, however these items do not allow to testifying the real consumption behavior. Moreover, the questions regarding the certified food products considered them as a single category that included all sustainable food products without take into account the different types of sustainable labels or product categories. This decision allowed the subjects to have clear examples of certified sustainable food, even if the certifications chosen are not all the possible ones. Moreover, future research could be implemented to deepen these results. In particular, given the controversial intention-behavior relationship, it would be interesting to understand if some psychological (such as social-influence, involvement in food etc.) and situational variables (related to the COVID-19 pandemic) can influence this relationship. It would also be interesting to understand how these variables differ in predicting diverse types of sustainable food products or particular sustainable labels. Finally, despite the presence of many studies that have investigated how COVID-19 has changed consumption habits, the majority of them focused on understanding how negative emotions caused by COVID-19 have worsened food habits, not considering what people have learned from this sanitary emergency. The Coronavirus will not be the last epidemic to hit us therefore it is necessary a preventive strategy based on the key issues that we learned from this pandemic. In this sense, further studies that focus on the "lessons taught" by COVID-19 (as this work) are necessary in order to exploit this knowledge to prevent possible future pandemics.

DATA AVAILABILITY STATEMENT

The data analyzed in this study is subject to the following licenses/restrictions: The dataset presented in the study is

available on request. Requests to access these datasets should be directed to GC, Greta.castellini@unicatt.it.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethics committee of Università Cattolica del Sacro Cuore in Milan (CERPS). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

GC: conceptualization, methodology, data curation, formal analysis, and writing—original draft. MS: validation, investigation, and writing—review and editing. GG: writing—review and editing and supervision. All authors have approved the final article.

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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.2021.622122/full#supplementary-material

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Trans Fat Free by 2023—A Building Block of the COVID-19 Response

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COVID-19 has brought to center stage the most important health issue of our era, largely ignored by policymakers and the public to date: non-communicable diseases (NCDs), the cause of 71% of deaths per year worldwide. People living with NCDs, and particularly those living with cardiovascular disease (CVD), are at higher risk of severe symptoms and death from COVID-19. As a result, the urgent need for policy measures to protect cardiovascular health is more apparent than ever. One example of "low-hanging fruit" in the prevention of CVD is the elimination of industrially-produced trans fatty acids (iTFA). Their removal from the global food supply could prevent up to 17 million deaths by 2040 and would be the first time an NCD risk factor has been eliminated.

Keywords: COVID-19, trans fat elimination, trans fatty acids, NCD prevention, food regulation, cardiovascular diseases, non-communicable disease, artificial trans-fatty acids

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INTRODUCTION

COVID-19 has illustrated the importance of public health and disease prevention measures, not only for infectious diseases, but also for NCD prevention and care. It is now recognized that COVID-19 and NCDs, often referred to as "underlying conditions," are deeply linked. It is estimated that 1.7 billion people worldwide are at an increased risk of severe COVID-19 should they become infected, mostly as a result of living with one or more NCDs (1). These vulnerabilities include diet-related NCDs such as CVD and type 2 diabetes which are to a large extent preventable. The deadly interplay of NCDs, inequities and COVID-19 has illuminated the need to respond to the current crisis by breaking down silos and addressing interlinkages as a syndemic [formed from "syn-" = together and (epi)demic].

The Syndemic of COVID-19 and NCDs

COVID-19 and NCDs interact to form a syndemic—parallel epidemics of health problems which interact synergistically, have intertwined risk factors and mutually enhance each other against a background of shared social and economic inequalities (2). The COVID-19 pandemic is occurring against the backdrop of a steadily rising NCD burden. NCDs are the leading cause of mortality worldwide with 41 million deaths annually, of which 32 million occur in low- and middle-income

countries (LMICs) and 18 million are due to CVD (2, 3). NCDs and COVID-19 share factors which influence health-seeking behavior, health decision-making, access to healthcare and other services, and risk exposure: poverty, discrimination, cultural norms and gender (4).

NCDs and infectious diseases have often been addressed in silos, yet their interlinkages are well-known (5). Infectious diseases can be a risk factor for several NCDs, such as HIV and chlamydia for CVD (6), while NCDs increase the susceptibility to and disease severity of infectious diseases. NCDs were a predictor of disease severity for Middle East Respiratory Syndrome (MERS) and Severe Acute Respiratory Syndrome (SARS) (7, 8). Consequently, the 2018 High-Level Political Declaration on NCDs (9) called for the integration of responses to NCDs and infectious diseases.

COVID-19 has also worsened the obesogenic environment by limiting opportunities for physical activity and decreasing food quality for many, thus negatively impacting two of the main NCD risk factors (10, 11). Access to fresh food has become more limited for many. Lockdown measures and a decline in purchasing power increase reliance on cheap foods and foods with a long shelf life, both of which are often ultra-processed and unhealthy. In many countries, consumers have been targeted with new, unhealthy offerings by the food industry, with marketing messages tailored to exploit the pandemic context (12). Decreased dietary quality may persist even after COVID-19 is under control due to economic pressures in the pandemic's aftermath (10–14).

COVID-19—A Historic Opportunity to Scale Up Health-Promoting Policy Measures

The interlinkage between infectious diseases, health emergencies and NCDs has brought about an unprecedented acknowledgment and visibility of the urgent need to address the ever-growing NCD burden. Unchecked, NCDs cause social and economic harm that far exceeds the damage caused by COVID-19. COVID-19 presents a historic imperative to prioritize and invest in public health by adopting health-promoting policy measures, including iTFA elimination. These measures must also address modifiable risk factors—including nutrition, hypertension and obesity—that drive both COVID-19 and the NCD burden.

Population groups of lower socio-economic status tend to consume higher amounts of iTFA and are therefore at higher risk of iTFA-attributable CVD. iTFA elimination can thus help reduce both CVD mortality and morbidity as well as health inequalities (15–18).

Nutrition Policy to Address the Modifiable Risk Factors of NCDs

Currently, almost all countries are off-track to achieve the World Health Organization's target of reducing overall mortality from the four main NCDs—CVD, cancers, diabetes, and chronic respiratory diseases—by 25% by 2025 (19), and Sustainable Development Goal 3.4 to reduce premature mortality from NCDs by a third by 2030 (20, 21). Implementing strong nutrition policies will save lives, accelerate progress toward these global NCD targets, and build healthier, more equitable and resilient populations that are better prepared to deal with future health emergencies.

Nutrition policy interventions are one of the reasons high-income countries have managed to reduce CVD deaths by more than 25% since 2000 (22). Conversely, LMICs largely have yet to introduce comprehensive CVD prevention policies and bear up to 90% of the global CVD burden (23), underscoring the need to extend iTFA elimination strategies globally. This is particularly relevant in countries where Universal Health Coverage (UHC) does not yet exist, or is weak, and where primary prevention strategies such as nutrition policies can support the feasibility and sustainability of UHC.

Regulations such as mandatory iTFA limits link political will to health policy and demonstrate government commitment to addressing population health. Their adoption signals that a government is prepared to invest appropriately in public health, creates a level playing field for industry, and is a strong signal to society that a healthy diet and diet-related NCDs must be taken seriously.

WHAT ARE TRANS FATS?

Trans fatty acids, or trans fats, are unsaturated fatty acids of either natural or artificial origin. Naturally occurring trans fats are produced by bacteria in the gut of ruminants; dairy and meat products derived from them contain small amounts of trans fats. iTFA are created in an industrial process that adds hydrogen to vegetable oil (hydrogenation) to produce partially hydrogenated oils (PHO), which are solid or semi-solid fats.

Globally, most iTFA is consumed through PHO which are common in baked goods, pre-packaged foods and some cooking oils. iTFA have no known health benefit and are a contributor to CVD worldwide, estimated to cause around 260,000 deaths and 6,162,986 disability-adjusted life years (DALYs) annually (24). Trans fat consumption increases the risk of death from any cause by 34% and from coronary heart disease (CHD) by 28% (25). For every 1% increase in daily energy obtained from trans fats, CHD mortality raises by 12% (18). iTFA intake has also been associated with an increased risk for other NCDs and related conditions such as ovarian cancer (26), infertility, endometriosis, Alzheimer's disease, diabetes and obesity (27, 28).

iTFA consumption induces low-grade systemic inflammation and is positively associated with endothelial dysfunction (a non-obstructive coronary artery disease without blockages of heart arteries, but with the large blood vessels of the hearts surface constricting instead of dilating) (29–33). Low-grade systematic inflammation, a higher concentration of pro-inflammatory cytokines and endothelial dysfunction are also induced by overweight and obesity which are metabolic risk factors for diet-related NCDs, and particularly for heart disease (34, 35). This is relevant in the context of COVID-19 which is a disease that triggers pro-inflammatory cytokines. Patients with severe COVID-19 frequently show cytokine storms, an excessive and

uncontrolled release of pro-inflammatory cytokines; cytokine storms are an indicator for poor prognosis of COVID-19 (34, 36).

WHO recommends that total trans fat intake does not exceed 1% of total energy intake, which translates to >2.2 g/day for a 2,000-calorie diet (37).

iTFA can be replaced in foods with healthier fats and oils containing polyunsaturated (preferred) or monounsaturated fats without impacting their consistency and taste (38).

BENEFITS OF iTFA ELIMINATION

Worldwide iTFA elimination could save 17 million lives by 2040 (39). Countries that have eliminated iTFA from their food supply have seen substantial health benefits:

- **Argentina:** iTFA elimination is associated with an estimated annual 1.3–6.3% reduction in CHD events (40).
- **Denmark**: In the 3 years following the implementation of an iTFA limit in 2004, CVD mortality decreased 3.2% in relation to comparable countries without iTFA regulation (41).
- **England and Wales**: iTFA elimination across the two countries is estimated to result in around 1,600 fewer deaths and 4,000 fewer hospital admissions per year (18).
- **New York**: Counties in the state of New York with iTFA restrictions saw 7.8% fewer hospital admissions for heart attacks between 2007 and 2013 than counties without iTFA restrictions (42).

The prevention of death and disease attributable to iTFA consumption lessens the burden on health systems, which is particularly important for health facilities overwhelmed by the COVID-19 response and where treatment services for CVD and other NCDs have been disrupted.

The economic value of investing in global iTFA elimination has not been calculated but local estimates demonstrate the intervention's cost-effectiveness.

- **Argentina**: iTFA elimination would save US$17-87 million annually in costs associated with the management of CHD complications and follow-up. These cost savings include implementation costs of the policy incurred by the Ministry of Health, but do not include other economic costs (e.g., lost productivity due to CVD) (40).
- **Australia**: iTFA elimination would save AU$80 million (US$60 million) in healthcare costs related to ischemic heart disease during the first 10 years and AU$538 (US$407 million) over the population lifetime. Policy costs would near AU$22 million (US$17 million) during the first 10 years and AU$56 million (US$42 million) over the population lifetime, mostly consisting of monitoring costs to government (17).
- **European Union**: Prior to adopting a mandatory 2% iTFA limit, the European Union estimated that phasing out iTFA would result in direct and indirect cost savings of €58–304 billion (US$68–358 billion) over 85 years (16).
- **United Kingdom**: One study found that iTFA regulation in England would result in cost savings of around £297 million (US$379 million), consisting of £42 million (US$54 million) in direct healthcare costs, £196 million (US$250 million) in informal care costs, and £59 million (US$75 million) in averted productivity loss over 5 years. Considering implementation costs to government and industry, net cost savings would range from £64–264 million (US$82–337 million) (15). Another study calculated that mandatory iTFA elimination in England and Wales over a 10-year period would bring cost savings of £755 million to £1.54 billion (US$965 million to US$1.97 billion), comprising £95–201 million (US$121–257 million) in direct healthcare costs, £368–727 million (US$470–929 million) in informal care costs, and £292–613 million (US$373–783 million) in averted productivity loss (18).
- **United States**: The removal of PHO over a 20-year time interval is estimated to result in net benefits of US$130 billion. The analysis included lives saved and non-fatal illnesses prevented as benefits, and as costs product reformulation and relabelling, increased costs of substitute ingredients, costs to consumers from changing recipes, reduced product acceptances, shorter product shelf life, and restaurants and bakeries learning how to operate without PHO (43).

WHO deems iTFA elimination a cost-effective and feasible intervention (a so-called "best buy" policy measure), recommended for implementation by all countries to prevent NCDs (44).

WHO'S REPLACE INITIATIVE

To support national governments to reach the goal of global iTFA elimination by 2023, WHO launched the REPLACE initiative in May 2018. The REPLACE action package (45) provides governments with evidence-based tools across six strategic areas to eliminate iTFA from their national food supply (see **Figure 1**). REPLACE is the first global initiative to eliminate an NCD risk factor. In September 2020, WHO announced a certification scheme which will recognize countries that achieve iTFA elimination, similar to the WHO certification scheme for polio eradication (47). Countries must show that they have implemented a best-practice iTFA policy and that effective monitoring and enforcement is in place to qualify for certification (48). This initiative is the first time that WHO has introduced certification to recognize government's achievements in addressing a modifiable NCD risk factor.

3.2 BILLION PEOPLE WILL BE PROTECTED BY iTFA POLICIES BY 2021 BUT OVER 100 COUNTRIES HAVE YET TO ACT

Substantial progress has been made in the last 10 years to remove iTFA from the global food supply. To date, 32 countries have enacted laws and regulations that currently protect 2.4 billion people from this harmful substance. Another 26 countries have passed laws and regulations that will come into effect in the next 2 years, covering a further 815 million people. Encouragingly, an increasing number of countries are introducing best practice

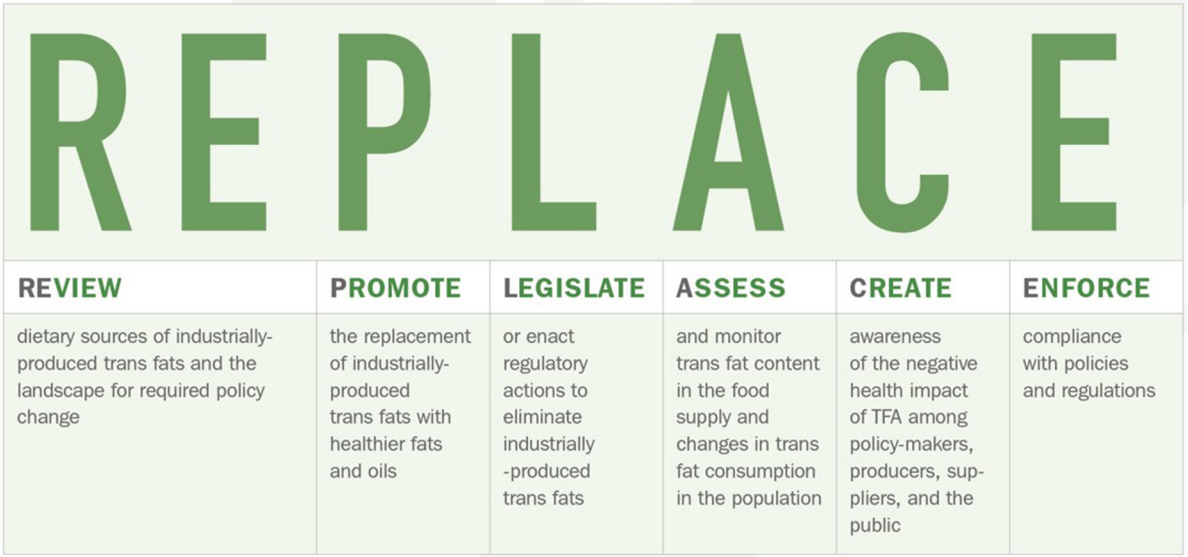

FIGURE 1 | The six areas of WHO's REPLACE action package to eliminate iTFA (46).

policies, which include setting a compulsory limit of 2 g of iTFA per 100 g of total fat/oil in all foods and/or banning PHO (the main source of iTFA). While in 2010 only two countries had a best practice policy in effect, this number has risen to 14 by 2020 and will reach 40 by 2022 (49). These developments show that adopting legal instruments to limit iTFA or ban PHO is politically, economically, and technically feasible (50).

Regional approaches to iTFA elimination have also progressed. Member States of the Pan American Health Organization (PAHO, WHO's Americas region) unanimously approved a Regional Plan of Action to Eliminate Industrially Produced Trans-Fatty Acids 2020–2025 (51), the first of its kind globally. Regional regulations include the European Union's 2% iTFA limit for all foods adopted in 2019 (52), a Gulf Cooperation Council standard limiting iTFA to 2% for fats and oils and 5% for other foods in 2015 (53), and the Eurasian Economic Union's 2% iTFA limit for oils and fats adopted in 2015 (54). Such regulatory approaches have the added benefit of spill-over effects, forcing countries surrounding these regions to consider iTFA elimination policies to allow for continued trade in foods.

However, over 100 countries have yet to act, and of the 15 countries with the highest proportion of CHD deaths due to trans fat intake, only four (Canada, Latvia, Slovenia, and USA) have introduced regulations to remove iTFA from their food supply. Ten countries (Azerbaijan, Bangladesh, Bhutan, Ecuador, Egypt, Iran, Mexico, Nepal, Pakistan, and Republic of Korea) have yet to do so, while India is on track for a best practice policy (49).

Countries with comparatively low iTFA intake and associated mortality also benefit from adopting iTFA regulations. Introducing regulation is a preventive measure to avoid increasing intakes of iTFA and associated health risks in the future, and to guard against food manufacturers increasing sales of iTFA-containing foods ("dumping") in unregulated markets. Additionally, average iTFA intake levels at national level may conceal high iTFA exposure levels in pockets of the population—regulation ensures that health disparities due to iTFA intake are minimized. And implementation of iTFA regulation is easier and cheaper when national levels of iTFA are low, also presenting an opportunity to strengthen regulatory capacity and systems in food safety (55).

Disparities in protection from iTFA also persist. Most laws and regulations have been adopted in high-income or upper-middle-income countries in Europe and the Americas. No low- or lower-middle-income country has implemented a best practice policy to date, resulting in geographic and socio-economic inequalities (49). This is particularly worrying given that CVD associated mortality is higher in LMICs than high-income countries (56).

MANDATORY REGULATION IS PREFERABLE TO VOLUNTARY COMMITMENTS TO PHASE OUT iTFA

In 2019, member organizations of the International Food & Beverage Alliance (IFBA) committed to limit iTFA to 2 g per 100 g fat/oil in their food products worldwide by 2023 and to reformulation without increasing the content of saturated fat (57). It will be important that adherence to and impact of these commitments is independently and transparently monitored and evaluated.

In the 2008 Trans Fat Free Americas Declaration (58), backed by PAHO, representatives of Latin America's major food companies (including some IFBA members), cooking oil companies and industry associations, together with delegates of national public health authorities, committed to a 2% iTFA limit in oils and margarines and a 5% limit in other foods.

These voluntary efforts, however, only cover a small percentage of packaged foods worldwide (49), and the food industry and suppliers of oils and fats have generally been slow to voluntarily phase out iTFA. Many large food producers have replaced iTFA with healthier fats in products sold to high-income countries—many of which have regulated iTFA—while resisting the replacement of iTFA in LMICs (49, 59).

Food industry and oil and fat suppliers may be reluctant to phase out iTFA for fear of competitors moving into the market if regulation is absent to create a level playing field. Additionally, compliance with voluntary commitments cannot be enforced by governments. Research shows that voluntary approaches are less effective than mandatory regulation in reducing iTFA content in foods (28, 60). Therefore, compulsory regulation combined with strong enforcement mechanisms is recommended over voluntary schemes.

iTFA ELIMINATION SHOULD BE EMBEDDED IN A COMPREHENSIVE POLICY APPROACH

Diet is one of the key modifiable risk factors to address underlying conditions of severe COVID-19. Therefore, including iTFA elimination in a comprehensive policy approach to improve the food environment will address both NCDs and the ongoing pandemic. It will also improve preparedness for and resilience to future pandemics, as a healthier population with a lower prevalence of NCDs is less susceptible to infections and better equipped to fight them.

In addition to iTFA regulation, a comprehensive policy package to prevent diet-related NCDs should comprise mandatory food labeling (ingredient lists, nutrient panels declaring trans fats, interpretative front-of-pack labeling based on nutrient profiles, rules on nutrient and health claims), restrictions on food marketing aimed at children and adolescents, mandatory standards for healthy school food, limits on salt/sodium content (61), and nutrition standards for public procurement. These policy measures can be accompanied by public awareness campaigns to educate consumers on healthy nutrition.

At the healthcare level, policy actions should include preventative measures such as blood pressure checks and hypertension control (62), weight-management support and nutrition counseling.

Additionally, taxing unhealthy foods and beverages alongside alcohol and tobacco—and removing any market-distorting subsidies—would reduce their intake and, in some cases, incentivize reformulation while mobilizing domestic revenue, which could be invested in health system strengthening and Universal Health Coverage. Such investments would not only contribute to future health, but also pandemic preparedness and health systems' resilience. Notably, if used progressively, such revenue would benefit poorer households and help tackle poverty and inequality. For example, raising the price of sugar-sweetened beverages, alcohol, and tobacco by 50% could raise around US$24.7 billion in 54 LMICs by 2030 (63).

CONCLUSION

Including iTFA elimination alongside a comprehensive policy approach including food policy, healthcare and taxation strategies—many of them WHO "best buys"—in recovery packages will strengthen global health systems, as compared to pre-pandemic levels. Using these population-wide primary prevention strategies in the COVID-19 response will serve as a stepping stone to tackle the world's biggest killer, cardiovascular disease; support economic recovery from the pandemic; and increase health security by making future generations more resilient to infectious diseases.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

This perspectives paper was conceived and written by SB. NR, LW, and IP reviewed the manuscript. All authors read and approved the final manuscript.

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Exploring Dietary Behavior Changes Due to the COVID-19 Confinement in Colombia: A National and Regional Survey Study

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The aim of this study was to evaluate the impact of coronavirus SARS-Cov2 (COVID-19) confinement measures in Colombia on the dietary behaviors of a large population sample, at national and regional levels. A survey was conducted to assess dietary behaviors during the COVID-19 confinement. The survey involved 2,745 participants, aged 18 years or older, from six regions of the country (Atlántica, Bogotá, Central, Oriental, Orinoquía and Amazonía, and Pacífica). Dietary intake of foods and foods groups in grams per day before and during the confinement was estimated by considering standard serving sizes of foods. One-way ANOVA was used to analyze differences between the regions with regard to dietary behavior changes during the confinement. Differences were deemed significant at p-value < 0.05. Dietary patterns (DPs) before and during the confinement were derived from principal component analysis. Certain dietary habits were adopted by the study population during the confinement (e.g., higher frequency of snacking and home cooking), with significant differences by regions with regard to these habits, as well as regarding culinary processes. The levels of consumption of several foods also changed during the confinement, nationally and regionally. We identified three DPs before the confinement (protein-rich, carbohydrate-rich, and sugar foods patterns) and four DPs during the confinement (westernized, carbohydrate-rich, protein-rich, fish and fruits-vegetable patterns), with an explained total variance of 33 and 45%, respectively. The profile of these DPs varied to some extent between the regions; their adherence to each DP also varied (p-value < 0.001). Our results show that there were marked differences by regions in the dietary behaviors of this population during the confinement, with an overall trend toward unhealthier DPs. These results may help to shape public health nutrition interventions in Colombia during the COVID-19 pandemic and in a post-COVID stage.

Keywords: dietary patterns, dietary habits, nutritional survey, culinary processes, COVID-19 confinement

INTRODUCTION

Public health measures implemented to halt the spread of coronavirus SARS-Cov2 (COVID-19) have produced major transformations in the society on a worldwide basis, both of qualitative and quantitative nature. For example, community confinement as a preventive isolation measure has been adopted by most countries to control the growth of the disease transmission, but this measure has been recognized as disturbing and problematic. One of its main social consequences is related to dietary behavior changes, which seem to have turned to healthier dietary patterns (DPs) in some European and Asian case studies (1). In Latin America, such confinement measures may have also changed dietary behaviors (2), but few studies have appraised the extent to which these measures have influenced the above. So far, a small study conducted among adolescents from Chile, Colombia, and Brazil noted an increased consumption of fried food, sweet food, legumes, vegetables, and fruits (3). A study from Chile, also reported major dietary changes in the population during the confinement (4). However, there is no study evaluating changes in dietary behaviors in the adult population from Colombia under this situation.

The Colombian government declared a mandatory confinement on March 25, 2020 (5), which remained in force, in full or in part by de-escalating means, until recently. This situation has given rise to changes in the daily life of the country's inhabitants, affecting not only social relations but also causing an economic disruption (6, 7). There have also been alterations in the food supply and consumption habits of the population; this being supported by national data on food demand and household expenditure. Detailed figures in this regard, with special emphasis on the population's dietary behaviors, are urgently needed to evaluate the impact of the COVID-19 confinement on this issue.

Prior to the COVID-19 pandemic, the Colombian National Survey on the nutritional status of the country of 2015 reported a significant growth in the indicators of obesity and overweight for the adult population between 18 and 64 years, reaching a 56.4% prevalence of excess weight (8). The adoption of unhealthier DP and lifestyle habits appear to be the main cause. An increased consumption of processed foods has been witnessed since the 1990s in this country, along with physical inactivity, longer working hours, and reduced mobility (8–10). The National Nutritional Surveys (ENSIN 2005 and 2015) also support the loss of traditional lifestyle and dietary habits (11). These changes have been associated with a higher prevalence of chronic non-communicable diseases such as cardiovascular diseases (12, 13) which are the main causes of mortality and morbidity in Colombia (14).

Besides, it is important to highlight that there are regional differences with regard to the aforementioned data on obesity and overweight, with Pacífica and Amazonía exhibiting the highest prevalence rates (8). The same trend has been made visible for DPs (11). Colombia is a country of great diversity relative to social and production systems, which affects food availability and supply (15). The current COVID-19 pandemic is supposed to affect the dietary behaviors in all regions of the country (16). It is therefore deemed necessary to characterize the changes in these habits of the Colombian population and to identify improvement needs in diet toward a better health and well-being.

This study aimed to assess how the COVID-19 confinement has influenced dietary behaviors of the Colombia adult population at the national and regional levels, with regard to the consumption of foods, the culinary processes applied, food safety measures, and other related variables. Herein, we describe for the first time dietary behaviors adopted by a large subset of the adult Colombian population taking survey data on changes in these behaviors since the adoption of the COVID-19 confinement.

METHODS

Study Design and Population

A cross-sectional study with the administration of a survey on dietary behaviors during the COVID-19 confinement was carried out. There were 2,745 adults (aged over 18 years) from Colombia participating in the survey. The survey was disseminated using snowball sampling strategies all over Colombia through different channels (mailings, conferences, social media, and press releases) and was running from the second to the eighth week of confinement.

The study protocol was approved by the Human Research Ethics Committee of the University of Granada (1526/CEIH/2020) since this study is part of the COVIDiet-Int study (ClinicalTrials.gov number NCT 04449731). The survey (open between April 6 and May 22, 2020) was administered online, and all participants were informed about the objective of the research. All agreed to participate anonymously in the study and authorized the use of the data for research and dissemination. Also, the survey was conducted in agreement with the Declaration of Helsinki and in due compliance with personal data protection regulations in Colombia (Legislative Decrees 1581/2012 and 1377/2013). No further IRB approvals were requested.

Data Collection

The survey was based on the one applied in the Spanish COVIDiet Study (17) and was further modified to adapt the questionnaire to the dietary behaviors of the Colombian population. Therefore, the same COVIDiet study survey was applied except for the dietary section on intake of foods. Given that, the dietary section did not account for Mediterranean Diet items as the Spanish study did, but for other foods typically consumed in Colombia. A pilot study was conducted among 20 volunteers to ensure the survey process and understanding and its effective implementation.

The questionnaire comprised 73 items within five distinct sections: (i) baseline characteristics (gender, age, type of housing, children in care, educational level, health status, height, and weight); (ii) dietary intake of foods during the confinement; (iii) cooking processes (cooking, frequency of frying and other culinary processes, type of oil used, and oil reutilization); (iv) lifestyle and dietary habits (physical activity, snacking, fast food consumption, meals out of home, water intake); (v) food security and safety issues (food hygienization, food availability

and supply, expenditure on food, and staid aid). The final four sections referred to dietary behaviors. Furthermore, the participants were asked whether or not they changed their dietary behaviors during the confinement with regard to their usual practices. In addition, data on changes during the confinement in alcohol consumption and perception about weight gain was collected.

Data Processing

Information on dietary intake regarded frequency of consumption in servings per day or per week (rating scale 0–5). Dietary intake was collected for 18 food groups: (1) cereals, (2) bakery and pastry, (3) tubers and plantains, (4) fruits and vegetables, (5) milk and dairy products, (6) red meat and processed, (7) poultry and processed, (8) fish, (9) eggs, (10) legumes, (11) fats (butter and margarine), (12) soft beverages, (13) sugar cane beverages, (14) coffee, (15) sugar or sugar cane, (16) desserts and sweets (desserts and ice cream), (17) snacks, and (18) nuts.

Moreover, since participants provided information on changes in the intake during the COVID-19 confinement, i.e., whether it was maintained the same, or whether it increased or decreased since the confinement was activated, it was possible to estimate the dietary intake of these foods before the confinement. In particular, we considered the reported intakes of food groups in servings/day. Then, this number of servings was kept the same when the dietary intake was reported to remain unchanged during the confinement. Instead, the number of servings was reduced by one when the intake increased during the confinement or was otherwise increased by one serving. In this way, we estimated the average servings of foods consumed by the participants before and during the confinement. Standard serving sizes in grams/day adapted from the Colombian dietary guidelines (18) were considered in order to estimate the dietary intake of these foods in grams/day (servings/day*grams/day of each serving), before and during the confinement. For cereals and legumes, a cooking factor was applied since their consumption was reported for cooked servings of these foods; weighted cooked servings were considered to quantify more precisely their intake. Thus, dietary intake information was obtained in servings/day and grams/day, before and during the confinement.

Finally, we estimated the week the survey was completed as a proxy of weeks of confinement by considering the difference in the launching and completion dates. Also, body mass index (BMI) was calculated by means of the reported weight and height of the participants [weight in kg/(height in m)^2]. BMI categories as defined by the WHO were considered (19).

Statistical Data Analysis

Descriptive statistics were derived for quantitative (mean and standard deviations) and categorical variables (frequencies and percentages). Relationships of variables by regions were also plotted using bar plots. Differences by regions were evaluated *via* one-way ANOVA or chi-squared test (or Fisher's exact-test for <5 observations), respectively.

Principal component analysis (PCA) was applied to obtain dietary clusters or DPs, i.e., components, before and during the COVID-19 confinement. Sixteen dietary items were used after collapsing some food groups: cereals including cereals and bakery and pastries; snacks including snacks and nuts. The components were rotated by orthogonal transformation (Varimax rotation) to facilitate their interpretation. Kaiser-Meyer-Olkin measure of sampling adequacy (KMO) and Bartlett's-test of sphericity values were >0.7, validating the use of PCAs in the study sample.

Eigenvalues >0.1 and scree plot graphs of the eigenvalue against the component number were considered to choose the optimum number of components. Then, factor loadings were obtained for each food group, to identify the groups most highly correlated with the DP. Food groups with factor loadings >0.30 were retained. The variability (variance) of the data explained by each component (pattern) was also calculated overall and by DP. Radial charts for visualizing and exploring DPs were used on the raw data (average serving sizes) and on the identified patterns.

Principal component analysis was applied on the entire study population due to sample size issues, although PCAs by regions were analyzed further to complement the analyses. Differences in adherence to the components by regions were evaluated to identify potential regional variations. For each DP, each subject received a score that was calculated as the sum of the intakes in each food group weighted by the corresponding factor loading. A higher score indicated a higher adherence to the respective DP. Non-parametric ANOVA-tests were considered (Kruskal-Wallis-test) to reveal differences by regions owing to the non-normal distribution of the scores (Kolmogorov-Smirnov-test, p-value < 0.05).

Likewise, all analyses were performed by weeks of confinement, to compare the short- and long-term impact of the confinement, i.e., the first 2 weeks (up to the fourth of confinement) with regard to the last 4 weeks (up to the eighth week of confinement), respectively.

Statistical significance was set at p-value < 0.05. The analyses were carried out with SPSS version 27 IBM for Windows (20), and R version 4.0.2 (21).

RESULTS

Sociodemographic Characteristics of the Study Sample, Nationally, and by Regions

Table 1 shows sociodemographic characteristics of the respondents by regions. Among the six regions, there were significant differences (p-value < 0.05) in the proportion of men and women, number of children in the household, and educational attainment. A major proportion of respondents were women (73.1%) and University graduates (77%). The state of health requiring to follow a special diet and age groups also differed significantly between the regions. For instance, while the majority of participants were aged <51 years, there were small variations by regions in the distribution of age groups. Most respondents in Orinoquía and Amazonas were young-aged (72.5% of years 18–35), whereas fewer were aged older than 51 years in comparison with the other regions. The

TABLE 1 | Baseline characteristics of the diet-COVID-19 survey respondents in Columbia by regions.

	National	Atlántica	Bogotá	Central	Oriental	Orinoquía and Amazonas	Pacífica	*p*-value[a]
	N = 2,745 (%)	*N* = 262 (%)	*N* = 1,374 (%)	*N* = 272 (%)	*N* = 476 (%)	*N* = 91 (%)	*N* = 270 (%)	
Gender[b]								0.013
Men	735 (26.8)	54 (20.6)	385 (28)	83 (30.5)	118 (24.8)	23 (25.3)	72 (26.7)	
Women	2,006 (73.1)	208 (79.4)	985 (71.7)	189 (69.5)	358 (75.2)	68 (74.7)	198 (73.3)	
Place of residence[c]								0.335
House	1,208 (44.0)	156 (59.5)	448 (32.6)	127 (46.7)	262 (55)	59 (64.8)	156 (57.8)	
Apartment	1,474 (53.7)	100 (38.2)	902 (65.6)	138 (50.7)	203 (42.6)	26 (28.6)	105 (38.9)	
Room	43 (1.6)	4 (1.5)	19 (1.4)	5 (1.8)	5 (1.1)	5 (5.5)	5 (1.9)	
Indigen home	20 (0.7)	2 (0.8)	5 (0.4)	7 (0.7)	6 (1.3)	1 (1.1)	4 (1.5)	
Children in care								0.006
0	1,647 (60)	145 (55.3)	862 (62.7)	172 (63.2)	277 (58.2)	39 (42.9)	152 (56.3)	
1	656 (23.9)	62 (23.7)	320 (23.3)	59 (21.7)	111 (23.3)	29 (31.9)	75 (27.8)	
2	358 (13)	44 (16.8)	158 (11.5)	35 (12.9)	71 (14.9)	20 (22)	30 (11.1)	
3	84 (3.1)	11 (4.2)	34 (2.5)	6 (2.2)	17 (3.6)	3 (3.3)	13 (4.8)	
Educational level								<0.001
None	10 (0.4)	1 (0.4)	4 (0.3)	1 (0.4)	0 (0)	1 (1.1)	3 (1.1)	
Primary school	33 (1.2)	3 (1.1)	10 (0.7)	10 (3.7)	4 (0.8)	1 (1.1)	5 (1.9)	
High school	326 (11.9)	22 (8.4)	161 (11.7)	29 (10.7)	47 (9.9)	20 (22)	47 (17.4)	
Graduate	263 (9.6)	20 (7.6)	142 (10.3)	14 (5.1)	45 (9.5)	9 (9.9)	33 (12.2)	
Professional	1,194 (43.5)	150 (57.3)	540 (39.3)	120 (44.1)	214 (45)	41 (45.1)	129 (47.8)	
Post-graduate	919 (33.5)	66 (25.2)	517 (37.6)	98 (36)	166 (34.9)	19 (20.9)	53 (19.6)	
State aid								0.594
No	2,625 (95.6)	241 (92)	1,336 (97.2)	257 (94.5)	462 (97.1)	79 (86.8)	250 (92.6)	
Yes	120 (4.4)	21 (8)	38 (2.8)	15 (5.5)	14 (2.9)	12 (13.2)	20 (7.4)	
Age (years)								<0.001
18–35	1,383 (50.4)	151 (57.6)	658 (47.9)	128 (47.1)	210 (44.1)	66 (72.5)	170 (63)	
36–50	791 (28.8)	66 (25.2)	408 (29.7)	81 (29.8)	159 (33.4)	18 (19.8)	59 (21.9)	
51–66	494 (18)	36 (13.7)	267 (19.4)	51 (18.8)	96 (20.2)	7 (7.7)	37 (13.7)	
>66	77 (2.8)	9 (3.4)	41 (3)	12 (4.4)	11 (2.3)	0 (0)	4 (1.5)	
Health status								0.004
No	2,237 (81.5)	193 (73.7)	1,125 (81.9)	227 (83.5)	382 (80.3)	81 (89)	229 (84.8)	
Yes	508 (18.5)	69 (26.3)	249 (18.1)	45 (16.5)	94 (19.7)	10 (11)	41 (15.2)	
Weight	66.1 ± 12.8	68.2 ± 14.8	65.4 ± 12.3	65.8 ± 12.5	67.1 ± 13.2	66.4 ± 13.4	66.0 ± 12.2	0.013
Height	1.64 ± 0.09	1.63 ± 0.09	1.64 ± 0.09	1.64 ± 0.08	1.63 ± 0.08	1.62 ± 0.08	1.65 ± 0.09	0.179
BMI (kg/m)								<0.001
<18.5	58 (2.3)	12 (5.1)	21 (1.7)	4 (1.6)	8 (1.8)	2 (2.4)	11 (4.5)	
18.5–24.9	1,467 (58.1)	107 (45.5)	778 (61.4)	164 (65.1)	232(52.3)	42 (51.2)	144 (58.8)	
25–29.9	770 (30.5)	84 (35.7)	372 (29.4)	67 (26.6)	152 (34.2)	27 (32.9)	68 (27.8)	
>30	230 (9.1)	32 (13.6)	96 (7.6)	17 (6.7)	52 (11.7)	11 (13.4)	22 (9.0)	

[a] *Differences between groups were evaluated by chi-squared-test or one-way ANOVA where appropriate. Differences between groups were evaluated by Fisher's exact-test with <5 observations in some categories.*

[b] *Only four respondents from Bogotá identify themselves with another unspecified gender identity.*

[c] *One respondent indicated other options.*

prevalence of participants with medical conditions varied from 11% (Orinoquía and Amazonas) to 26% (Atlántica). In addition, there were significant differences in weight (p-value = 0.013) and BMI (p-value < 0.001) between the regions, with Central and Bogotá regions showing the lowest obesity prevalence rates (<8%). There were no differences with regard to place of residence, state aid, support, and height.

Dietary Behaviors at National and Region Levels

Regional variations in the rates of consumers and non-consumers of specific food groups are shown in **Table 2**. Noteworthy, regardless of the region, over 90% of respondents consumed cereals, bakery, and pastry (except in the Pacifica region), tubers and plantains, fruits and vegetables (except in the Orinoquía

TABLE 2 | Food groups consumed (C) and non-consumed (NC) by the diet-COVID-19 survey respondents in Colombia by regions.

Food groups	National	Atlántica	Bogotá	Central	Oriental	Orinoquía and Amazonas	Pacífica
	N = 2,745	*N* = 262	*N* = 1,374	*N* = 272	*N* = 476	*N* = 91	*N* = 270
	C/NC (%)	C/NC (%)	C/NC (%)	C/NC (%)	C/NC (%)	C/NC (%)	C/NC (%)
Cereals	98/2	98/2	98/2	99/1	99/1	99/1	98/2
Bakery and pastries	91/9	88/12	92/8	94/6	98/10	92/8	86/14
Tubers and plantains	91/9	95/5	90/10	94/6	93/7	92/8	91/9
Fruits and vegetables	95/5	92/8	97/3	95/5	94/6	85/15	96/4
Milk and dairy products	85/15	85/15	86/14	83/17	83/17	71/29	87/13
Red meat and processed	89/11	91/9	89/11	88/12	93/7	91/9	86/14
Fish	71/29	77/23	74/26	67/33	70/30	64/36	64/36
Poultry and processed	96/4	95/5	96/4	93/7	97/3	92/8	95/5
Eggs	98/2	96/4	98/2	95/5	99/1	98/2	97/3
Legumes	93/7	93/7	92/8	95/5	92/8	93/7	96/4
Nuts	95/5	95/5	95/5	94/6	95/5	97/3	95/5
Fats	69/31	71/29	66/34	78/22	70/30	73/27	69/31
Soft beverages	36/64	46/54	33/67	35/65	36/64	51/49	36/64
Coffee	78/22	73/27	79/21	80/20	80/20	73/27	78/22
Sugar cane beverages	52/48	52/48	48/52	52/48	57/43	64/36	53/47
Sugar or sugar cane	61/39	73/27	57/43	56/44	64/36	75/25	63/37
Desserts and sweets	54/46	44/56	56/44	60/40	51/49	45/55	51/49
Snacks	40/60	40/60	41/59	36/64	34/64	44/56	39/61
Alcohol beverages	47/53	42/58	49/51	51/49	44/56	51/49	41/59

and Amazonas regions), red meat and processed (except in the Pacifica, Central, and Bogotá regions), poultry, eggs, legumes, and nuts. Milk and dairy products were consumed by around 85% of the respondents, and coffee by 80% of them (except in the Orinoquía and Amazonas region for both food groups). Foods with consumption rates ranging between 50 and 75% were fish, fats, sugar or sugar cane, and sugar cane beverages (except in Central and Bogotá regions), and desserts and sweets (except in Atlántica and Orinoquía and Amazonas regions). Finally, consumption rates were lower (below 50%) for soft beverages (except in the Orinoquía and Amazonas region), snacks (40%) and alcoholic beverages (47%).

Table 3 presents changes in dietary behaviors due to the COVID-19 confinement by regions. Compared to dietary behaviors before the confinement, a higher frequency of snacking between meals was reported by nearly half of the respondents, or even more (63% in Orinoquía and Amazonas), but in the Central region (39%), the differences between the regions being statistically significant (p-value = 0.01). A higher consumption of fast food during the confinement was also reported in Orinoquía and Amazonas (36%) when compared to the other regions (<25%) (p-value = 0.005). Interestingly, Orinoquía and Amazonas respondents seemed to be more likely to gain weight (p-value = 0.003) despite reporting to practice more physical activity (p-value = 0.001) and home-cooking (p-value = 0.001) during the confinement when compared to the other regions. Respondents from the Orinoquía and Amazonas region were also found to eat more frequently out of home (before the confinement) (p-value = 0.032) and to experience difficulties in finding specific foods during the confinement compared to other regions (p-value < 0.001). Statistically significant differences (p-value < 0.05) between the regions were also observed for alcohol intake (higher in the Central region), water intake (higher in the Atlántica and Pacífica regions) and expenditure on food (higher in the Orinoquía and Amazonas region). However, no significant differences by regions were seen with regard to hygiene measures, perishable foods consumption and eating more at each meal.

Table 4 shows dietary behaviors by culinary processes and regions during the confinement. There were no significant differences observed in the frequency of frying food by regions (p-value = 0.254), but for other culinary processes: boiling (p-value = 0.02), baking (p-value < 0.001), microwaving (p-value = 0.02), stewing (p-value = 0.02), and griddling (p-value = 0.03). Specifically, boiling (47.5%) and griddling (40%) were the most often applied processes (4–5 points on the 0–5 frequency scale). Lower-frequency levels (3–2–1 points) were also reported for boiling (47.8%), frying (72.3%), and baking, stewing, and griddling (between 51.3 and 53.1%). Microwaving and baking were the less used culinary processes; 75.1 and 34.8% of respondents, respectively, never used it.

Table 5 shows dietary behaviors concerning fried food consumption by regions. While fried food consumption frequency was found to be similar between the regions (**Table 4**), we observed that the change in the consumption of these foods before and during the confinement differed significantly between them. The largest increase in fried consumption during the

TABLE 3 | Dietary behaviors of the diet-COVID-19 survey respondents in Colombia by regions.

	National	Atlántica	Bogotá	Central	Oriental	Orinoquía and Amazonas	Pacífica	*p*-value[a]
	N = 2,745 (%)	*N* = 262 (%)	*N* = 1,374 (%)	*N* = 272 (%)	*N* = 476 (%)	*N* = 91 (%)	*N* = 270 (%)	
Snacking								0.011
As before	835 (30.4)	82 (31.3)	412 (30)	97 (35.7)	154 (32.4)	20 (22)	70 (25.9)	
Lower	593 (21.6)	62 (23.7)	299 (21.8)	69 (25.4)	90 (18.9)	14 (15.4)	59 (21.9)	
Higher	1,317 (48)	118 (45)	663 (48.3)	106 (39)	232 (48.7)	57 (62.6)	141 (52.2)	
Fast food								0.005
As before	1,238 (45.1)	106 (40.5)	621 (45.2)	134 (49.3)	226 (47.5)	31 (34.1)	120 (44.4)	
Lower	929 (33.8)	95 (36.3)	471 (34.3)	89 (32.7)	166 (34.9)	27 (29.7)	81 (30)	
Higher	578 (21.1)	61 (23.3)	282 (20.5)	49 (18)	84 (17.6)	33 (36.3)	69 (25.6)	
Eat more								0.275
As before	967 (35.2)	101 (38.5)	474 (34.5)	108 (39.7)	165 (34.7)	30 (33)	89 (33)	
Lower	544 (19.8)	43 (16.4)	287 (20.9)	61 (22.4)	87 (18.3)	16 (17.6)	50 (18.5)	
Higher	1,234 (45)	118 (45)	613 (44.6)	103 (37.9)	224 (47.1)	45 (49.5)	131 (48.5)	
Physical activity								0.001
Never	307 (11.2)	49 (18.7)	126 (9.2)	32 (11.8)	55 (11.6)	15 (16.5)	60 (22.2)	
As before	499 (18.2)	48 (18.3)	246 (17.9)	52 (19.1)	78 (16.4)	14 (15.4)	68 (25.2)	
Lower	1,317 (48)	124 (47.3)	672 (48.9)	127 (46.7)	235 (49.4)	17 (18.7)	28 (10.4)	
Higher	622 (22.7)	41 (15.6)	330 (24)	61 (22.4)	108 (22.7)	45 (49.5)	114 (42.2)	
Weight gain								0.003
No	1,036 (37.7)	89 (34)	539 (39.2)	113 (41.5)	174 (36.6)	22 (24.2)	99 (36.7)	
Yes	613 (22.3)	76 (29)	295 (21.5)	42 (15.4)	117 (24.6)	29 (31.9)	54 (20)	
Unknown	1,096 (39.9)	97 (37)	540 (39.3)	117 (43)	185 (38.9)	40 (44)	117 (43.3)	
Meals out of home[b]								0.032
Never	368 (13.4)	36 (13.7)	161 (11.7)	46 (16.9)	84 (17.6)	9 (9.9)	32 (11.9)	
1	513 (18.7)	48 (18.3)	280 (20.4)	37 (13.6)	83 (17.4)	13 (14.3)	52 (19.3)	
2	471 (17.2)	44 (16.8)	246 (17.9)	40 (14.7)	75 (15.8)	22 (24.2)	44 (16.3)	
3	1,393 (50.7)	134 (51.1)	687 (50)	149 (54.8)	234 (49.2)	47 (51.6)	142 (52.6)	
Alcohol intake								0.001
Never	1,445 (52.6)	151 (57.6)	694 (50.5)	133 (48.9)	265 (55.7)	45 (49.5)	157 (58.1)	
As before	607 (22.1)	44 (16.8)	336 (24.5)	68 (25)	97 (20.4)	16 (17.6)	46 (17)	
Lower	498 (18.1)	48 (18.3)	238 (17.3)	41 (15.1)	94 (19.7)	25 (27.5)	52 (19.3)	
Higher	195 (7.1)	19 (7.3)	106 (7.7)	30 (11)	20 (4.2)	5 (5.5)	15 (5.6)	
Water intake								<0.001
As before	1,043 (38)	94 (35.9)	544 (39.6)	116 (42.6)	185 (38.9)	27 (29.7)	77 (28.5)	
Lower	707 (25.8)	34 (13)	400 (29.1)	64 (23.5)	127 (26.7)	26 (28.6)	56 (20.7)	
Higher	995 (36.2)	134 (51.1)	430 (31.3)	92 (33.8)	164 (34.5)	38 (41.8)	137 (50.7)	
Hygiene measures								0.068
As before	466 (17)	31 (11.8)	239 (17.4)	47 (17.3)	94 (19.7)	18 (19.8)	37 (13.7)	
Higher	2,279 (83)	231 (88.2)	1,135 (82.6)	225 (82.7)	382 (80.3)	73 (80.2)	233 (86.3)	
Perishable foods								0.309
As before	1,033 (37.6)	108 (41.2)	509 (37)	102 (37.5)	183 (38.4)	30 (33)	101 (37.4)	
Lower	334 (12.2)	24 (9.2)	153 (11.1)	38 (14)	64 (13.4)	17 (18.7)	38 (14.1)	
Higher	1,378 (50.2)	130 (49.6)	712 (51.8)	132 (48.5)	229 (48.1)	44 (48.4)	131 (48.5)	
Expenditure on food								0.010
As Before	544 (19.8)	65 (24.8)	273 (19.9)	59 (21.7)	89 (18.7)	14 (15.4)	44 (16.3)	
Lower	251 (9.2)	11 (4.2)	148 (10.8)	28 (10.3)	38 (8)	7 (7.7)	19 (7)	
Higher	1,950 (71.0)	186 (71)	953 (69.4)	185 (68)	349 (73.3)	70 (76.9)	207 (76.7)	
Difficult to find food								<0.001
No	1,831 (66.7)	168 (64.1)	968 (70.5)	182 (66.9)	300 (63)	43 (47.3)	170 (63)	
Yes	914 (33.3)	94 (35.9)	406 (29.5)	90 (33.1)	176 (37)	48 (52.7)	100 (37)	

(Continued)

TABLE 3 | Continued

	National	Atlántica	Bogotá	Central	Oriental	Orinoquía and Amazonas	Pacífica	*p*-value[a]
	N = 2,745 (%)	*N* = 262 (%)	*N* = 1,374 (%)	*N* = 272 (%)	*N* = 476 (%)	*N* = 91 (%)	*N* = 270 (%)	
Frequency of home-cooking								0.001
Not before, but now	196 (7.1)	20 (7.63)	104 (7.57)	17 (6.25)	31 (6.51)	5 (5.49)	19 (7.04)	
Never	158 (5.8)	14 (5.34)	79 (5.75)	19 (6.99)	29 (6.09)	1 (1.10)	16 (5.93)	
As before	640 (23.3)	88 (33.6)	285 (20.7)	70 (25.7)	115 (24.2)	17 (18.7)	65 (24.1)	
Lower	124 (4.5)	26 (9.92)	39 (2.84)	20 (7.35)	19 (3.99)	9 (9.89)	11 (4.07)	
Higher	1,627 (59.3)	114 (43.5)	867 (63.1)	146 (53.7)	282 (59.2)	59 (64.8)	159 (58.9)	

[a]*Differences between groups were evaluated by chi-squared-test.*
[b]*Number of meals out of home before the quarantine.*

confinement was found in Orinoquía and Amazonas (38.5%), and the lowest in Bogotá (18.5%), the differences in the change being statistically significant between the regions (p-value $<$ 0.001). Half of the respondents consumed fried food one to three times/week. Over 6% of respondents from Orinoquía and Amazonas reported to eat fried food more than seven times/week compared with <2% of respondents from the other regions (p-value = 0.002). Also, stir-fry frequency was higher in this region (25% of respondents, more than five times/week) compared with the others (p-value $<$ 0.001). The most consumed oil for frying was sunflower oil followed by canola and soybean oils. Also, oil type consumption differed significantly between the regions (p-value $<$ 0.001). Oil reutilization was more uncommon in Bogotá (48.3% of respondents) but frequently applied in Orinoquía and Amazonas (85.7% of respondents) (p-value $<$ 0.001).

Dietary Patterns at National and Region Level

Figure 1 shows the average daily serving consumption of 18 food groups before and during the confinement at the country level. Comparing the two situations, the consumption pattern seemed to change more importantly with regard to cereals, legumes, eggs, fats, coffee, sugar or sugar cane, and their beverages; their intake increased notably during the confinement. This change was seen in all regions although to a varying extent (**Supplementary Figure 1**). Particularly with regard to cereals, during the confinement, their consumption was reported to be as usual by 60–70% of the respondents, while over 20% of them reported an increase in their consumption (**Supplementary Figure 2**). As shown in **Figure 2**, this increased consumption resulted in a higher amount of servings/day during the confinement in all regions. On the other hand, intake of other food groups, such as fish and nuts, decreased in all regions during the confinement; that of fruits and vegetables seemed to decline in every region, except in Bogotá and Central regions (**Supplementary Figure 2**). Nonetheless, during the confinement, significant differences by regions in the dietary intake of all foods were observed, except for snacks (**Supplementary Table 1**).

Figure 3 shows food intake in the form of dietary clusters derived from PCA, similarly before and during the confinement. We observed three main clusters (i.e., DPs) before confinement: a protein-rich and carbohydrate-rich dietary cluster characterized by high intakes of food sources of these nutrients, and a sugary dietary cluster characterized by high positive loadings (>0.3) on soft beverages, sugar, and cane, but negative loadings (>-0.3) on fruits and vegetables. During the confinement, the protein and carbohydrate dietary clusters remained to a certain extent, albeit with some modifications, mostly in the carbohydrate cluster. The latter incorporated sugared foods such as sugar and sugar cane, and beverages, whereas other food components were depleted (fruits and vegetables, and milk and dairy products). In addition, two new clusters emerged: a westernized-diet-like cluster scoring positively for soft beverages, sugar and fats, snacks, milk and dairy products, red meat and processed, and desserts, and another cluster characterized by positive loadings on fruits, vegetables, and fish. Factor loadings of foods in each cluster and explained variance of the dietary clusters are shown in **Supplementary Table 2**. The explained variance was highest for the protein-rich cluster before the confinement and for the westernized dietary cluster during the confinement, both followed by the carbohydrate-rich dietary cluster. Dietary clusters were relatively stable during the survey (**Supplementary Figure 3**); they remained similar with regard to the protein-rich and carbohydrate-rich dietary clusters in the early confinement and later. Remarkably, the fruits and vegetable and fish dietary cluster appeared from the fourth week of confinement.

By regions (**Supplementary Figure 4**), we observed that all showed the carbohydrate-rich dietary cluster before the confinement, but with some differences. For instance, the cluster was similar among most regions, but snacks were part of this dietary cluster in Atlántica, and Orinoquía and Amazonas showed a mixed cluster with cereals, bakery, soft beverages, and fish. This dietary cluster became more diversified during the confinement in some regions: tubers and plantains with cereals and bakery constituted a separate component in Atlántica and Bogotá regions, while cereals and bakery clustered with some protein foods in Orinoquía and Amazonas, Central, and Pacifica regions. The fruits and vegetable, and fish dietary cluster emerged

TABLE 4 | Dietary behaviors of the diet-COVID-19 survey respondents in Colombia by regions according to the culinary processes applied.

Process		National	Atlántica	Bogotá	Central	Oriental	Orinoquía and Amazonas	Pacífica	*p*-value[b]
applied[a]		*N* = 2,745 (%)	*N* = 262 (%)	*N* = 1,374 (%)	*N* = 272 (%)	*N* = 476 (%)	*N* = 91 (%)	*N* = 270 (%)	
Boiled	0	131 (4.8)	19 (7.3)	53 (3.9)	16 (5.9)	17 (3.6)	6 (6.6)	20 (7.4)	0.016
	1	267 (9.7)	31 (11.8)	123 (9)	31 (11.4)	44 (9.2)	8 (8.8)	30 (11.1)	
	2	524 (19.1)	54 (20.6)	264 (19.2)	47 (17.3)	94 (19.7)	13 (14.3)	52 (19.3)	
	3	522 (19)	48 (18.3)	245 (17.8)	54 (19.9)	84 (17.6)	28 (30.8)	63 (23.3)	
	4	471 (17.2)	45 (17.2)	244 (17.8)	52 (19.1)	80 (16.8)	12 (13.2)	38 (14.1)	
	5	830 (30.2)	65 (24.8)	445 (32.4)	72 (26.5)	157 (33)	24 (26.4)	67 (24.8)	
Fried	0	392 (14.3)	31 (11.8)	207 (15.1)	41 (15.1)	65 (13.7)	5 (5.5)	43 (15.9)	0.254
	1	838 (30.5)	71 (27.1)	410 (29.8)	95 (34.9)	151 (31.7)	27 (29.7)	84 (31.1)	
	2	621 (22.6)	63 (24)	303 (22.1)	69 (25.4)	105 (22.1)	24 (26.4)	57 (21.1)	
	3	528 (19.2)	57 (21.8)	268 (19.5)	43 (15.8)	95 (20)	17 (18.7)	48 (17.8)	
	4	242 (8.8)	25 (9.5)	127 (9.2)	15 (5.5)	42 (8.8)	9 (9.9)	24 (8.9)	
	5	124 (4.5)	15 (5.7)	59 (4.3)	9 (3.3)	18 (3.8)	9 (9.9)	14 (5.2)	
Baked	0	955 (34.8)	122 (46.6)	430 (31.3)	87 (32)	166 (34.9)	50 (54.9)	100 (37)	<0.001
	1	517 (18.8)	39 (14.9)	265 (19.3)	44 (16.2)	106 (22.3)	15 (16.5)	48 (17.8)	
	2	464 (16.9)	40 (15.3)	236 (17.2)	52 (19.1)	91 (19.1)	8 (8.8)	37 (13.7)	
	3	427 (15.6)	35 (13.4)	214 (15.6)	50 (18.4)	68 (14.3)	12 (13.2)	48 (17.8)	
	4	227 (8.3)	14 (5.3)	136 (9.9)	23 (8.5)	31 (6.5)	5 (5.5)	18 (6.7)	
	5	155 (5.6)	12 (4.6)	93 (6.8)	16 (5.9)	14 (2.9)	1 (1.1)	19 (7)	
Microwave	0	2,068 (75.3)	210 (80.2)	996 (72.5)	199 (73.2)	386 (81.1)	77 (84.6)	200 (74.1)	0.022
	1	303 (11)	25 (9.5)	160 (11.6)	28 (10.3)	47 (9.9)	8 (8.8)	35 (13)	
	2	168 (6.1)	13 (5.0)	101 (7.4)	19 (7)	17 (3.6)	3 (3.3)	15 (5.6)	
	3	109 (4.0)	8 (3.1)	55 (4.0)	18 (6.6)	14 (2.9)	2 (2.2)	12 (4.4)	
	4	51 (1.9)	3 (1.1)	31 (2.3)	2 (0.7)	7 (1.5)	1 (1.1)	7 (2.6)	
	5	46 (1.7)	3 (1.1)	31 (2.3)	6 (2.2)	5 (1.1)	0 (0)	1 (0.4)	
Stew	0	694 (25.3)	86 (32.8)	313 (22.8)	83 (30.5)	121 (25.4)	31 (34.1)	60 (22.2)	0.017
	1	426 (15.5)	38 (14.5)	197 (14.3)	49 (18)	69 (14.5)	14 (15.4)	59 (21.9)	
	2	554 (20.2)	48 (18.3)	291 (21.2)	47 (17.3)	99 (20.8)	18 (19.8)	51 (18.9)	
	3	477 (17.4)	40 (15.3)	264 (19.2)	40 (14.7)	72 (15.1)	10 (11)	51 (18.9)	
	4	379 (13.8)	31 (11.8)	197 (14.3)	36 (13.2)	74 (15.5)	11 (12.1)	30 (11.1)	
	5	215 (7.8)	19 (7.3)	112 (8.2)	17 (6.3)	41 (8.6)	7 (7.7)	19 (7)	
Griddle	0	199 (7.2)	26 (9.9)	86 (6.3)	26 (9.6)	31 (6.5)	10 (11)	20 (7.4)	0.027
	1	364 (13.3)	34 (13)	164 (11.9)	41 (15.1)	73 (15.3)	15 (16.5)	37 (13.7)	
	2	569 (20.7)	49 (18.7)	292 (21.3)	49 (18)	107 (22.5)	24 (26.4)	48 (17.8)	
	3	519 (18.9)	50 (19.1)	266 (19.4)	38 (14)	93 (19.5)	14 (15.4)	58 (21.5)	
	4	565 (20.6)	45 (17.2)	301 (21.9)	53 (19.5)	103 (21.6)	15 (16.5)	48 (17.8)	
	5	529 (19.3)	58 (22.1)	265 (19.3)	65 (23.9)	69 (14.5)	13 (14.3)	59 (21.9)	

[a] *Culinary processes applied: include a 5-point scale ranging from "never" (0) to "very often" (5).*

[b] *Differences between groups were evaluated by chi-squared-test.*

in Bogotá, Central, and Oriental regions, as well as in Atlántica and Pacífica, albeit with some variations. More details on the changes in factor loadings from pre-to-post-confinement are shown in **Supplementary Figure 5**.

Adherence scores to the nationally derived dietary clusters also varied by regions (**Supplementary Table 3**). No consistent differences in adherence by sex, age, or other variables observed (data not shown). Before the confinement, the Orinoquía and Amazonas region showed a higher adherence to the protein and sugary dietary clusters compared with the other regions (p-value = 0.03 and p-value < 0.001, respectively). During the confinement, however, adherence to the carbohydrate-rich dietary clusters was highest for Orinoquía and Amazonas and Pacifica compared with the others (p-value < 0.001).

Given the importance of the carbohydrate-rich dietary cluster, we analyzed further the variation of consumption of starchy foods and sugar from pre-to-post-confinement (**Figure 4**). Overall, a higher proportion of participants reported to have increased the consumption of these foods during confinement, except that of tubers and plantains. The largest increase was observed for sugar cane beverages (from around 7 to 18%).

TABLE 5 | Fried food consumption before and during confinement among the diet-COVID-19 survey respondents in Colombia by regions.

	National	Atlántica	Bogotá	Central	Oriental	Orinoquía and Amazonas	Pacífica	*p*-value[a]
	N = 2,745 (%)	*N* = 262 (%)	*N* = 1,374 (%)	*N* = 272 (%)	*N* = 476 (%)	*N* = 91 (%)	*N* = 270 (%)	
Fried food frequency								<0.001
Never	341 (12.4)	27 (10.3)	187 (13.6)	35 (12.9)	44 (9.2)	9 (9.9)	39 (14.4)	
As before	1,354 (49.3)	117 (44.7)	682 (49.6)	134 (49.3)	253 (53.2)	38 (41.8)	130 (48.1)	
Lower	511 (18.6)	62 (23.7)	251 (18.3)	61 (22.4)	84 (17.6)	9 (9.9)	44 (16.3)	
Higher	539 (19.6)	56 (21.4)	254 (18.5)	42 (15.4)	95 (20)	35 (38.5)	57 (21.1)	
Fried food intake								0.002
Never or <1 times/week	900 (32.8)	81 (30.9)	472 (34.4)	96 (35.3)	134 (28.8)	20 (19.9)	94 (34.8)	
1–3 times/week	1,429 (52.1)	140 (53.4)	720 (52.4)	136 (50)	261 (54.8)	44 (48.4)	128 (47.4)	
4–6 times/week	371 (13.5)	40 (15.3)	164 (11.9)	36 (13.2)	67 (14.1)	21 (23.1)	43 (15.9)	
≥7 times/week	45 (1.6)	1 (0.4)	18 (1.3)	4 (1.5)	11 (2.3)	6 (6.6)	5 (1.9)	
Stir-fry frequency								<0.001
<3 times/week	1,008 (36,7)	118 (45.0)	465 (33.8)	129 (47.4)	149 (31.3)	26 (28.6)	121 (44.8)	
3–4 times/week	1,114 (40.6)	111 (42.4)	577 (42.0)	81 (29.8)	188 (39.5)	42 (46.2)	115 (42.6)	
≥5 times/week	623 (22,7)	33 (12.6)	332 (24.2)	62 (22.8)	139 (29.2)	23 (25.3)	34 (12.6)	
Oil type[b]								<0.001
Sunflower oil	1,144 (41.7)	103 (39.3)	604 (44)	104 (38.2)	204 (42.9)	24 (26.4)	105 (38.9)	
Canola oil	315 (11.5)	17 (6.5)	170 (12.4)	37 (13.6)	62 (13)	3 (3.3)	26 (9.6)	
Corn oil	59 (2.1)	10 (3.8)	25 (1.8)	4 (1.5)	11 (2.3)	1 (1.1)	8 (3)	
Olive oil	327 (11.9)	18 (6.9)	193 (14)	33 (12.1)	50 (10.5)	6 (6.6)	27 (10)	
Palm oil	90 (3.3)	19 (7.3)	24 (1.7)	13 (4.8)	18 (3.8)	5 (5.5)	11 (4.1)	
Soy bean oil	279 (10.2)	38 (14.5)	93 (6.8)	35 (12.9)	47 (9.9)	26 (28.6)	40 (14.8)	
Mixed oils	246 (9)	33 (12.6)	109 (7.9)	19 (7)	46 (9.7)	16 (17.6)	23 (8.5)	
Other	196 (7.1)	1 (0.4)	56 (4.1)	7 (2.6)	15 (3.2)	3 (3.3)	7 (2.6)	
UK	89 (3.2)	23 (8.8)	100 (7.3)	20 (7.4)	23 (4.8)	7 (7.7)	23 (8.5)	
Oil reutilization								<0.001
Never	1,114 (40.6)	66 (25.2)	663 (48.3)	92 (33.8)	194 (40.8)	13 (14.3)	86 (31.9)	
2 times	1,082 (39.4)	133 (50.8)	498 (36.2)	107 (39.3)	196 (41.2)	41 (45.1)	107 (39.6)	
≥3 times	388 (14.1)	47 (17.9)	141 (10.3)	53 (19.5)	68 (14.3)	29 (31.9)	50 (18.5)	
UK	161 (5.9)	16 (6.1)	72 (5.2)	20 (7.4)	18 (3.8)	8 (8.8)	27 (10)	

[a] *Differences between groups were evaluated by chi-squared-test.*
[b] *Refers to oil type used for frying and other culinary processes.*
UK, unknown.

Despite this increase, almost half of the respondents were non-consumers of these beverages during the confinement, and 40% did not consume any sugar or sugar cane. In contrast, over half of the respondents consumed one serving per day of tubers and plantains, and 20–30% of them consumed one serving per day of all other starchy foods and sugar (**Supplementary Table 1**).

DISCUSSION

The present study, aimed at evaluating the impact of the COVID-19 confinement on the dietary behaviors of a convenience sample of the Colombian population at the national and regional levels, shows that there were important regional differences with regard to these domains. Specifically, cooking frequency and snacking between meals increased during the confinement and was found to differ substantially between the regions. Conversely, frequency of frying remained stable but with considerable differences across regions. Dietary habits in the form of food intake or as DPs, prior to and during the confinement, also differed between the different regions. Importantly, the COVID-19 confinement led to an overall higher consumption of cereals, legumes, eggs, fats, and sugar and sugar cane and its beverages and lower consumptions of fish and nuts, as reflected by a different shape of DPs when compared with those present before the confinement. These changes underscore the fact that a transition toward the consumption of several unhealthy foods took place during the confinement.

Although significant differences were found between the regions with regard to the consumption of foods during the confinement, we observed a general trend toward an increased intake of cereals, eggs, fats, sugars, and sugar cane. The majority of the study population (>90%) reported that, during the confinement, they regularly consumed cereals, bakery and

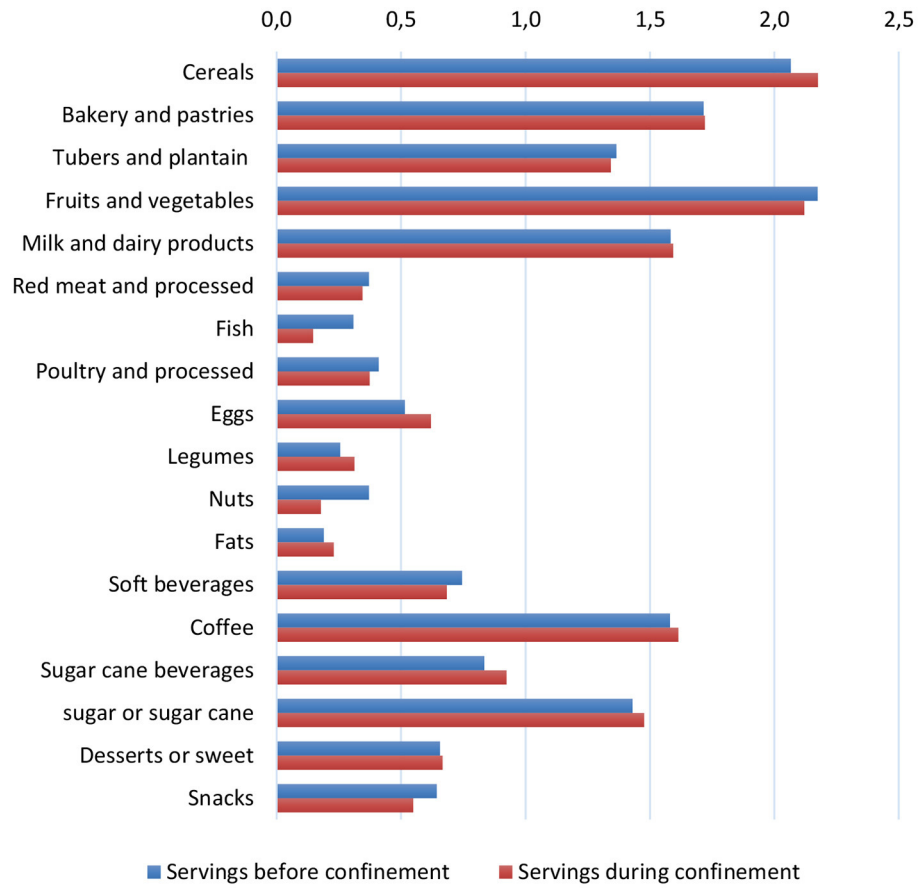

FIGURE 1 | Bar plots showing consumption of main food groups in servings/day among the diet-COVID-19 survey respondents in Colombia, before and during the confinement. Information on dietary consumption of main food groups during the confinement was gathered by the respondents in servings per days. Consumption before the confinement was estimated considering information on whether consumption was alike, higher, or lower during confinement than before (similar servings, one serving less and one serving more, respectively).

pastries, and tubers and plantains, these food groups being the base of their diet. An important proportion of this population (>60%) also consumed poultry and red and processed meat, eggs, legumes, fruits and vegetables, milk and dairy products, fish, coffee, and fats, and approximately one-half of them consumed sugar, cane and cane beverages, sweetened beverages, snacks, and alcoholic beverages. Together, this consumption profile is slightly different to those reported by the country's National Nutritional Surveys ENSIN (22) and the Latin American Study of Nutrition and Health ELANS (23). For instance, over 70% of the study participants consumed fish, compared with 21% of the Colombian population in the ELANS study (23). It is also noteworthy that there were fewer consumers (between 36 and 61%) of food groups with added sugars (desserts and sweets, sugar or cane sugar, sugar beverages, soft beverages) than that of basic foods. In particular, only 61% referred to consume sugar or cane sugar and 52% consumed traditional sugar cane beverages, known as "water with panela." In this study population, the prevalence of snack eaters was also low (40%). This may, in part, be due to the fact that the studied population included mostly young aged women of high educational level, possibly more likely to make healthier food choices.

Overall, but with certain regional differences, the confinement also implied an increase in the practice of home-cooking (59.3%) and a greater purchase of perishable foods (50%), both being possibly associated with a maintenance or decrease (33.8%) in the consumption of fast foods and carbonated beverages, sodas, and soft drinks with respect to the pre-COVID-19 confinement period. However, about half of the participant reported to have increased their snacking frequency, to eat more and to practice less physical activity during the confinement. Conversely, a high proportion of participants were unaware of weight gain (40%), and only 22.3% reported to have gained weight. In Colombia, the increasing prevalence of overweight and obesity is of great concern due to its association with non-communicable chronic diseases, which contribute significantly to the morbidity and mortality of the country's adult population (8, 24, 25). In fact, the prevalence of overweight and obesity in Colombian adults aged over 18 years is 34.6 and 16.5%, respectively, these rates being higher in women. In the surveyed population, these proportions

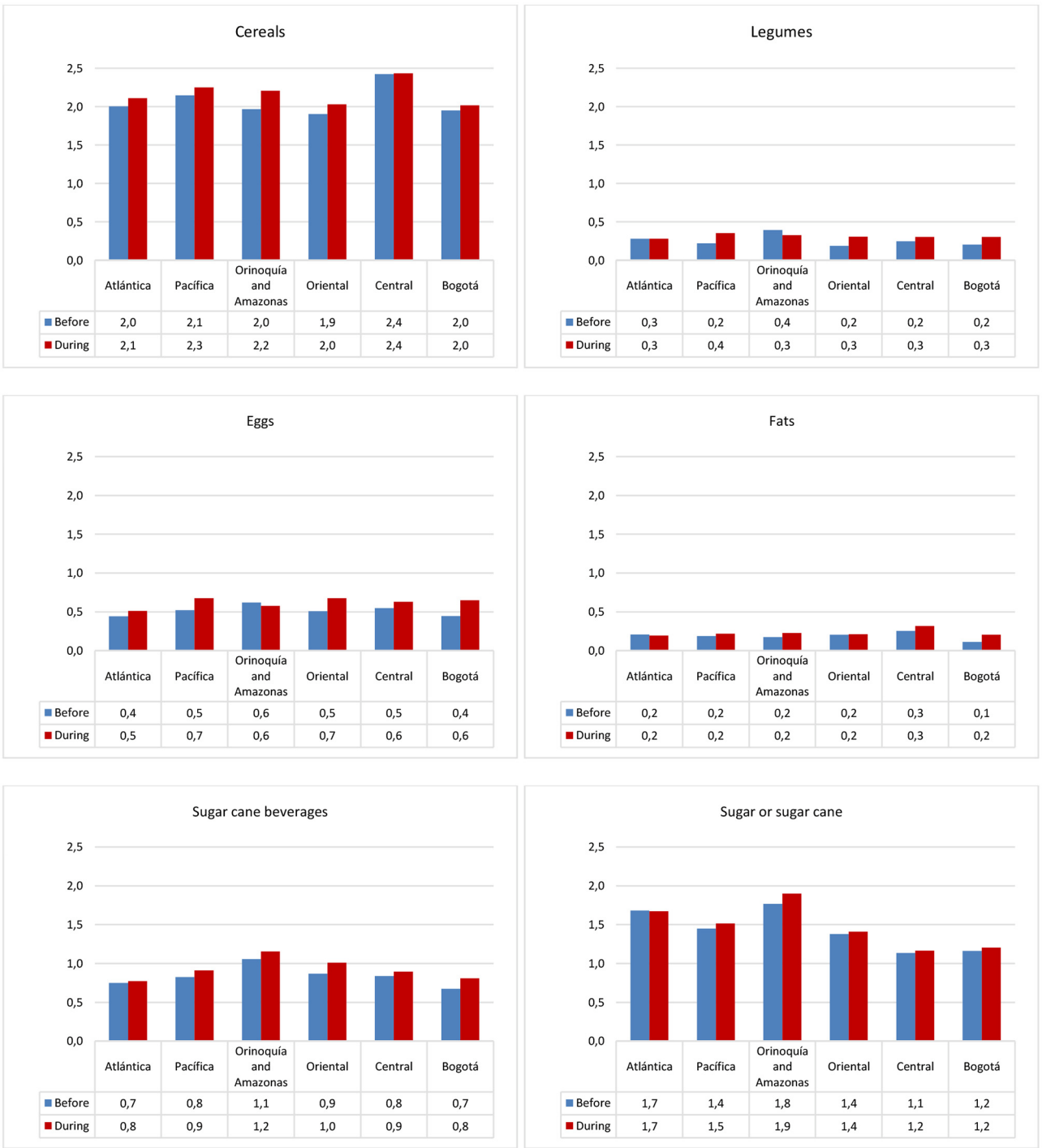

FIGURE 2 | Bar plots showing consumption of food groups in servings/day among the diet-COVID-19 survey respondents in Colombia by regions, before and during the confinement. Only food groups that increased more importantly during the confinement are shown.

were 30.5 and 9.1%, respectively; only 18.5% reported to have modified their diet due to health issues.

With regard to culinary processes applied during the confinement, boiling was the most commonly reported one, followed by griddling. However, frying is a culinary technique widely used in the Colombian gastronomy. It ranks second after boiling of traditional preparations or meals and the main oils used are sunflower, soy, and palm and mixtures of palm with other oils. The frequency per day reported by the ENSIN survey was 0.5 serving/day (8). By contrast, in our study, fried foods

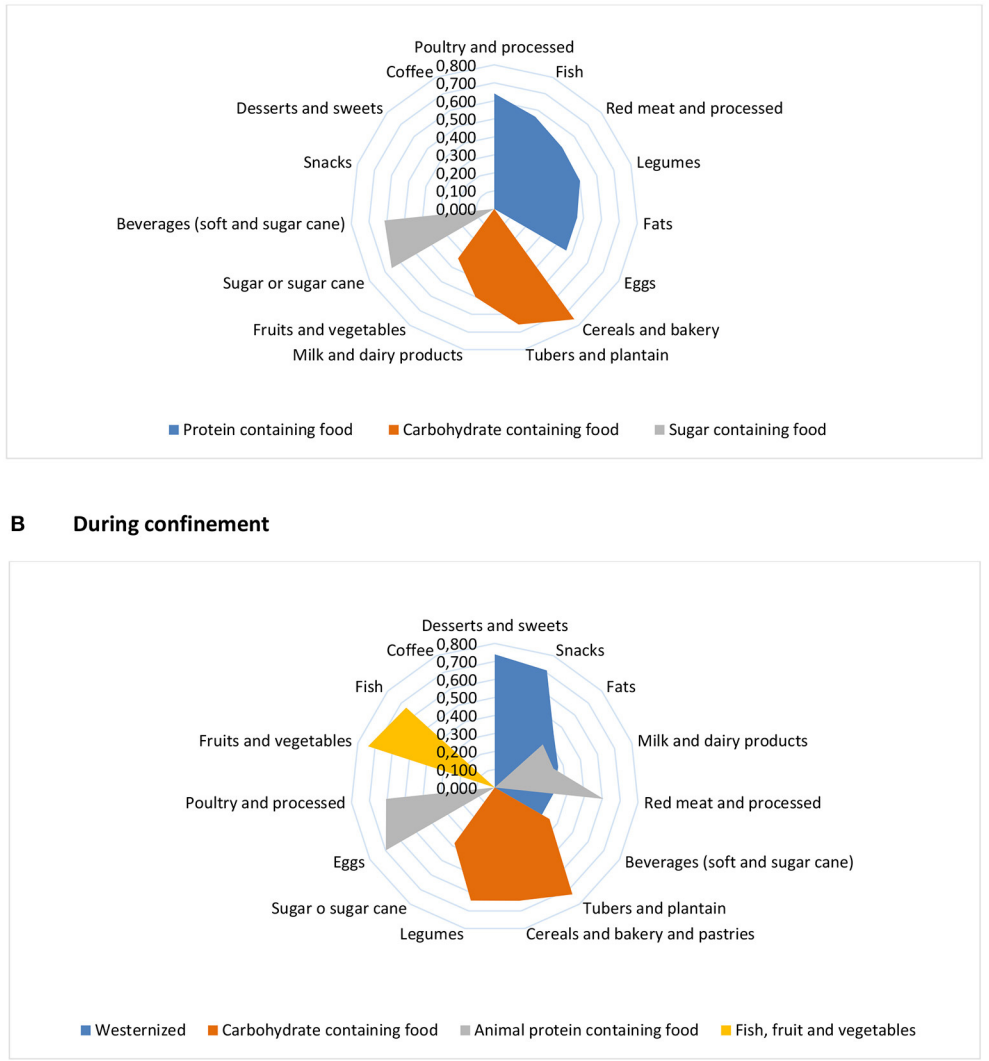

FIGURE 3 | Radial charts showing dietary clusters derived from principal component analysis among the diet-COVID-19 survey respondents in Colombia, before **(A)** and during **(B)** the confinement. Factor loadings (>0.3) are presented along the *x*-axis. Information on dietary consumption of main food groups during the confinement was gathered by the respondents in servings per days or weeks. Consumption before the confinement was estimated considering information on whether consumption was alike, higher, or lower during confinement than before (similar servings, one serving less, and one serving more, respectively). Dietary intake in grams/day was estimated by applying standard portion sizes of each food.

were consumed between one and three times/week by more than half of the population, and <1 time or not consumed by a third of the population, suggesting that our study population adopted healthier cooking practices. Also, sunflower oil was more frequently used by the participants. These findings may be related to behavioral characteristics of our study population.

We have identified three main DPs before the confinement by considering the reported consumption and its change due to the confinement: the protein-rich, the carbohydrate-rich and the sugary DPs. In a cross-sectional study of 37,667 persons aged 5–64 years within the ENSIN survey from 2010, there were also three DPs identified: traditional/starch pattern, fruit-vegetable/dairy patterns, and snack pattern (26). In a subsequent study on these patterns on the ENSIN 2015 data (27), it was found that adherence to these three patterns was maintained. However, the adherence to these patterns was lower in adults (aged 27–64 years) than in children, adolescents, and young adults, suggesting that the patterns were driven by the younger population. While our study population is not directly comparable as it comprised adults only, mostly below 35 years, with high levels of education and women, and despite we did not coincide in timing, the DPs resembled to some extent those reported by the ENSIN survey. With regard to the timing, it is also important to highlight that food import policies over

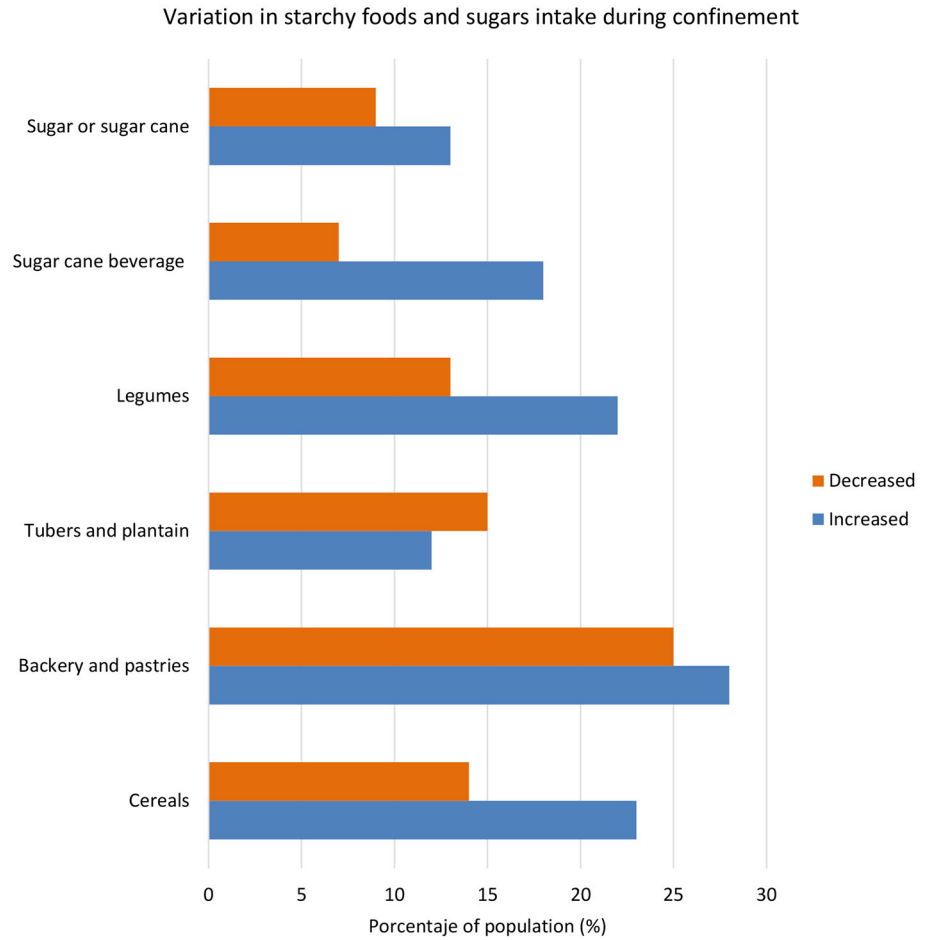

FIGURE 4 | Variation in consumption of starchy foods and sugars during confinement when compared with previous intake among the diet-COVID-19 survey respondents (% of respondonts) in Colombia.

time are likely to have played a role in the population's eating behavior. The following are major differences between our study and the ENSIN survey to be aware of: (1) the carbohydrate-rich pattern included fruits and vegetables, milk and dairy products, cereals, and tubers and plantains, this pattern being similar to the fruit-vegetable/dairy and the traditional/starch patterns in ENSIN. (2) We identified an additional DP of protein-rich foods, of which some foods (red and processed meat, and fats) were part of the snack pattern in ENSIN. This pattern reflects the higher consumption of meats, eggs, fish, and fats of our study population, inasmuch intakes of these foods are adopted by those of a greater attained educational level. (3) Sweetened beverages and sugars clustered in our study into the sugary pattern, whereas these foods were included in the snack pattern in ENSIN. Adherence to this snack pattern seemed to decrease between 2010 and 2015 (27), which may explain why this DP was not prevailing our study. Indeed, only 40% of our population consumed snacks during the confinement. It is also worth noting that the ENSIN study collected dietary data by means of a food frequency questionnaire of 30 food items. Similar to our study, our questionnaire inquired about the frequency of intake of 28 foods or food groups, typically consumed in Colombia. Besides, the ENSIN surveys also showed regional variations with regard to these DPs, especially with regard to the fruit-vegetable/dairy and the traditional/starch patterns (27). Both were found to be predominant in the Northwestern region and the Andean and South-Central regions, respectively. We also found differences in the patterns by regions, which were also apparent when examining adherence to the DPs in each region. For instance, adherence to the protein-rich and sugary DPs was highest in the Orinoquía and Amazonas region.

During the confinement, there was a change in the aforementioned DPs toward an unhealthier DP, i.e., a Westernized-like DP. This pattern was more prominent in the Central region. Interestingly, we identified the fish, fruits, and vegetable DP, which seemed to have a greater presence in the Bogotá region. Importantly, this DP emerged more importantly from the fourth week of confinement. At that time, the Easter period took place and this is known to change the nation's eating habits since fish consumption typically increases to

accommodate dietary requests of the Catholic Holy Week. This was probably more likely in regions subjected to receiving fresh food products during the confinement. On the other hand, the protein-rich and carbohydrate-rich food pattern seemed to be relatively constant, except that the latter became more sugared by incorporating sugar or sugar cane and beverages while losing components such as fruits and vegetables. Thus, this study shows that a Westernized DP predominated during the confinement in Colombia. This pattern is common in more developed countries, but in Colombia a transition from the traditional food pattern to a more Westernized pattern is already underway according to the ENSIN surveys, although with regional differences (26, 27). This nutritional transition goes along with demographic changes in the country, with both driving dietary behavior changes (23). The increasing prevalence of the overweight and obesity, indeed, has been attributed to the adoption of poorer dietary habits of the population (28, 29). Furthermore, there are important variations by regions with regard to social inequalities and poverty, with the Pacifica and Southeast regions being the most affected, and thus more prone to experience such food transitions. Our study reveals that the Westernized pattern and the carbohydrate-rich foods pattern were the strongest ones during the confinement. Overall, the regions Orinoquía and Amazonas (Southeast region), Central, and Pacifica showed the highest adherence to these patterns, whereas Bogotá showed the lowest. Hence, this result is consistent with the above. Moreover, these two DPs featured not only the consumption of unhealthy foods but also of foods most often fried or cooked with oils of all kinds. Sweetened beverages, cane and cane beverages were also major components of these DPs. Altogether, these foods, have been associated with detrimental health effects and risk of developing chronic diseases in numerous studies (30–35); e.g., with type 2 diabetes, obesity, metabolic syndrome, and cancer. Likewise, the Westernized DP and some types of carbohydrate-rich DPs (36), mostly those rich in glycemic foods, have been associated with an increased risk of these diseases too (37, 38). Such DPs are also likely to affect the nutritional and immunological state of the population owing to their low content of essential nutrients (39–41), thereby possibly increasing the risk infectious diseases and cancer. This negative effect might be mediated by various mechanisms through the human microbiome (42). Indeed, a healthy balanced diet is related to gut microbe symbiosis, which in turn plays a decisive role on the immune response against the virus, whereas unhealthy DPs lead to microbial dysbiosis underlying the inactivation of the host immune response (42, 43). Also, several studies have claimed that dietary micronutrients with anti-inflammatory and immune-modulating potential are key to prevent COVID-19 disease (44–47).

There are several limitations to note. Firstly, as stated before, the study population was not representative of the Colombian population; extrapolation of the findings to the general population is therefore limited. In fact, the majority of the survey's respondents were young adults and women of high educational level. Secondly, the sample size was relatively small and there were fewer respondents in some regions, such as in Orinoquía and Amazonas, which might imply that numbers were limited to extract significant results. Also, there were differences in the baseline characteristics of the study sample by regions. However, similar DPs were observed on a homogenous subset of the study population (360 subjects of the same age, BMI and educational level) (data not shown).

Regarding strengths, the questionnaire was completed by all participants; thus, information bias is unlikely. Also, a large number of subjects from all the regions of the country participated in this study, making it possible to establish a nation-wide study and to make comparisons at the region level. Information on dietary behaviors during the confinement, and changes on the basis of prior habits, was collected in the form of an extensive questionnaire. At such a level of detail, we were able to analyze dietary behaviors related to cooking habits and others and to derive food consumption patterns before and during the confinement. Thus, this is the first study evaluating dietary behaviors related to culinary processes in Colombia, alongside changes in DPs during the COVID-19 confinement.

In conclusion, our study reveals that the COVID-19 confinement had a great impact on the dietary behaviors of a large adult population from Colombia. The fact that this population seemed to adopt less healthy dietary habits shows the need of evaluating this dietary transition in the near term and in the general population. This knowledge is essential for implementing appropriate public health nutrition interventions, aimed at promoting the consumption of healthy foods, of high nutritional value, together with varied and safety cooking practices, in the Colombian population during the COVID-19 pandemic and in a post-COVID stage.

DATA AVAILABILITY STATEMENT

The original contributions generated in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by The Human Research Ethics Committee of the University of Granada (1526/CEIH/2020) and is part of the COVIDiet-Int study (ClinicalTrials.gov Number NCT 04449731). Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

CR-P, MR-L, EM-M, VV, EG-H, RA, and BG-V formalized the theoretical framework and methodology. SP-C and EM-M contributed to data analysis. SP-C, EM-M, and BG-V wrote the original draft. BG-V supervised the whole work. All authors contributed to the review and editing of the final manuscript and have read and agreed the published version of the manuscript.

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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.2021.644800/full#supplementary-material

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Purchases of Meats and Fish in Great Britain During the COVID-19 Lockdown Period

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The purpose of this paper is to provide an analysis of the purchases of meat and fish in Great Britain during the lockdown period using time series constructed from a unique scanner panel dataset available since 2013 and which is based on information about 30 thousand households. The time series available for the analysis represent the purchases (expenditure and quantities) of all consumers and by income groups were used to compute price and quantity indices all the meats together and for each meat (i.e., beef, lamb, pork, poultry, and other meats) and fish. The changes in expenditure were decomposed into changes in prices, quantities purchased and changes in quality purchased (trading up/down in quality) i.e., whether cheaper meat or fish were purchased. A further extension of the analysis was produced by considering the evolution of calories, saturated fats and sodium per purchased quantity for meat and fish during the period of study. The results indicate that although the shares of quantities remained relatively constant, the calories, saturated fats and sodium from the purchased quantities showed an increasing trend, indicating that most of the incomes groups were lowering the nutritional quality of their meat and fish purchases. This is clearly shown by the fact "other meats" represents on average 39 percent of the calories contributed by meat and fish, 49 per cent of the saturated fats and about 68 of the total sodium in meat and fish during the lockdown period. This result highlights the need to emphasize healthy messages related to the purchases of meat.

Keywords: UK meat market, consumers' response, COVID-19 pandemic, nutrition quality, UK diet

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INTRODUCTION

There are several reasons why the analysis of the purchases of meat is important. Some of them are from a nutritional point of view and another is from an environmental one. From the nutritional side, according to the NHS (1) meat is a good source of protein, vitamins and minerals in the diet and eating meat can be part of a healthy and balanced diet (2). In fact, a balanced diet can include protein from meat, as well as from non-animal sources such as beans and pulses.

It is important to note that some meats are high in saturated fat, which can raise blood cholesterol levels. High consumption of red and processed meat has been linked to bowel cancer (1). Processed meat refers to meat that has been preserved by smoking, curing, salting or adding preservatives. This includes sausages, bacon, ham, salami and pâtés. As a reference, 90 g is equivalent to around three thinly cut slices of beef, lamb or pork, where each slice is about the size of half a piece of sliced bread. A cooked breakfast containing two typical British sausages and

two rashers of bacon is equivalent to 130 g (1). Thus, the NHS advice is to reduce the cooked weight of red and processed meat a day down to 70 g, which is the average daily consumption in the UK (1).

Meat consumption has gathered plenty of attention due to the environmental impact of animal production (3–5). There is an increasing interest in more environmentally friendly food production as shown by the report from the Assembly Citizens (6) chapter 6 about the food we eat and how we use the land. The report indicated that members of the assembly were willing to lower meat and dairy consumption by 20–40 percent by 2050.

The COVID-19 period, i.e., since March 2020, is interesting one to analyse consumption because (at least at the beginning) households shifted toward supermarket purchases due to the food service closure and also because literature has indicated changes in consumption habits [e.g., (7, 8)]. Using the latest figures from UK Department of Food, Environment and Rural Affairs (Defra) Family Food annual report (9), if the lockdown would have been perfect, and all the meals had been taken at home (i.e., all the money is still spent on food), it would have implied a maximum average increase in demand for household supplies of around 44 percent; this is, of course, an average figure with the first income decile (i.e., the least affluent group) being able to spend 24 percent more on their household food items and the last decile (i.e., the most affluent group) 66 percent (10).

The purpose of this paper is to provide an analysis of the meat purchases during the COVID-19 period (i.e., March to June 2020) using time series derived from a large panel dataset, the Kantar Worldpanel dataset. In particular, the study is interested to study the evolution of different meats and their nutritional contribution considering the purchases of households of different income groups.

The underlying dataset, from where the available time series used in this analysis come from, comprises grocery purchases for about 30,000 households in Great Britain (the dataset does not contain information for Northern Ireland). The time series, which were available since 2013, were constructed using about gross up weights at the level of purchases and also households classification by income groups. It is important to highlight that the Kantar's information (as well as Defra's) refer to food purchases and not to actual consumption although it is common to call them by both names given the close association between them.

The structure of the paper is as follows: it starts with a review of the purchases of meat and fish in the UK based on the publicly available dataset [e.g., Defra's Family Food, (9)], which provides annual information by food categories from 1974 until 2018; next, the methodology and data are presented, followed by the results and discussion.

PURCHASES OF MEAT AND FISH IN THE UK

According to United Nations Food and Agriculture Organisation (FAO) data (11), the biggest meat consumers in the world are those in the U.S. where 98.6 kg was consumed per person in 2017. Britain's meat consumption at 61.4 kg per person per year is similar to other European countries such as Ireland, France and Germany.

Due to its importance for the food sector, several papers have addressed the demand for meats in the UK focusing on the importance of price, income and household variables (12–14). Additionally, other papers have modeled meat and fish demand as part of the demand for food [e.g., (15)]. However, the purpose of these studies has been to study the response of meats to changes in prices and income and not the evolution of the purchases of different meats and their contribution to nutrients due to a massive exogenous shock such as COVID-19.

Defra's Family Food (Defra's, 2020) provides time series information about the average per capita quantities purchased per week from 1974 to 2018-19. This information is collected from the Living Costs and Food Survey (former Expenditure and Food Survey). This is a survey conducted by the Office for National Statistics (ONS) and the Department for Environment, Food and Rural Affairs (DEFRA) which collects data about private household expenditure and quantity purchased in the United Kingdom from a sample of about 5–6 thousand households. **Figure 1** presents the purchases of all meat and fish together over time.

Figure 1 shows there are no single trends on the series, but it can be broken by periods. Thus, there is an increase in the purchases of meat from 1974 to 1980, followed by a decreasing trend from 1980 until 1999, where the purchases decreased from about 1,300–1,100 g. After a short period of non-linear increase up to 2005-06, the series decreased to 1,082 g to finally present an increasing trend. Since as shown in the introduction not all the meat has the same nutritional contribution, it is important to break them down into the different types of meats. These are presented in **Figure 2**.

The first fact shown in the figure is the importance of other meats on the total purchases. This group includes burgers, sausages, offals, meat takeaways. This processed meat group is an important contributor of calories and saturated fats (unfortunately Defra's data only presents information about the nutritional content of the entire purchases and not the contribution of each component).

The second fact in **Figure 2** is the increasing trend on the consumption of poultry (particularly chicken) from 133 g in 1974 to 258 according to the 2018-19 survey. By contrast sheep-meat (mostly lamb) consumption has seen a gradual decline. According to Savills Co (16) this is likely due to limited cooking versatility and a perceived higher price point. The trends on beef and pork consumption, as shown in **Figure 2**, are similar to that observed for lamb. It is possible that these negative trends on red meat are associated to changes in consumption patterns due to healthy messages.

The third fact is that the per capita consumption of fish, as shown in **Figure 2**, has remained relatively constant over time, representing an average of 146 g per week.

Note that the alternative protein sector (plant-based meat substitutes) is not considered here due to the fact that despite the increase in its market it still represents <1 percent of the meat market (16).

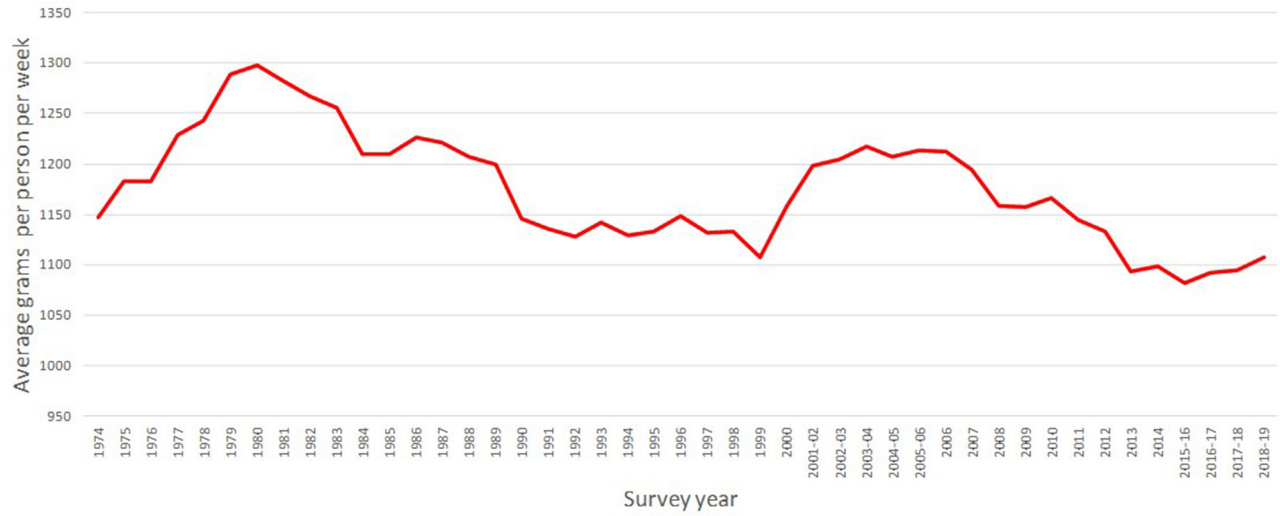

FIGURE 1 | United Kingdom—Per capita meat and fish quantities purchased, 1974 to 2018-19. Source: Defra's family food.

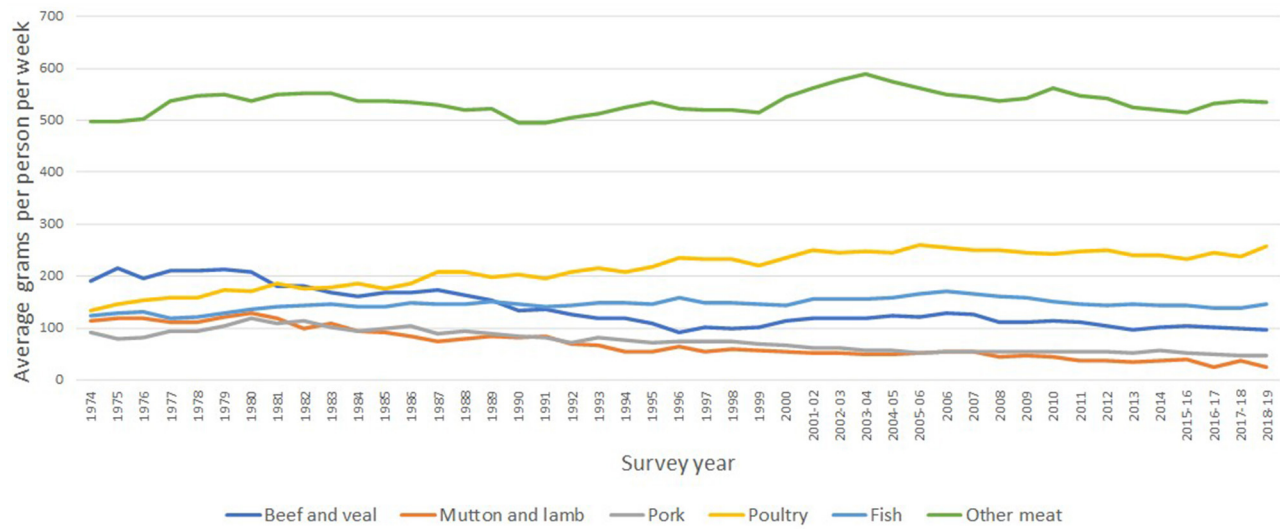

FIGURE 2 | Per capita quantities purchased of meat and fish, 1974 to 2018-19. Source: Defra's family food. Note: Other meat also includes takeways and ready meals that contain meat.

The other source of information on the UK consumption is the National Diet and Nutrition Survey (NDNS). The NDNS rolling programme is a continuous, cross-sectional survey. It is designed to collect detailed, quantitative information on the food consumption, nutrient intake and nutritional status of the general population aged 1.5 years and over living in private households in the UK (17). The survey covers a representative sample of around 1,000 people per year. Fieldwork began in 2008. It is important to note that NDNS statistics refer to food consumption in contrast with Defra's Family Food, which refers to food purchases.

According to the NDNS, the intake of red and processed meat is continuing to fall. For teenagers, there was a decrease of 15 g a day over the 9-year period. However, the average consumption for adult men remains above the recommended maximum of 70 g a day.

MATERIALS AND METHODS

Data

The data used in the analysis were time series from the Kantar Worldpanel dataset for Great Britain for the period 2013 to 2020. The underlying dataset, i.e., from which the time series were constructed collects information about purchases at the level of actual products by about 30 thousand households. The data exclude food for out-of-household consumption. The time series

were constructed by Kantar using gross up weights that allow to compute country-level- time series.

It should be noted that Kantar data use months of 4 weeks (i.e., a year is made of 13 months), therefore, the dataset starts in 2013 (week commencing the 6th of January) and end in 2020 (week commencing the 12th of July) comprised 98 observations. For the analysis defined five periods of interest were defined. The pandemic outbreak was from February 24 to March 22, 2020 (the first death from Coronavirus in the UK was confirmed on March 5). For easy of reference, this period is defined as period t. The first lockdown period (or period t+1) was from March 23 to April 19, as the UK government enforced restrictive measures starting March 20. The second lockdown period (or period t+2) was from April 20 to May 17 (as the UK government started easing restrictive measures at the very end of this period). The first and the second post-lockdown periods went were from May 18 to June 14 (period t+3) and from June 15 to July 12 (period t+4), respectively.

The household data contain information about their income ranges (i.e., £0–29,999, £30,000–39,999, £40,000–49,999, £50,000–59,999, £60,000 - over) and it was used to estimate purchases time series by income group in per capita terms. The income ranges were provided by Kantar.

The meat products were aggregated based on Kantar World panel categories. Thus, beef refers to fresh and frozen beef cuts (it also includes chilled burgers, unlike Defra's survey in **Figure 2**; frozen burgers, which is a marginal category was classified as part of other meats); lamb (fresh and frozen lamb meat); pork (fresh and frozen pig meat); poultry (fresh and frozen poultry meat); fish (fresh and frozen fish) and other meats (made of the remaining meats, which are mostly sausages, bacon, and offal). In contrast with Defra's data it does not include takeaways because Kantar does not collect that information. The dataset also includes nutritional information at the level of product (in contrast to food category as in the case of Defra's Family Food). This is collected from the back or side of packaging nutrition information. Therefore, the available nutrients in the dataset were calories, proteins, carbohydrates, sugar, fats, saturates, fiber and sodium. In this study, the focus was on calories, saturated fats and sodium.

Methods

The methods start with the evolution of the expenditure, prices and quantities purchased of meats and fish. It is followed by the decomposition of expenditure during the COVID-19 period, and finally, a trend analysis is carried out to test whether the purchase of calories, saturated fats and sodium during the COVID-19 emergency period was different to the ones from previous periods.

Price and Quantity Index Numbers

The methodology consisted of constructing time series for the period 2013 to 2020 for meats (beef, lamb, pork, and poultry) by income group. As expenditure shares change over time Tornqvist-Theil-Divisia (TTD, hereafter) price and quantity indices (18) were produced. These indices are a weighted geometric average of the price and quantity relatives using arithmetic averages of the value shares in the two periods as weights, in other terms, they have the advantage to capture changes in the composition of the purchased basket. The TTD indices for prices and quantity are given by (1) and (2):

$$\frac{\mathrm{P_t}}{\mathrm{P_{t-1}}} = \prod_{\mathrm{i=1}}^{\mathrm{n}} \left(\frac{\mathrm{p_{i,t}}}{\mathrm{p_{i,t-1}}} \right)^{\frac{1}{2}\left[\frac{\mathrm{p_{i,t-1}q_{i,t-1}}}{\sum_{\mathrm{j=1}}^{\mathrm{n}} \left(\mathrm{p_{j,t-1}q_{j,t-1}}\right)} + \frac{\mathrm{p_{i,t}q_{i,t}}}{\sum_{\mathrm{j=1}}^{\mathrm{n}} \left(\mathrm{p_{j,t}q_{j,t}}\right)} \right]} \quad (1)$$

$$\frac{\mathrm{Q_t}}{\mathrm{Q_{t-1}}} = \prod_{\mathrm{i=1}}^{\mathrm{n}} \left(\frac{\mathrm{q_{i,t}}}{\mathrm{q_{i,t-1}}} \right)^{\frac{1}{2}\left[\frac{\mathrm{p_{i,t-1}q_{i,t-1}}}{\sum_{\mathrm{j=1}}^{\mathrm{n}} \left(\mathrm{p_{j,t-1}q_{j,t-1}}\right)} + \frac{\mathrm{p_{i,t}q_{i,t}}}{\sum_{\mathrm{j=1}}^{\mathrm{n}} \left(\mathrm{p_{j,t}q_{j,t}}\right)} \right]} \quad (2)$$

Where $\frac{P_t}{P_{t-1}}$ in (1) is the price index representing the average change in prices for the group in question (e.g., meat) from period t-1 to t; $\frac{p_{i,t}}{p_{i,t-1}}$ is the price index of product i (e.g., Aberdeen Angus beef steak price index, within the beef price calculation). $q_{i,t-1}$ is the quantity of product i in period t-1; $\frac{p_{i,t-1}q_{i,t-1}}{\sum_{j=1}^{n}(p_{j,t-1}q_{j,t-1})}$ and $\frac{p_{i,t}q_{i,t}}{\sum_{j=1}^{n}(p_{j,t}q_{j,t})}$ are the expenditure shares of the product i (e.g., Aberdeen Angus beef steak) in the total expenditure of category (e.g., beef) in period t-1 and t. The formula in (2) is similar to (1) but in terms of quantities, where $\frac{Q_t}{Q_{t-1}}$ is the quantity index.

Purchases Decomposition

The construction of the indices was followed by analyzing the income groups response to changes in prices (P_t), by changes in the expenditure (E_{it}), in the quantities purchased (Q_{it}) and in the quality purchased ($\frac{v_{it}}{P_t}$ i.e., trading up and down in quality), where v_{it} is a unit value ($\frac{E_{it}}{Q_{it}}$) (19, 20). For income group i in time period t, identity (3) was used to analyse the meat and fish purchase data:

$$\mathrm{E_{it}} = \mathrm{P_t} \times \mathrm{Q_{it}} \times \left(\frac{\mathrm{v_{it}}}{\mathrm{P_t}} \right) \quad (3)$$

Writing (3) in terms of indices that show the changes from period of t-1 to t one obtains (4):

$$\frac{\mathrm{E_{it}}}{\mathrm{E_{it-1}}} = \frac{\overline{\mathrm{P}}_{\mathrm{t}}}{\overline{\mathrm{P}}_{\mathrm{t-1}}} \times \frac{\mathrm{Q_{it}}}{\mathrm{Q_{it-1}}} \times \frac{\left(\frac{\mathrm{v_{it}}}{\overline{\mathrm{P}}_{\mathrm{t}}} \right)}{\left(\frac{\mathrm{v_{it-1}}}{\overline{\mathrm{P}}_{\mathrm{t-1}}} \right)} \quad (4)$$

Expressing (4) in terms of rates of change we get (4')

$$\left(1 + \widehat{E_{it}}\right) = \left(1 + \hat{\overline{P}}_t\right) \times \left(1 + \widehat{Q_{it}}\right) \times \left(1 + \frac{\hat{v_{it}}}{\overline{P}_t}\right) \quad (4')$$

Where the '^' indicates the rate of change of the variable with respect to a previous period (e.g., $\frac{x_t}{x_{t-1}} - 1$). As explained by McKelvey (20), $\frac{v_{it}}{\overline{P}_t}$ is a measure of the quality of the group purchase. A higher expression means that the chosen Q_{it} is more expensive per unit of group consumption and this is interpreted as buying a higher quality (21).

The expression $\frac{v_{it}}{\overline{P}_t}$ can be further broken down as in expression (5), which multiplies the nutrient per quantity by the price of the nutrient in real terms. For this paper, the nutrient per quantity purchased is of particular interest because it is a measure

of the nutritional quality of the purchased products. Note that this differs from the approach followed by Fousekis and Revell (13) where their notion of quality does not represent nutrition just meat substitutions.

$$\frac{v_{it}}{\overline{P}_t} = \left(\frac{N_{it}}{Q_{it}}\right) \times \left(\frac{\frac{E_{it}}{\overline{P}_t}}{N_{it}}\right) \quad (5)$$

Where:

E_{it} = All meats expenditure in period t by group i

$\overline{P}_t$ = Average price of meat in period t (i.e., over all groups)

Q_{it} = Total purchased quantity of meat in period t by group i

N_{it} = Total nutrient (e.g., calories) in period t by group i

Trend Analysis

The nutrient per quantity purchased was subject to a trend analysis. For this, the both the calories, saturated fats and sodium per quantity, were first seasonally adjusted before estimating the trends. This was done to avoid confuse any change during the COVID-19 period with a seasonal component. Based on the observed data graphs model (6) was estimated:

$$\frac{N_{it}}{Q_{it}} = \alpha_0 + \beta_0 \times t + \alpha_1 \times d_1 + \beta_1 \times d_1 \times t + \alpha_2 \times d_2 + \beta_2 \times d_2 \times t \quad (6)$$

Where:

α_i = Intercept of the trend regression for the full period (i = 0,1,2)

β_i = Slope of the trend regression for the full period (i = 0,1,2)

t = Trend (defined as 0, 1, 2….)

d_1 = binary variable that takes the value of 1 for the period 2018-01 to 2020-02

d_2 = binary variable that takes the value of 1 for the period 2020-03 to 2020-07

Note that if α_2 is statistically different than zero (using a t-test and 95 percent significance level), it means that the COVID-19 intercept of the trend regression line is equal to $(\alpha_0+\alpha_2)$. Similarly, the slope of the regression line if β_2 is statistically different than zero is equal to $(\beta_0+\beta_2)$.

RESULTS

Evolution of Aggregated Meat Expenditure, Prices and Purchased Quantities

The pandemic emergency was associated with a sharp increase in expenditure for meat and fish products. **Figure 3** shows that after the pandemic outbreak (early March 2020), the Great Britain expenditure for at-home purchase of meat and fish, instead of declining to the usual low-season level, jumped to a level that was comparable to the previous Christmas peak and slowly decreased thereafter.

During the outbreak period, when the purchasing surge was at its peak, a moderate price decrease was detected (0.74 percent). Prices of meat and fish were two percent higher than before the outbreak were observed starting from the t+1 period. This result is roughly consistent with the EU food inflation estimate by Akter (22) but much lower than the data by the US Bureau of Labor Statistics (23) reporting a 10.3 percent increase in the consumer price index in the meats, poultry, fish, and eggs category between March and June 2020.

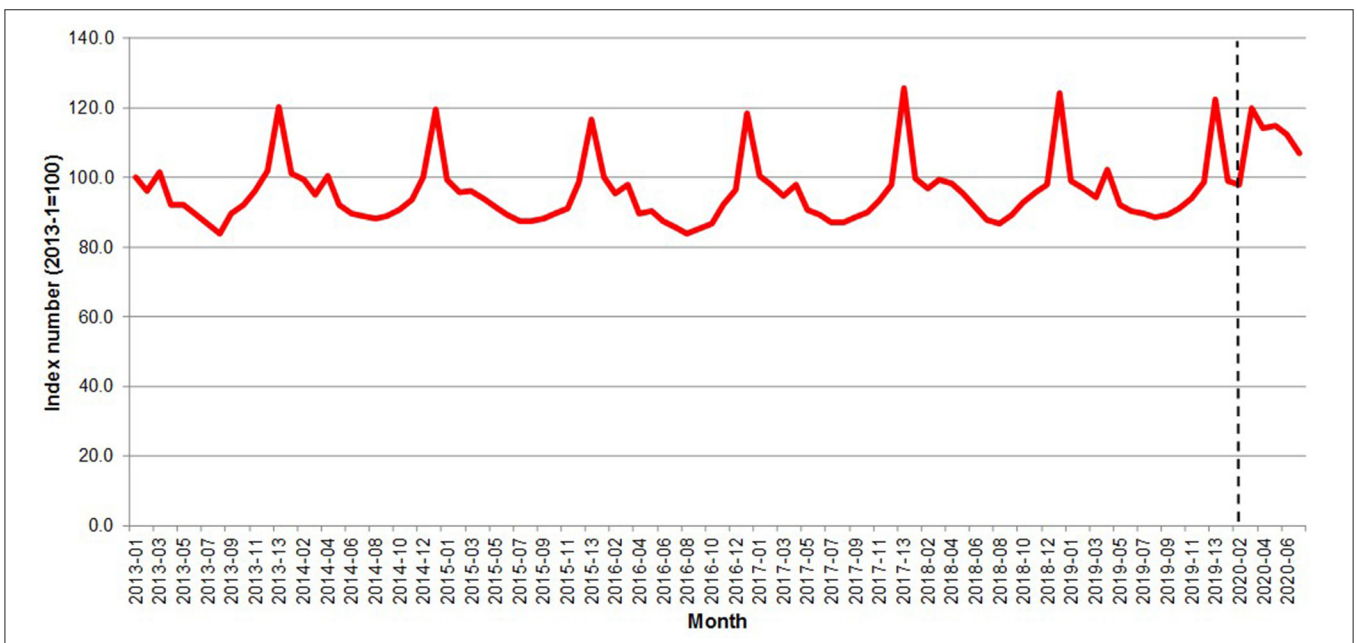

FIGURE 3 | Great Britain—Evolution of the per capita meat expenditure 2013–2020. Source: Own elaboration based on Kantar Worldpanel data. Note: The dotted line represents the start of the lockdown in March 2020.

FIGURE 4 | Great Britain—Evolution of the price and per capita meat quantity 2013–2020. Source: Own elaboration based on Kantar Worldpanel data. Note: The dotted line represents the start of the lockdown in March 2020.

Figure 4 shows the meat and fish aggregated price and quantity indices; the pandemic outbreak was associated with a rapid surge in quantity at the outbreak (22.4-point index increase) quickly reverting to the long-term average and with a much slower but persistent increase in prices (2.9-point index increase over the entire pandemic period). The result is consistent with the observed price rigidity in the pre-pandemic periods, when the variability in prices over time was much smaller than the one in quantities.

Decomposition of Meat and Fish Expenditure

Using the Deaton (19) and McKelvey's (20) method the change in meat and fish expenditure with respect to the pre-emergency 2013-2020 average was decomposed into three components: price, quantity and quality (trading up or down). **Figure 5** presents the results.

Figure 5 shows a major surge in meat and fish expenditure (22 percent) during the outbreak period, even before restrictive measures and lockdown were imposed. A possible explanation for this behavior is a stockpiling effect due to consumers' concerns for future shortage as well as shift toward home consumption due to the closure of the food service (7, 10). In this period, the overall increase was determined by the increase in purchase quantity (22.6 percent), while average prices decreased slightly (0.6 percent). The trade up/down effect was almost negligible (0.05 percent).

During the lockdown periods, the meat and fish expenditure was still higher than the pre-pandemic levels, but lower than during the outbreak period. The changes were +16 percent in period t+1 and +15.9 percent in period t+2. Quantity was the main driver of the change still (+15.9 in t+1 and +15.7 in t+2), yet a moderate average price increase was detected (+0.7 and +1.8 percent, respectively). In these periods, a small trade down effect was observed (−0.6 and −0.7 percent, respectively).

A possible explanation of the increase with respect to pre-pandemic level is consumer replacement of away-from-home food for food to consume at home while the decrease with respect to the outbreak period might be explained with the lower concerns about future shortage as consumers became aware of the stable food supply despite the pandemic.

In the post-lockdown periods, decreases in the expenditure for meat and fish were observed. The level was still higher than the pre-emergency average (+14.1 percent in t+3 and +8.7 in t+4), but lower than during the lockdown periods. The main driver was still the increased consumption, yet the average price levels were higher than in the pre-emergency period (+2.1 percent and +2.2 percent, respectively), and a moderate trade up effect was detected in period t+4 (+0.9 percent). The data from first 2 months after lockdown suggested a consumption trend slowly reverting to pre-pandemic behavior, and a persistence in a price increase of ∼2 percent.

The changes in meat and fish expenditure were the result of heterogeneous trends in the consumption of different types of product. **Table 1** reports the decomposition of expenditure for six product categories: beef, lamb, pork, poultry, other meat and fish. Poultry was the fastest category to revert to pre-emergency consumption level and registered the smallest variation in prices. On the other hand, fish exhibited a remarkable price surge starting in period t+1, a relatively small increase

FIGURE 5 | Great Britain—Decomposition of meat and fish expenditure after the pandemic outbreak. Note: Computed using the Deaton-McKelvey decomposition of meat and fish expenditure increase after the pandemic outbreak in the UK. All changes are computed with respect to the pre-emergency average meat and fish expenditure in Great Britain.

in consumption and a distinctive persistence of the change in consumer behavior. Pork and other meat categories exhibited fluctuating trends.

The analysis of quality trade-up/down found a moderate trade down when the entire (aggregated) category of meat and fish was considered (**Figure 5**). Instead, when specific types of products were considered, no trade-down effect was detected and a limited (0.38 at most) trade-up was found (**Table 1**). The results might be explained by cross-product substitution. Consumers willing to reduce expenditure bought cheaper types of meat (e.g., moving from fish to poultry) instead of buying cheaper cuts of the same meat.

Figure 6 reports the quantity shares of each type of meat in the aggregated consumer basket. The Figure shows very small changes during the lockdown periods with the shares remaining mostly constant, with changes at most of two percent points compared to the pre-pandemic composition.

Figure 6 does not show the impact of the composition of the meat and fish basket on nutrition. In order to illustrate this effect, **Figure 7** reports calories and saturated fat in the consumer meat and fish basket.

Figure 7 shows three potential periods, namely: 2013-01 to 2017-13, 2018-01 to 2020-02 and 2020-03 onwards. The data indicate during lockdown, the substitution of fish and poultry toward other meat products determined a shift toward less healthy meat consumption (+2.0 percent, +5.5 percent +2.5 percent in a month for saturated fats, energy and sodium, respectively). However, the effect is attenuated in the post-lockdown periods, suggesting a transitory effect and a possible reversion to the long-run trend after the pandemic.

Analysis by Income Group

In this section the effects of the pandemic shocks are investigated by computing the decomposition of the change in meat and fish expenditure by household income group. **Table 2** reports the results of the analysis, showing remarkable differences in behavior.

Although all group exhibited similar reactions during the outbreak period, the behavior during and after the lockdown diverged. Starting from period t+1, consumers in the lowest income group (< £30,000 per year) exhibited a moderate increase in consumption and a trading-up effect. Instead, households in the highest income groups (over £ 50,000) increased their consumption by 25 percent in period t+1, slowly declining to a +14 percent in period t+4. They exhibited a limited trading-down effect, which was compensated in part by trading-up in period t+4. Middle class groups (between £30,000 and 49,999) were characterized by the deepest trading-down effect.

The decomposition showed that the change in expenditure for meat and fish was explained mainly by variations in quantity, while price and trading-up or down effects were limited. The main differences across income groups concerned the magnitude of the quantity adjustments and the direction of the trading-up/down effects. As expected, lower income groups exhibited higher price sensitivity. Households in the <£-30,000 income group increased consumption largely during the outbreak period, when prices were lower than the pre-emergency average and the stockpiling effect was at its peak. In the following periods, as prices increased, consumption decreased. Finally, in period t+4, the group consumption fell below the pre-emergency average quantity. The consumption of high-income groups (£ 50,000 and above) did not exhibit such direct association with prices. Instead,

TABLE 1 | Great Britain—Decomposition of the change in expenditure by meat and fish (%).

Product	Outbreak period			
	ΔP	ΔE	ΔQ	T
Beef	−2.27	24.77	27.67	0.00
Lamb	0.03	20.39	20.29	0.04
Pork	−0.87	27.21	28.28	0.04
Poultry	0.31	19.14	18.74	0.03
Fish	−1.11	16.28	17.56	0.02
Other meats	0.35	27.29	26.63	0.18

Product	Lockdown period 1				Lockdown period 2			
	ΔP	ΔE	ΔQ	T	ΔP	ΔE	ΔQ	T
Beef	−3.69	17.95	22.36	0.09	0.84	20.32	19.21	0.09
Lamb	−2.39	64.82	68.58	0.16	1.87	8.99	6.83	0.14
Pork	2.97	20.68	17.13	0.07	3.06	27.87	24.08	0.00
Poultry	0.69	17.71	16.64	0.24	−0.79	12.58	13.21	0.24
Fish	3.15	−1.38	−4.70	0.32	4.95	9.90	4.49	0.21
Other meats	2.36	18.12	14.97	0.38	1.50	23.25	20.97	0.39

Product	Post-lockdown period 1				Post-lockdown period 2			
	ΔP	ΔE	ΔQ	T	ΔP	ΔE	ΔQ	T
Beef	0.06	12.37	12.15	0.13	2.89	9.63	6.44	0.10
Lamb	2.76	11.58	8.43	0.13	3.40	16.58	12.71	0.03
Pork	5.50	27.33	20.60	0.08	2.19	17.71	15.15	0.04
Poultry	−0.16	7.33	7.24	0.25	−0.35	−0.79	−0.65	0.22
Fish	5.61	14.96	8.62	0.21	5.34	11.16	5.39	0.12
Other meats	0.85	18.79	17.34	0.38	0.33	10.71	10.01	0.30

Source: Own elaboration based on Deaton and McKelvey.

ΔE stands for the change in expenditure, ΔP is the change in price, ΔQ is the change in quantity and T is trading up/down effect by product after the pandemic outbreak in the UK. All changes are computed with respect to the pre-emergency averages in the UK.

it was driven by the movement restrictions. It increased during the outbreak period, peaked during the lockdown and slowly declined afterward as movement restrictions were eased and the fear of contagion. Noticeably, the impact on quantity for high-income groups seems to be associated with the psychological pressure of the contagion, while the additional effect of the restrictions was limited (10).

The change in consumption behavior had an impact on nutrition. **Figures 8–10** compare the calories, saturated fat and sodium per kilogram of meat and fish by income group, respectively. The pandemic emergency was associated with an increase in calories, saturated fat showing that all groups moved to more caloric and less healthy meat and fish purchases. On average, both calories and saturated fat per kilogram have been growing at a monthly rate of 0.37 percent from 2013 to 2020. **Figure 10** shows that the amount of sodium per kilogram also increased over time (it grew 0.48 percent per month from 2013 to 2020). Particularly interesting is that the most affluent group (over £60,000) purchased meat and fish with more sodium per kilogram (∼30 percent more than the average of the other income groups).

Table 3 reports the percentage change in the average calories, saturated fat per kilogram and sodium of meat and fish in the emergency periods with respect to the same periods in 2019, in order to account for seasonality in consumption.

The data highlight differences between the lowest income group and the other ones. The former exhibited a sharp surge in the variables during the first lockdown period and a moderate increase compared to previous year afterwards. Households with income equal or higher than £30,000 registered the peak increase during the second lockdown period and a slow decline afterwards in the rate of change. Noticeably, the higher income groups seem to be faster in reverting to the previous year nutrition behavior than lower income groups (with a partial exception for households with income over £60,000).

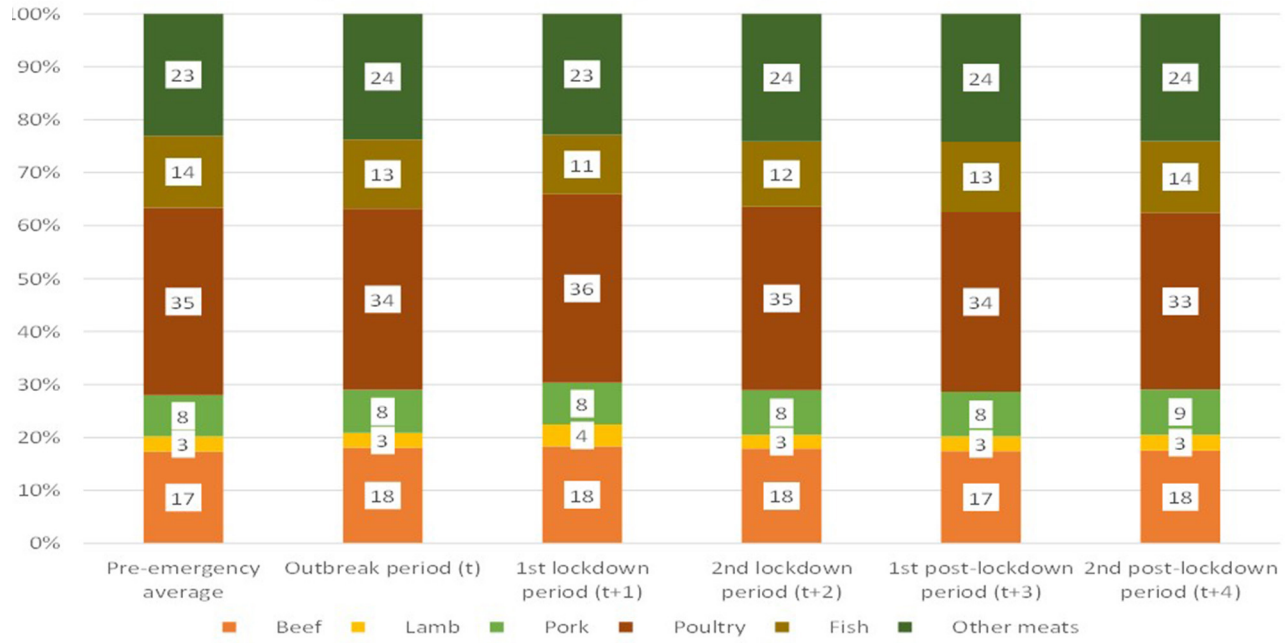

FIGURE 6 | Great Britain—Composition of the meat and fish purchased quantities. Source: Own elaboration based on Kantar Worldpanel data.

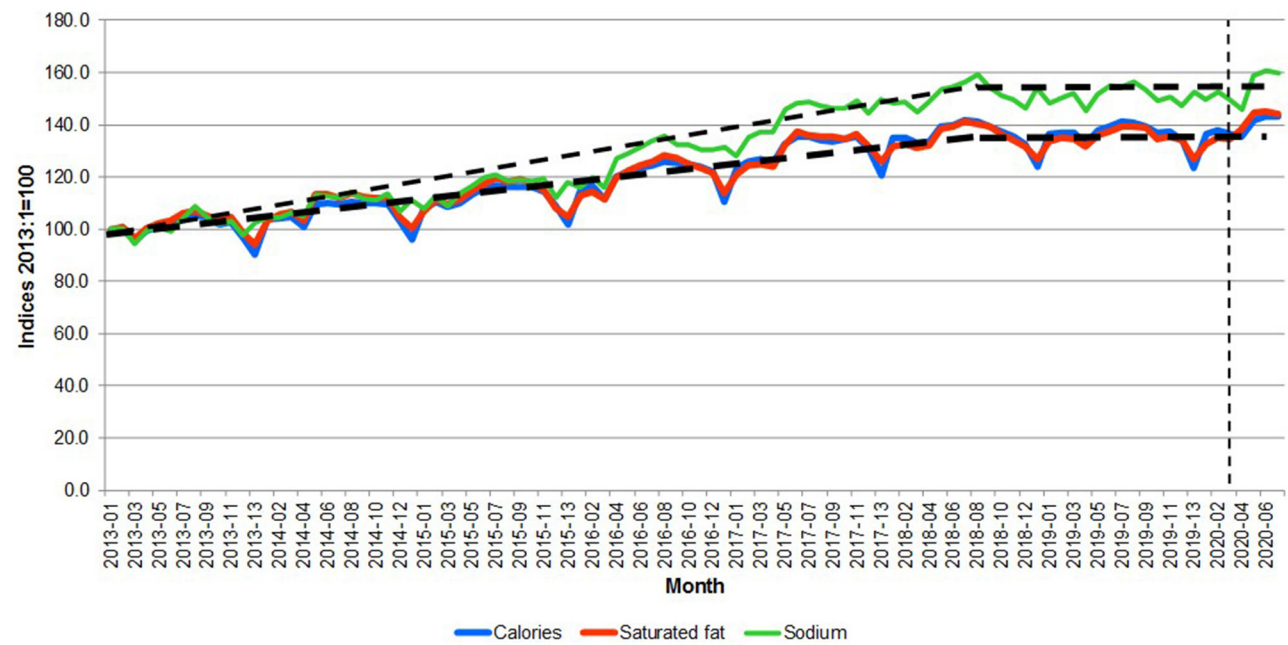

FIGURE 7 | Great Britain—Calories, saturated fat and sodium content per kilogram of purchased meat and fish. Source: Own elaboration based on Kantar Worldpanel data. Note: The thin dotted line represents the start of the lockdown in March 2020. The thick dotted lines represent trends.

The results suggest that nutrition consequences of the lockdown were more severe for higher income groups than other ones, as far home meat and fish consumption was concerned. These households registered high increase in consumption of saturated fat and calories from those categories. This result is consistent with the large increase in meat purchases during the pandemic emergency that was observed for these groups.

TABLE 2 | Great Britain—Decomposition of the change in expenditure for meat and fish by income group (%).

Income group	Outbreak period (t)							
	ΔP	ΔE	ΔQ	T				
<£ 30,000	−0.63	19.99	19.74	0.85				
£30,000–39,999	−0.63	24.06	25.74	−0.70				
£40,000–49,999	−0.63	24.01	24.74	0.02				
£50,000–59,999	−0.63	22.29	22.03	0.86				
Over £60,000	−0.63	20.62	23.08	−1.37				
Income group	**Lockdown period 1 (t+1)**				**Lockdown period 2 (t+2)**			
	ΔP	ΔE	ΔQ	T	ΔP	ΔE	ΔQ	T
<£ 30,000	0.70	8.48	7.46	0.24	1.83	9.37	6.71	0.65
£30,000–39,999	0.70	11.18	12.26	−1.65	1.83	14.64	14.43	−1.61
£40,000–49,999	0.70	23.00	24.00	−1.53	1.83	23.26	22.46	−1.18
£50,000–59,999	0.70	26.07	25.29	−0.08	1.83	26.07	24.93	−0.90
Over £60,000	0.70	29.38	29.36	−0.68	1.83	26.04	24.87	−0.87
Income group	**Post-lockdown period 1 (t+3)**				**Post-lockdown period 2 (t+4)**			
	ΔP	ΔE	ΔQ	T	ΔP	ΔE	ΔQ	T
<£ 30,000	2.02	6.75	3.34	1.25	2.18	1.74	−2.11	1.71
£30,000–39,999	2.02	12.90	10.73	−0.06	2.18	6.43	3.03	1.09
£40,000–49,999	2.02	20.41	18.61	−0.52	2.18	12.27	8.14	1.57
£50,000–59,999	2.02	19.45	18.32	−1.05	2.18	15.18	11.96	0.68
Over £60,000	2.02	25.81	23.45	−0.10	2.18	17.78	13.77	1.32

Source: Own elaboration based on Deaton and McKelvey.

ΔE stands for the change in expenditure, ΔP is the change in price, ΔQ is the change in quantity and T is trading up/down effect by product after the pandemic outbreak in the UK. All changes are computed with respect to the pre-emergency averages in the UK.

Trend Analysis of Calories and Saturated Fats per Quantity of Meat and Fish Purchased

Table 4 presents the results of the trend analysis of calories, saturated fats and sodium per quantity by income group. Recall that the purpose of this analysis is to explore whether the trend during the COVID-19 period (i.e., since 2020-03) was different to the trend considering the full period.

As shown in the Table, excepting in the case of the £50,000–59,999 group, which show a decreasing trend both in terms of calories and saturated fats (with statistically significant t statistics), all the other income groups show that the estimated trend using the full sample is appropriate for the COVID-19 period. Also note that this is not the case for the 2018-01 to 2020-02, which showed a line almost flat (i.e., no trend) as shown in **Figure 7** for all the meats together.

The trend analysis of **Table 4** is reflected in the composition of calories, saturated fats and sodium by meat and fish and income group presented in **Figure 11**. As shown in the figure, "other meats" has a significant contribution to calories, saturated fats and particularly to sodium for all the income groups. In the case of calories, the 'other meats' represent on average 39 percent of the total calories, 49 percent of the total saturated fats and 64 percent of the total sodium coming from meat and fish purchases.

DISCUSSION

The purpose of this study has been to study consumers reaction in terms of their purchases of meat and fish during the COVID-19 period using time series constructed from a scanner panel dataset for Great Britain by income groups.

It is important to note that the increase in the demand for particular meat cuts (e.g., mincemeat), the lack of demand from the food service and mild supply issues due to workers in processing plants contracting the Covid-19 virus created a temporary problem for the industry affecting the carcass balance, the demand for high quality meat and labor shortage, respectively. However, these now appear to have been solved as the industry has responded increasing the volumes delivered to supermarkets and recruiting additional labor force (24).

In aggregated terms, results indicated that consumers reacted initially to the lockdown by increasing their expenditure on at-home consumption of meat and fish, which was derived from a significant increase of the purchased quantities (10). This is consistent with previous demand analyses that indicated that meats had positive income elasticities [e.g., (13)]. Prices, in contrast, remained almost unchanged despite the demand pressure. Even more, the shares (computed from quantities) of the different meat and fish products remained very similar over time.

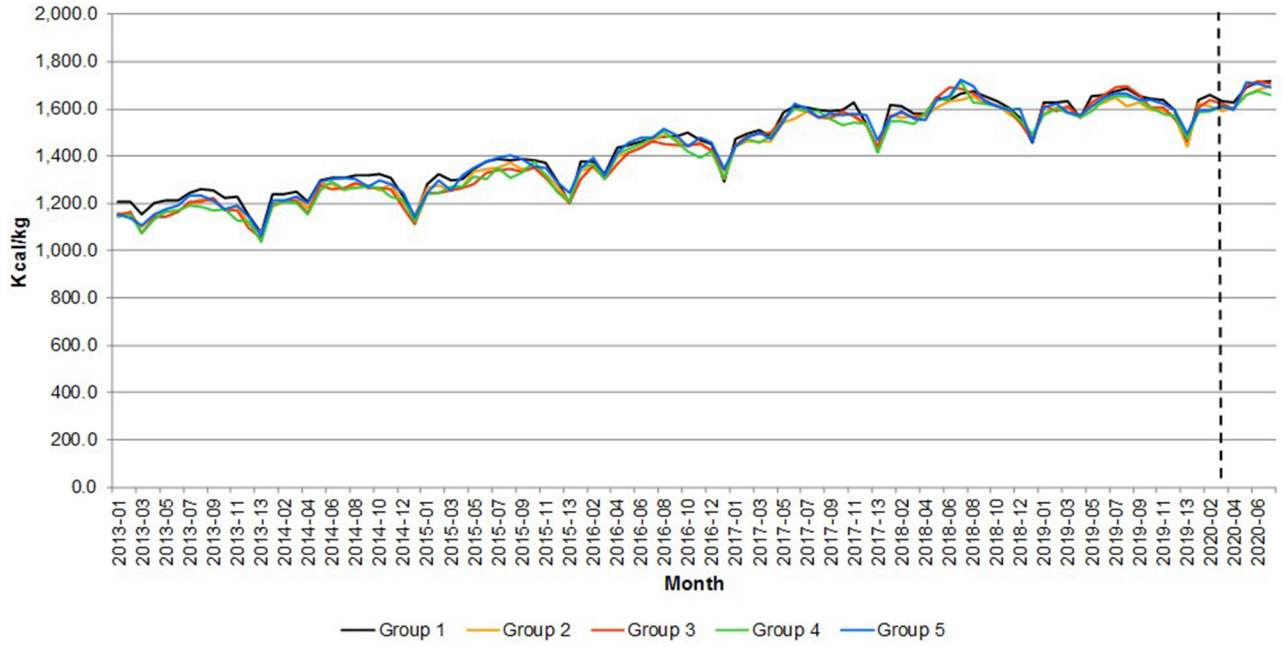

FIGURE 8 | Great Britain—Calories per quantity of meat and fish. Source: Own elaboration based on Kantar Worldpanel data. Note: The dotted line represents the start of the lockdown in March 2020. Group 1 = <£30,000, Group 2 = £30,000–39,999, Group 3 = £40,000–49,999, Group 4 = £50,000–59,999, and Group 5 = over £60,000.

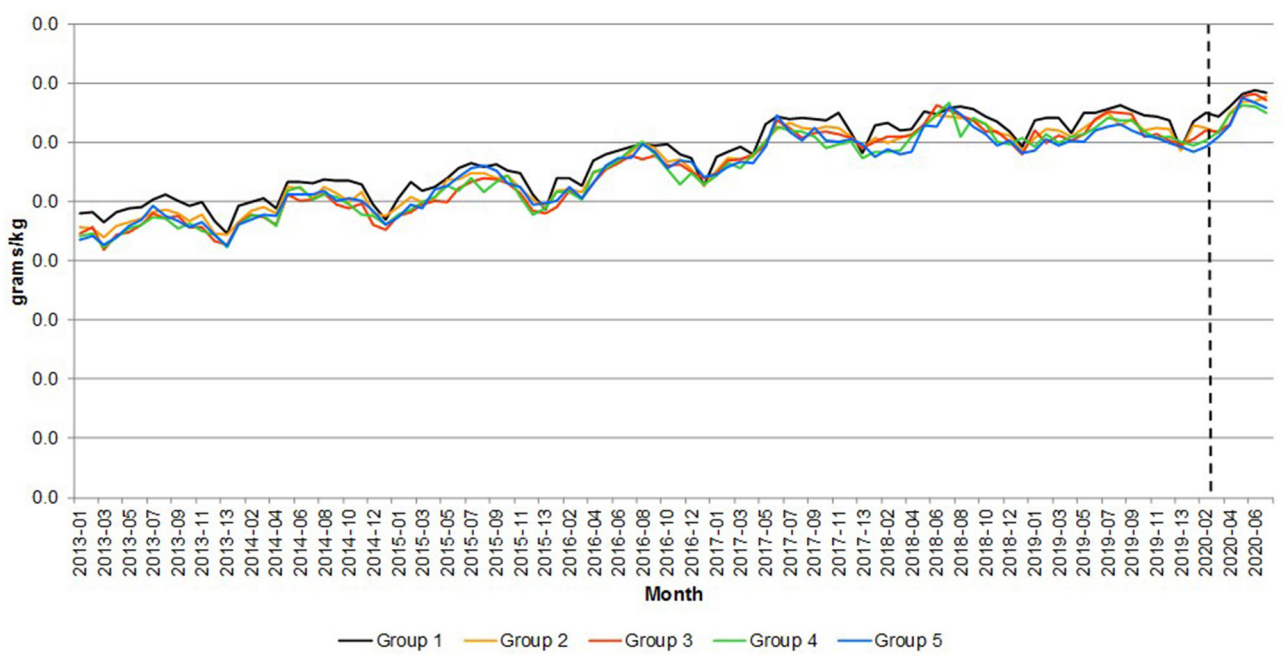

FIGURE 9 | Great Britain—Saturated fats per quantity of meat and fish. Source: Own elaboration based on Kantar Worldpanel data. Note: The dotted line represents the start of the lockdown in March 2020. Group 1 = <£30,000, Group 2 = £30,000–39,999, Group 3 = £40,000–49,999, Group 4 = £50,000–59,999, and Group 5 = over £60,000.

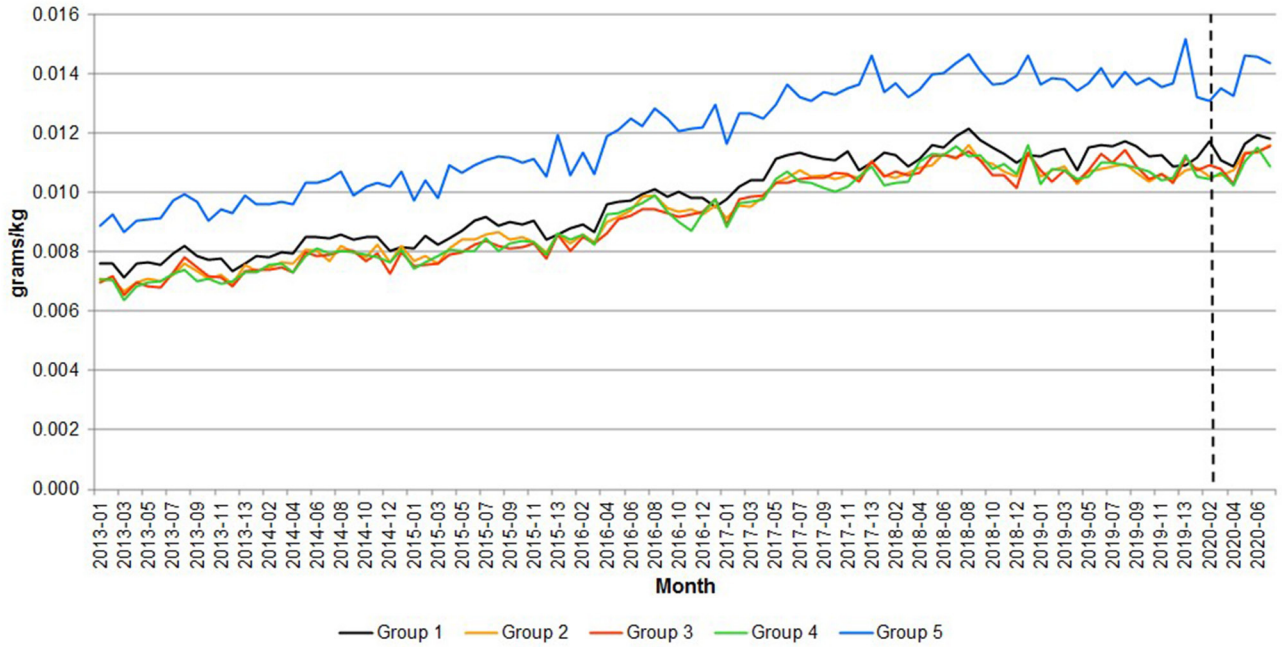

FIGURE 10 | Great Britain—Sodium per quantity of meat and fish. Source: Own elaboration based on Kantar Worldpanel data. Note: The dotted line represents the start of the lockdown in March 2020. Group 1 = <£30,000, Group 2 = £30,000–39,999, Group 3 = £40,000–49,999, Group 4 = £50,000–59,999, and Group 5 = over £60,000.

TABLE 3 | Great Britain—Calories, saturated fats and sodium per kilogram of meat and fish (12-month percent change).

Income group	Per-kg average calories				
	Outbreak	**Lockdown 1**	**Lockdown 2**	**Post-lockdown 1**	**Post-lockdown 2**
<£ 30,000	−0.14	4.07	2.52	3.43	2.30
£30,000–39,999	−0.87	2.74	3.14	3.19	2.89
£40,000–49,999	0.59	1.84	4.24	3.60	0.94
£50,000–59,999	1.30	2.61	4.10	2.45	0.43
Over £60,000	1.46	1.56	6.28	3.46	1.69
Income group	**Per-kg saturated fats**				
	Outbreak	**Lockdown 1**	**Lockdown 2**	**Post-lockdown 1**	**Post-lockdown 2**
<£ 30,000	0.06	7.32	4.94	5.80	4.28
£30,000–39,999	−0.57	6.50	7.21	4.85	4.19
£40,000–49,999	1.32	4.75	10.32	6.50	3.03
£50,000–59,999	3.25	6.27	8.02	5.69	1.29
Over £60,000	2.55	4.26	12.37	7.55	5.06
Income group	**Per-kg sodium**				
	Outbreak	**Lockdown 1**	**Lockdown 2**	**Post-lockdown 1**	**Post-lockdown 2**
<£ 30,000	−3.06	0.95	1.32	2.88	2.10
£30,000–39,999	−2.99	4.27	6.08	5.15	6.51
£40,000–49,999	0.29	−0.92	5.26	0.66	4.80
£50,000–59,999	−0.94	−2.09	4.65	4.31	−1.34
Over £60,000	−2.10	−1.20	6.65	2.92	5.81

Source: Own elaboration based on Kantar Worldpanel data.

TABLE 4 | Great Britain—Trend regression analysis of calories and saturated fats per purchased kilogram for all meats and fish.

	Full sample		2018–2020-02		Covid		R^2
	Intercept	Trend	Intercept	Trend	Intercept	Trend	
< £ 30,000							
Calories	−298.5	6.5	389.5	−5.5	437.7	−5.8	0.98
	−48.9*	39.5*	8.4*	−9.0*	0.6	−0.7	
Saturated fats 2/	−5.5	0.1	7.2	−0.1	9.7	−0.1	0.97
	−41.6*	33.7*	7.1*	−7.8*	0.6	−0.7	
Sodium 2/	−2.7	0.1	4.6	−0.1	0.5	0.0	0.96
	−38.4*	31.2*	8.6*	−9.1*	0.1	−0.2	
£30,000–39,999							
Calories	−309.1	6.8	442.5	−6.3	171.6	−3.2	0.98
	−53.5*	43.7*	10.1*	−10.9*	0.2	−0.4	
Saturated fats 2/	−5.7	0.1	7.4	−0.1	0.4	0.0	0.97
	−42.2*	34.8*	7.2*	−8.1*	0.0	−0.1	
Sodium 2/	−2.6	0.1	5.1	−0.1	−3.3	0.0	0.97
	−40.4*	33.0*	10.3*	−10.9*	−0.4	0.3	
£40,000–49,999							
Calories	−328.3	7.1	455.0	−6.3	587.3	−7.5	0.98
	−46.4*	37.4*	8.5*	−9.0*	0.7	−0.8	
Saturated fats 2/	−6.1	0.1	9.4	−0.1	2.2	0.0	0.96
	−38.7*	31.7*	7.8*	−8.5*	0.1	−0.2	
Sodium 2/	−2.7	0.1	4.4	−0.1	−3.0	0.0	0.96
	−34.9*	28.1*	7.6*	−7.9*	−0.3	0.2	
£50,000–59,999							
Calories	−321.7	7.1	467.6	−6.6	1551.3	−17.9	0.98
	−47.8*	39.1*	9.2*	−9.9*	1.9	−2.1*	
Saturated fats 2/	−5.9	0.1	7.6	−0.1	38.6	−0.4	0.96
	−36.8*	30.2*	6.3*	−7.1*	2.0	−2.1*	
Sodium 2/	−2.6	0.1	4.9	−0.1	6.3	−0.1	0.96
	−35.6*	28.6*	8.8*	−9.0*	0.7	−0.8	
Over £60,000							
Calories	−314.6	7.0	453.0	−6.5	935.0	−11.3	0.98
	−53.6*	44.2*	10.2*	−11.2*	1.3	−1.5	
Saturated fats 2/	−5.7	0.1	8.2	−0.1	17.3	−0.2	0.96
	−39.5*	33.5*	7.5*	−8.9*	1.0	−1.1	
Sodium 2/	−3.3	0.1	5.7	−0.1	−0.7	0.0	0.97
	−40.6*	33.4*	9.3*	−10.0*	−0.1	−0.1	

*1/ First rows are the coefficients and the second rows are the standard error of the coefficients. *indicates that the coefficient is statistically different from zero at 95% significance.*
*2/ Coefficient multiplied by 1,000. Second row are t statistics. *indicates that the coefficient is statistically different from zero at 95% significance.*

The results of the decomposition show the reaction of the UK meat and fish chain to an unexpected shock of unprecedented magnitude. The pandemic outbreak was associated to an immediate surge in meat and fish purchases. The increase might be explained by three effects: movement restriction, reduction of social interaction and stockpiling. Movement restrictions and spontaneous reduction of social interaction determined the substitution of food services (such as restaurants and catering) with at-home consumption. Also, uncertainty fear of shortage might trigger stockpiling behavior (10, 25). Nicola et al. (26) reported that "panic-buying has resulted in an increase of £1bn worth of food in UK homes."

The combination of the three effects might explain the surge in home consumption during the outbreak period, and the declining trends thereafter. In the outbreak period stockpiling and voluntary reduction of social interaction took place, resulting in the largest increase in purchase. In the lockdown period the stockpiling effect faded, as home stocks were full and the perceived risk of food supply disruption declined, but movement restriction sustained home consumption as a substitute for away-from-home meals. In the post-lockdown periods, only the voluntary reduction of social interaction remained, and consumption trends slowly were reverting to pre-emergency levels.

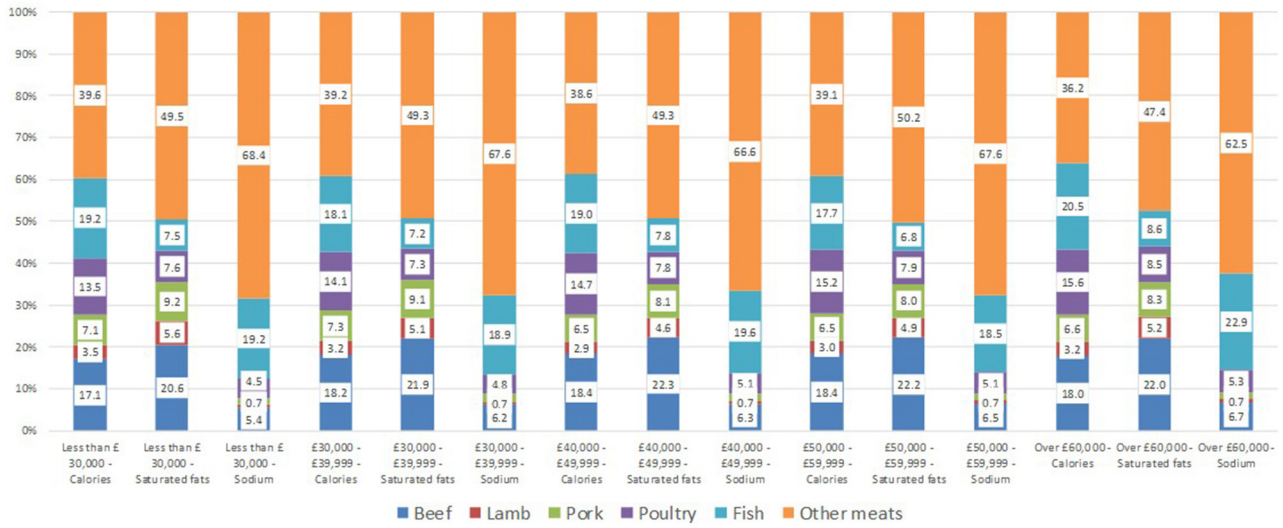

FIGURE 11 | Great Britain—Average contribution of meat and fish to calories, saturated fats and sodium by income group during the COVID-19 period (2020-03 to 2020-07). Source: Own elaboration based on Kantar Worldpanel data.

It is important to note that the industry reacted quickly to the effects created by the lockdown (e.g., demand for cheaper meat cuts, lack of demand of the food service industry) by expanding the supply to supermarkets and also improving labor safety in the workplace (10). The price time series reflects this trend.

The evolution of the nutrients per quantity purchased (using calories and saturated fats as the chosen nutrients), which can be considered a measure of the nutritional quality of the purchases, indicated an increasing trend, which is consistent with the COVID-19 period. This contrasts with the period 2018 to 2020 before the lockdown, where there was almost no trend. Moreover, the quality of the meat and fish purchases is represented by the fact that the group "other meats" represented on average 39 percent of the calories contributed by meat and fish and 49 percent of the saturated fats during the period lockdown period.

The above results highlight the importance of emphasizing consumers' education and information as regards meat purchases. In this sense, NHS (1) recommendations pointing out at choosing lean cuts; if buying pre-packed meat to check the nutrition label to see the level of fat content, to purchase turkey and chicken without the skin as these are lower in fat (or remove the skin before cooking) and to limit processed meat products (other meats in the studied dataset) such as sausages, salami, pâté are very important.

DATA AVAILABILITY STATEMENT

The data used in the paper may be available upon request to the author.

AUTHOR CONTRIBUTIONS

CR-G: conceptualization, data preparation, investigation, visualization, formal analysis, writing—original draft, writing—review, and editing. CR: conceptualization, investigation, writing—review, and editing. Both authors contributed to the article and approved the submitted version.

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Socio-Demographic and Knowledge-Related Determinants of Vitamin D Supplementation in the Context of the COVID-19 Pandemic: Assessment of an Educational Intervention

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Vitamin D is a pro-hormone, essential for musculo-skeletal health, normal immune system, and numerous other body functions. Vitamin D deficiency is considered as a risk factor in many conditions, and there is growing evidence of its potential role in the severity of COVID-19 outcomes. However, an alarmingly high prevalence of vitamin D deficiency is reported in many regions, and vitamin D supplementation is commonly recommended, particularly during wintertime. To reduce the risk for vitamin D deficiency in the Slovenian population during the COVID-19 pandemic, we conducted mass media intervention with an educational campaign. The objective of this study was to investigate vitamin D supplementation practices in Slovenia before and during the COVID-19 pandemic, and to determine the effects of the educational intervention on supplementation practices. Two data collections were conducted using an online panel with quota sampling for age, sex, and geographical location. A pre-intervention (N = 602, April 2020) and post-intervention (N = 606, December 2020) sampling were done during the first and second COVID-19 lockdown, respectively. We also focused on the identification of different factors connected to vitamin D supplementation, with a particular emphasis on vitamin D-related knowledge. Study results showed significant increase in vitamin D supplementation in the population. Penetration of the supplementation increased from 33% in April to 56% in December 2020. The median daily vitamin D intake in supplement users was 25 μg, with about 95% of supplement users taking safe vitamin D levels below 100 μg/daily. Vitamin D-related knowledge (particularly about dietary sources of vitamin D, the health-related impact of vitamin D, and the prevalence of deficiency) was identified as a key independent predictor of vitamin D supplementation. Based on the study findings, we prepared recommendations to support the development of effective awareness campaigns for increasing supplementation of vitamin D.

Keywords: vitamin D, supplementation, deficiency, knowledge, COVID-19

INTRODUCTION

Vitamin D is a pro-hormone, essential for musculo-skeletal health, normal immune system, and many other body functions (1–3). This micronutrient is also at the frontier of many debates about possible dietary interventions during the COVID-19 pandemic, which has introduced unique threats to the population and has challenged healthcare systems worldwide.

The worst COVID-19 outcomes and higher mortality rates are reported among immunocompromised subjects, including older adults and malnourished people (4). Nutritional risks have been identified as particularly relevant, highlighting the need for nutritional interventions (5). Vitamin D deficiency has been recognized as a possible risk of COVID-19 infection and severe disease outcomes (6, 7), therefore vitamin D supplementation is included in recommendations for nutritional support for COVID-19 patients (8–11). While some researchers highlighted important role of vitamin D in prevention of acute respiratory tract infections (12–15) and suggested vitamin D supplementation as a possible therapeutic strategy (16–23), some are highlighting that available results are not yet fully conclusive (24). While it is clear that well-controlled intervention studies are needed in these areas, the high prevalence of vitamin D deficiency in many populations is a rational cause for concerns—with or without COVID-19 pandemic. Some countries therefore updated their Vitamin D supplementation recommendations recently. In the UK for example, revised governmental advice was issued in April 2020 (during the first COVID-19 lockdown), recommending the use of vitamin D supplements for everyone during the autumn and winter months (24). According to additional UK guidance from December 2020, clinically vulnerable people were offered a free supply of daily vitamin D supplements for 4 months (25).

Vitamin D in the body may come both from dietary sources and from biosynthesis in the skin, triggered by sun exposure, more specifically ultraviolet B (UVB) irradiation. The latter represents the main vitamin D source for most of the population, but the efficiency of vitamin D biosynthesis depends on the latitude, season, and several other environmental and personal factors (26). The usual biomarker for the assessment of vitamin D status is the serum concentration of 25-hydroxy-vitamin D [25(OH)D]. Vitamin D deficiency is typically set at serum 25(OH)D concentrations below 50 nmol/l (27), while some researchers suggest even higher optimal target threshold (28, 29). Although it has been assumed that sun exposure during summer is sufficient to avoid severe vitamin D deficiency year-round, it is now known that this is not the case in many geographic areas (3, 26, 30), including Europe (31). Actually, across the northern hemisphere, at latitudes greater than 35°N, the small amount of UVB in sunlight from October to March is insufficient to initiate effective vitamin D synthesis. Therefore, substantial proportions of the European population rely on dietary vitamin D and body stores to maintain a sufficient vitamin D status during the extended winter season, and quite a high prevalence of vitamin D deficiency is reported in many countries worldwide (30–33). Alarmingly, in a very recent nationally representative study for Slovenia (34), during the extended winter season vitamin D deficiency was found in about 80% of adults (18–74 years), while almost 40% had a severe vitamin D deficiency, with serum 25(OH)D levels below 30 nmol/l.

Natural foods are very limited sources of vitamin D; the most notable sources are oil-rich fish and egg yolks. Consequently, the dietary intake of vitamin D is low in most countries, except in those where oily fish are consumed in high quantities and those with mandatory fortification of foods with vitamin D (35). A large European survey, which included several countries, revealed that the mean daily intake of vitamin D is in most cases below 5 μg (200 IU) (36) and such low intakes were confirmed in other studies (30, 37, 38). Systemic food fortification has been implemented in many countries in order to increase dietary intake of vitamin D, for example, in the USA, Canada, Australia, and Finland (33). On the contrary, most European countries do not have formal public health fortification or supplementation policies (30). Slovenia is also an example of a European country that does not have any formal advice or policies regarding the enrichment of food products with this vitamin, and vitamin D supplementation (10 μg/day) is advised routinely only for infants up to 1 year. Recent study revealed the penetration of vitamin D supplementation in Slovenian adults (18–74 years) reached about 10% (34), but the design of that study did not enable additional analyses, for example, about insights on the seasonal variations in practices of vitamin D supplementation.

In the absence of mandatory food fortification and/or supplementation policies, supplementation practices in the population are on a voluntary basis. Although many factors influence individual behaviors, knowledge is a crucial factor to consider in the development of health promotion programs (39). People are exposed to various types of information from different sources and we would expect that personal vitamin D supplementation decisions depend on the knowledge related to this vitamin. Deschasaux et al. reported that, at least in Europe, people are often confused about the sources as well as health effects of vitamin D (40). Similar observations were also reported in other studies from different countries (39, 41–43). Physicians and the media were identified as key information providers on this topic, and it was suggested that health professionals should also be better informed about the health effects of vitamin D, and particularly about the vitamin D deficiency risk factors (40). Moreover, the public should receive information that reflects the current knowledge on vitamin D health effects and sources. This could contribute to improved vitamin D status in the population.

Vitamin D-related knowledge has not yet been systematically investigated in the Slovenian population, but the high prevalence of vitamin D deficiency and building evidence about its role in COVID-19 have caused increased attention of mass media for this essential micronutrient, which could have affected not only vitamin D-related knowledge, but also supplementation practices. Monthly frequency of articles mentioning vitamin D in Slovenian mass media in the period 2019–2020 is presented in **Figure 1**. There are visible peaks in media coverage of vitamin D during the first COVID-19 lockdown

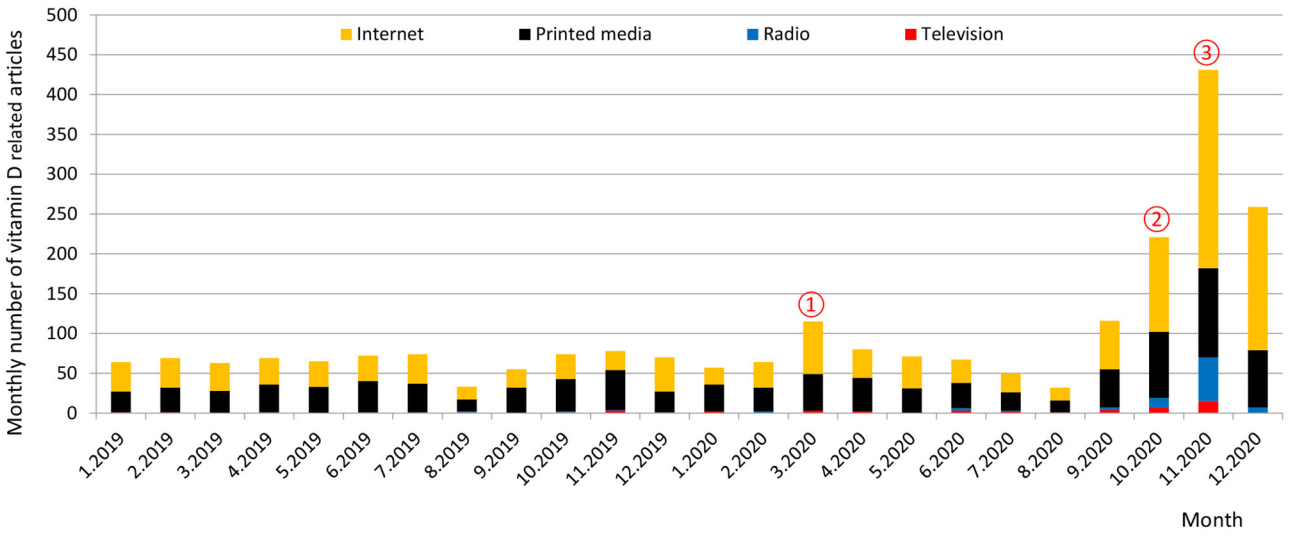

FIGURE 1 | A monthly number of vitamin D-related articles in Slovenian mass media in the years 2019 and 2020. This **Figure 1** was constructed using the press coverage data of Kliping media agency (Slovenia), which collects full texts of publications from all relevant mass media channels in Slovenia [covering major television and radio stations (transcripts), print media, and internet portals]. Press coverage peaks correspond with: ① Media communication of physician D. Siuka about 10-steps in the fight against COVID-19 (44) ② Release of recommendations for supplementation with vitamin D for physicians (45) ③ Mass media intervention: Press release about the prevalence of vitamin D deficiency in Slovenia by the Nutrition Institute (46), followed by series of interviews and media reports.

in March, and particularly in the last quartal of 2020. March 2020 peak corresponds with media communication of physician Darko Siuka (44), who proposed 10-steps in the fight against COVID-19 (vitamin D supplementation was mentioned as one of the steps), another peak can be further observed in October 2020, when vitamin D supplementation recommendations for physicians were published on the web site of Slovenian endocrine society (45), while a major peak occurred in November 2020, after an educational intervention: A press release (46) was sent to major mass media channels, focused on recent results of the national Nutrihealth study (34) about the wide prevalence of vitamin D deficiency in the Slovenian population.

Considering these challenges, the objective of study was to investigate individual vitamin D supplementation practices in Slovenia before and during the COVID-19 pandemic and to determine the effects of the abovementioned educational intervention on supplementation practices. Two data collections were conducted: during the first COVID-19 lockdown in April 2020, and during the second COVID-19 lockdown in December 2020—after an educational intervention. We were focused on the identification of different factors connected to vitamin D supplementation, with a particular emphasis on vitamin D-related personal knowledge. In the absence of mandatory food fortification and vitamin D supplementation, the identification of key knowledge gaps in the population is essential for the preparation of efficient and educational public health campaigns for reducing vitamin D deficiency. Identified knowledge gaps were used for the educational intervention, which was evaluated with sampling in December 2020.

MATERIALS AND METHODS

Data Collection

This study was conducted in Slovenia, Europe. Sampling was done using an online panel survey in two periods. Frist (pre-intervention) sampling period was between 22nd and 27th April 2020, during the first COVID-19 lockdown, while the second (post-intervention) sampling ($N = 606$) was between 11th and 30th December 2020, during the second COVID-19 lockdown.

Educational intervention (press release to mass media) was done between both collections, on 2nd November 2020 (details provided in section Educational intervention). The survey was conducted in the Slovenian language as an amendment to the international Food-COVID-19 survey. Participants provided their informed consent to participate using an online form. Ethical approval for the study was obtained from the Bioethical Committee of the Higher School of Applied Sciences in Ljubljana, Slovenia (VIST ET-6/2020).

Participants were recruited via a consumer panel marketing research institute with quota sampling for age groups, gender, and region. The selected on-line panel (about 35,000 subjects from Slovenia) was used to generate random invitations in the selected quotas. Participants completed the online survey upon invitation. The international Food-COVID-19 questionnaire (47) was amended with additional socio-demographic details (self-reported financial and health status; see details in section Variables), with questions about individual vitamin D supplementation practices before and during the COVID-19 pandemic (detail provided in section Variables), and vitamin D-related knowledge (detail provided in section Vitamin D-related knowledge). Only valid responses for subjects that

passed two attention check questions and provided responses to all survey questions are included.

April 2020 pre-intervention sample included $N = 602$ valid responses. Same subjects were also invited to participate in December 2020 post-intervention survey, with a response rate of 62% ($n = 373$). To assure a comparable sample size, additional 233 participants were recruited via the same consumer panel marketing research institute, again with quota sampling for age groups, gender, and region. Complete December 2020 post-intervention sample therefore contained a total of $N = 606$ valid responses.

Variables

Respondents provided information about their age, which, for the purpose of the analysis, was transformed into a categorical variable with four levels: 18–35, 36–49, 50–65, and ≥66 years. Using participants' postal codes and the classification proposed by the European Commission (48), respondents were classified into three categories: urban, intermediate, and rural. Educational status was also collected using EUROSTAT categorization (Primary school; Upper secondary—vocational school; Upper secondary—high school; Vocational post-secondary school; First cycle Bologna degree; University or second cycle Bologna degree; Scientific MSc or Ph.D.). For statistical analyses, these categories were joined into three larger education categories—lower (primary school), medium (vocational school or high school), and higher (beyond high school). Self-reported financial status was also measured ("How you would assess financial status of your household": 1—Very below average; 2—Below average; 3—Average; 4—Above average; 5—Very above average). For statistical analyses, respondents were then classified into three categories: the below average income category (includes respondents indicating very below and below average financial status); the average group (indicates average financial status); and the above average category (indicates above and very above average self-reported financial status). Respondents also reported the size of their household, which was classified into three categories: household with children, single person household, household with 2+ adults without children living together. Self-assessed health condition was surveyed with a question "How you would assess your general health condition" (1—very low, 2—low, 3—medium, 4—high, 5—very high). For statistical analyses we created three categories: The first included those with very low- and low health condition, the second included respondents with average health condition, and the third included participants indicating high and very high self-reported health condition. Moreover, participants were asked to report if they were supplementing their diet with vitamin D (a) before and (b) during the COVID-19 pandemic. If supplementation was reported, the participant was asked to provide the dosage of vitamin D. As we needed details about the supplementation to enable a calculation of individual daily vitamin D dosage, we used following wording of the question: "Provide the dosage of vitamin D that you used (for example: 1,000 IU per day, 100 mg/week, five drops of Plivit D® per day, etc.). Please provide as much details as possible, to enable us calculation of your daily vitamin D dosage. If possible, check intake of vitamin D on the labeling of the product that you used for supplementation of vitamin D." Questions were also asked about the extent to which their household had been afflicted with COVID-19 using three questions that asked about infection, isolation or quarantine, and hospitalized members. For the purpose of the analysis, these categories were further joined by one variable with two levels. The participants who responded positively to any of the three questions were classified in the "COVID-19 affected households" group, and the remaining respondents in the "COVID-19 not affected households" group. The following three questions measured respondents' perceived risk in relation to the disease: (1) the likelihood of any member of your household becoming infected by the virus; (2) the likely severity of the virus for any member of your household; and (3) the level of your anxiety concerning the potential impact of the virus on your household. Participants were asked to score these on a scale from 1 (very low) to 5 (very high).

Vitamin D-Related Knowledge

Vitamin D-related knowledge was measured using an online tool, developed, and described in detail by Boland et al. (39). This questionnaire contains questions on the following dimensions of vitamin D: (a) dietary sources; (b) health impact; (c) dietary needs; (d) sun exposure and biosynthesis; (e) other factors of biosynthesis; and (f) prevalence of deficiency. The following modifications of the questionnaire were needed:

(1) Translation to Slovenian language.
(2) The sun exposure and biosynthesis dimension (d) of the original questionnaire has two questions about the time one needed to spend in the sun to get enough vitamin D—one for fair-skinned persons, and one for non-fair-skinned (i.e., non-Caucasian) persons. We only used the question for fair-skinned persons, as the vast majority of the Slovenian population is Caucasian.
(3) The dietary needs (d) of the original questionnaire refer to the daily amount of vitamin D recommended for adults by Health Canada. This question was changed to refer to recommendations applicable in Slovenia, and responses were provided both in International Units and micrograms of vitamin D (only IU in the original questionnaire). While, in the original questionnaire, the correct response was 600 IU (according to Health Canada recommendations), responses of 600 IU/15 μg and 800 IU/20 μg were considered as correct in our survey, because of the differences between regional and EU-level recommendations (49, 50).

The vitamin D-related knowledge questionnaire used is provided in the **Supplementary Material**. Six questions were used to assess six of the above-mentioned dimensions of vitamin D-related knowledge, and each question contributed equally to the calculation of the total knowledge score. Every knowledge question was worth 1 point, producing a maximum score of 6 points. Single questions were scored with 1 if the answer was correct, and 0 if the answer was incorrect. For multiple choice questions, each correct response accounted for a fraction of the overall question. For instance, if a question had 5 correct answers, each contributed 0.2 points. When calculating the total score, the sum of correct responses was deducted from the sum of incorrect

responses multiplied by the fraction parts. In this way, a penalty for guessing was implemented to prevent participants from scoring maximum by selecting all possible responses as correct. For this reason, the response "don't know" was not penalized within the knowledge score. Penalization only occurred within a specific question. In cases where negative scores were given, the whole question was scored as zero.

Educational Intervention

Results of pre-intervention data collection in April 2020 were used to identify vitamin D-related knowledge dimensions, connected with vitamin D supplementation practices. Population-based educational intervention started with the launch of a press release on November 2nd 2020, which was sent to e-mail addresses of major Slovenian media channels. The press release was focused on the wide prevalence of vitamin D deficiency in the Slovenian population (46). Intervention resulted in several interviews and numerous publications in mass media. For example, in the last quartal of 2020 there were more vitamin D-related publications ($N = 911$) in mass media, than together in the whole year 2019 ($N = 786$) (**Figure 1**).

Data Analysis

All statistical analyses were done using STATA version 15.1 (StataCorp LLC, Coledge Station, TX, USA). Descriptive characteristics (mean, median, proportions) are presented for different socio-demographic and individual-based variables and those related to vitamin D supplementation before and during the COVID-19 pandemic. Multivariable linear and logistic regression analyses were used to investigate the predictors of knowledge and supplementation with vitamin D and to determine differences between different sub-populations in terms of knowledge and supplementation. The estimates of vitamin D-related knowledge were determined using age, sex, place of living, education, financial status, health status, and employment, while the estimates of supplementation with vitamin D were determined with respect to age, sex, place of living, education, financial status, and health status. Additionally, a multivariable logistic regression analysis was used to investigate predictors of an increase in vitamin D-related knowledge (December vs. April scoring). In this regard the analyses were conducted using a subsample of subjects, which participated in both pre-intervention (April 2020) and post-intervention (December 2020) data collection, with the exploitation of previously mentioned socio-demographic determinants (age, sex, place of living, education, financial, and health status). Multivariable logistic regression analysis was also used to investigate the influence of different dimensions of vitamin D-related knowledge on supplementation with vitamin D, separately for first (April 2020) and second (December 2020) COVID-19 lockdown. For the purpose of binomial regression analysis, respondents were classified into two categories: respondents taking and not taking vitamin D supplements. The model parameters were estimated by the maximum likelihood method. Odds ratios (ORs) with 95% confidence intervals (CIs) were calculated. A z-test for proportions was used to identify significant changes between the pre- and post-intervention supplementation practices. In addition, a *t*-test for independent samples was used to test the difference in overall vitamin D-related knowledge in pre- and post-intervention sample. Differences were considered significant at $p < 0.05$.

RESULTS

Socio-Demographic and Other Characteristics of the Sample

Socio-demographic and other characteristics of the participants are presented in **Table 1**. The compositions of the pre-intervention (April 2020; $N = 602$), the post-intervention (December 2020; $N = 606$), and the combined sample (April and December 2020; $N = 835$) study samples are close to the distribution in the population. Both sex and age distribution are quite comparable, with age groups 19–35 and 36–49 slightly over-represented, while the 50+ age group is somewhat under-represented. Regarding educational level, the sample is under-represented for the lower education group. Nevertheless, as the study was done as an online survey, such data could not be considered representative, because the population who do not have access to the internet cannot be included.

The results in **Table 1** reveal that about 9% of participants were somehow affected by COVID-19 in April 2020, while the mean COVID-19 risk perception scores were below medium = 3. While the proportion of participants from COVID-19-affected households was much higher in December (25%), all mean risk perception scores (rated from 1—very low to 5—very high) were still below scale medium. In April the mean score for the likelihood of a household member becoming infected with the virus (2.2 ± 0.9) was lower in comparison with the score for the likely severity of the virus for household members, and the score for the level of anxiety concerning the potential impact of the virus on the household (2.6 ± 1.2 and 2.7 ± 1.1, respectively). This changed in December, when we observed significant increase ($p < 0.001$) in the reported likelihood of a household member becoming infected with the virus in comparison with April (score 2.7 vs. 2.2, respectively). We should also note that almost half of the sample (45.2 and 46.4% in April and December, respectively) was from a rural environment, which might have affected the COVID-19 risk perceptions of study participants.

Vitamin D-Related Knowledge

The results of the measurements of vitamin D-related knowledge are presented in **Table 2** and **Figure 2**. The maximum vitamin D-related knowledge score would be 6, but in the April 2020 pre-intervention study the highest observed score in our survey was 5.37, with a mean score of 1.60 (95% CI: 1.53–1.67). The specific dimensions of the vitamin D knowledge provide even more interesting results. Mean scores for dietary vitamin D sources (Q1) and vitamin D's health impact (Q2) were both 0.26 (95% CI: 0.25–0.28), while mean score for dimension affecting the biosynthesis of vitamin D (Q5) was somewhat lower (0.23; 95% CI: 0.21–0.24). The majority of the respondents (54.5%) were aware that the prevalence of vitamin D is above 20%, while the proportion of participants (Q3) were aware of

TABLE 1 | Socio-demographic and other characteristics of study participants (Slovenia, 2020).

Variables	Levels	April 2020 *N* (%)	December 2020 *N* (%)	Combined sample* *N* (%)
Sample size		602 (100)	606 (100)	835 (100)
Age	Mean age in years (SD)	44.1 (13.5)	42.94 (13.8)	41.92 (13.7)
Age groups	18–35 years of age	179 (29.7)	206 (34.0)	301 (36.1)
	36–49 years of age	202 (33.6)	184 (30.4)	273 (32.7)
	50–65 years of age	186 (30.9)	187 (30.9)	224 (26.8)
	66 years and above	35 (5.8)	29 (4.8)	37 (4.4)
Sex	Male	300 (49.8)	312 (51.5)	416 (49.8)
	Female	302 (50.2)	294 (48.5)	419 (50.2)
Place of living	Urban	125 (20.8)	123 (20.3)	169 (20.2)
	Intermediate	205 (34.1)	202 (33.3)	283 (33.9)
	Rural	272 (45.2)	281 (46.4)	383 (45.9)
Education	Primary school	24 (4.0)	22 (3.6)	32 (3.8)
	Upper secondary—vocational school	77 (12.8)	52 (8.6)	92 (11.0)
	Upper secondary—high school	231 (38.4)	227 (37.5)	320 (38.3)
	Vocational post-secondary school	69 (11.5)	84 (13.9)	107 (12.8)
	First cycle Bologna degree	94 (15.6)	107 (17.7)	132 (15.8)
	University or second cycle Bologna degree	95 (15.8)	100 (16.5)	133 (15.9)
	Scientific MSc or PhD	12 (2.0)	14 (2.3)	19 (2.3)
Financial status	Very below average	22 (3.7)	28 (4.6)	27 (3.2)
	Below average	115 (19.1)	119 (19.6)	157 (18.8)
	Average	363 (60.3)	361 (59.6)	505 (60.5)
	Above average	101 (16.8)	95 (16.7)	143 (17.1)
	Very above average	1 (0.2)	3 (0.5)	3 (0.4)
Health status	Very low	6 (1.0)	5 (0.8)	6 (0.7)
	Low	17 (2.8)	18 (3.0)	21 (2.5)
	Average	121 (20.1)	126 (20.8)	159 (19.0)
	High	326 (54.2)	330 (54.5)	460 (55.1)
	Very high	132 (21.9)	127 (21.0)	189 (22.6)
Employment	Full time employed	318 (52.8)	331 (54.6)	449 (53.8)
	Part time employed	26 (4.3)	29 (4.8)	37 (4.4)
	Unemployed	71 (11.8)	70 (11.6)	101 (12.1)
	Keeping house or home maker	8 (1.3)	8 (1.3)	10 (1.2)
	Self-employed	31 (5.2)	23 (3.8)	36 (4.3)
	Student	49 (8.1)	58 (9.6)	92 (11.0)
	Retired	99 (16.5)	87 (14.4)	110 (13.2)
Household composition	Household with children	247 (41.0)	286 (47.2)	389 (46.6)
	Single person household	53 (8.8)	54 (8.9)	70 (8.4)
	Household with 2+ adults without children	302 (50.2)	266 (43.9)	376 (45.0)
From COVID-19 affected households	Affected	53 (8.8)	151 (24.9)	N/A
	Not affected	549 (91.2)	455 (75.1)	N/A
COVID-19 risk perception: Mean score ± SD	The likelihood of any member of your household becoming infected with the virus.	2.2 ± 0.9	2.7 ± 1.0	N/A
	The likely severity of the virus for any member of your household.	2.6 ± 1.2	2.8 ± 1.2	N/A
	The level of your anxiety concerning the potential impact of the virus on your household.	2.7 ± 1.1	2.9 ± 1.1	N/A

SD, standard deviation; N/A, Not applicable COVID-19 risk perception score on scale from 1 (very low) to 5 (very high).

**Combined sample include different participants included in both April and December 2020 samples (373 subjects participated in both April only and December surveys, 229 in April study only, and 233 in Decembers study only).*

recommended daily intake of vitamin D (15–20 μg) and (Q4) the necessary sun exposure for an average fair-skinned person, when legs and arms are exposed (10–60 min per week), was 10 and 28%, respectively.

December 2020 measurements after educational intervention showed a statistically significant increase in vitamin D-related knowledge scores ($p < 0.001$). Mean total score significantly increased for 38% and notable differences were also observed in specific dimensions of the vitamin D knowledge (**Table 2**), particularly in scores for vitamin D's health impact (Q2: +54%), and factors affecting the biosynthesis of vitamin D (Q5: +96%). As presented in knowledge distribution histograms in **Figure 2**, the educational intervention resulted in increase in knowledge on the tail of the distribution, with the population with poor pre-intervention vitamin D-related knowledge having most notable knowledge increase after the intervention.

To provide further insights, linear regression analyses were used to determine adjusted means of vitamin D-related knowledge, considering various socio-demographic and other factors—namely age, sex, place of living, education, financial status, health, and employment status. Analyses were done separately for pre-intervention (April 2020) and post-intervention (December 2020) sample (**Table 3**). The pre-intervention analysis shows that age, sex, and financial status significantly affected vitamin D-related knowledge in different population groups. Older respondents with a higher financial status had significantly higher vitamin D-related knowledge, as shown by the groups' marginal means. Additionally, significantly higher vitamin D-related knowledge was observed for females compared to the male population. On the other hand, in the post-intervention analyses (December 2020), financial status and sex were not identified as significant factors affecting vitamin D-related knowledge anymore. However, the effect of age was still significant, and the effect of place of living also became significant, with the highest knowledge scores in participants from urban areas.

Intervention-related changes were additionally investigated using a sample of subjects, for which we had available two measurements of vitamin D-related knowledge. These were $N = 373$ subjects, who collaborated in both pre-intervention (April 2020) and post-intervention (December 2020) surveys. We investigated predictors of an increase in vitamin D-related knowledge using multivariable logistic regression analysis, focusing on age, sex, place of living, education, financial, and health status (**Table 4**). Altogether, 74% ($N = 274$) of subjects had increased vitamin D-related knowledge scores in December, in comparison with their April 2020 knowledge scoring. Education of the respondents have shown to be the only significant predictor of increased knowledge score.

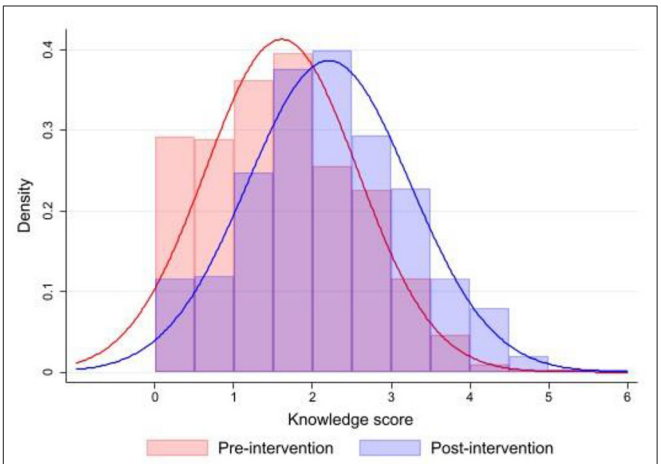

FIGURE 2 | Histograms of pre-intervention ($N = 602$; April 2020) and post-intervention ($N = 606$; December 2020) vitamin D-related knowledge in the study sample. The horizontal (x) scale uses the vitamin D-related knowledge score units, while the respondent's knowledge distribution is represented by the vertical bars (Red color line depicts normal Gaussian distribution of pre-intervention knowledge score, while blue color line depicts normal Gaussian distribution of post-intervention knowledge score).

TABLE 2 | Vitamin D-related knowledge score in study samples ($N = 602$ in April 2020; $N = 606$ in December 2020).

Sampling period	**April 2020**	**December 2020**
Variables	**Result**	**Result**
Number of subjects; *N* [%]	602 [100%]	606 [100%]
Knowledge total score:		
Mean (95% CI)	1.60 (1.53–1.67)[a]	2.21 (2.12–2.90)[b]
Vitamin D-related knowledge for all dimensions*:		
Food and other sources (Q1)—mean score (95% CI)	0.26 (0.25–0.28)	0.28 (0.27–0.30)
Health impact (Q2)—mean score (95% CI)	0.26 (0.25–0.28)[a]	0.40 (0.38–0.43)[b]
Dietary needs (Q3)—*N* (%) of correct answers	60.0 (10.0)	49 (8.2)
Sun exposure and biosynthesis (Q4)—*N* (%) of correct answers	171 (28.4)	167 (27.6)
Other factors and biosynthesis (Q5)—mean score (95% CI)	0.23 (0.21–0.24)[a]	0.45 (0.43–0.47)[b]
Deficiency prevalence (Q6)—*N* (%) of correct answers	328 (54.5)[a]	436 (72.0)[b]

**Knowledge score consider sum of scores from two types of questions: three multiple choice questions scaled from 0 to 1 and three single choice questions with two discrete options: correct and incorrect. Different letters next to numbers denote significant difference determined with independent sample t-test and z-test for proportions.*

TABLE 3 | Pre-intervention ($N = 602$; April 2020) and post-intervention ($N = 606$; December 2020) adjusted mean (95% CI) levels of vitamin D-related knowledge by age, sex, place of living, education, financial status, health status, and employment.

		Pre-intervention (April 2020)		Post-intervention (December 2020)	
Variables	**Levels**	***N* (%)**	**Adjusted**	***N* (%)**	**Adjusted**
Overall		602 (100)		606 (100)	
Age groups	18–35 years of age	179 (29.7)	1.43 (1.30–1.58)[a]	206 (34.0)	1.99 (1.83–2.15)[a]
	36–49 years of age	202 (33.6)	1.53 (1.39–1.67)[ab]	184 (30.4)	2.08 (1.92–2.24)[a]
	50–65 years of age	186 (30.9)	1.80 (1.66–1.95)[b]	187 (30.9)	2.52 (2.36–2.68)[b]
	66 years and above	35 (5.8)	1.86 (1.47–2.25)[ab]	29 (4.8)	2.53 (2.08–2.97)[ab]
Sex	Male	300 (49.8)	1.49 (1.39–1.60)[a]	312 (51.5)	2.15 (2.03–2.26)
	Female	302 (50.2)	1.71 (1.60–1.82)[b]	294 (48.5)	2.27 (2.15–2.39)
Place of living	Urban	125 (20.8)	1.65 (1.48–1.82)	123 (20.3)	2.41 (2.23–2.59)[b]
	Intermediate	205 (34.1)	1.60 (1.50–1.73)	202 (33.3)	2.18 (2.04–2.32)[ab]
	Rural	272 (45.2)	1.59 (1.49–1.70)	281 (46.4)	2.13 (2.02–2.26)[a]
Education	Lower	24 (4.0)	1.64 (1.25–2.03)	22 (3.6)	1.98 (1.54–2.42)
	Medium	308 (51.2)	1.56 (1.46–1.67)	279 (46.0)	2.11 (1.99–2.24)
	Higher	270 (44.9)	1.65 (1.53–1.77)	305 (50.3)	2.31 (2.19–2.42)
Financial status	Below average	137 (22.8)	1.36 (1.19–1.53)[a]	147 (24.3)	2.12 (1.94–2.77)
	Average	363 (60.3)	1.65 (1.55–1.75)[b]	361 (59.6)	2.22 (2.03–2.41)
	Above average	102 (16.9)	1.78 (1.59–1.98)[b]	98 (16.2)	2.26 (2.06–2.47)
Health status	Low	23 (3.8)	2.04 (1.64–2.44)	23 (3.8)	2.35 (1.93–2.77)
	Average	121 (20.1)	1.65 (1.47–1.83)	126 (20.8)	2.22 (2.03–2.41)
	High	458 (76.1)	1.57 (1.48–1.66)	457 (75.4)	2.19 (2.10–2.29)
Employment	Employed	375 (62.3)	1.63 (1.53–1.73)	383 (63.2)	2.16 (2.05–2.27)
	Unemployed	79 (13.1)	1.43 (1.19–1.68)	87 (14.4)	2.16 (1.88–2.43)
	Student	49 (8.1)	1.70 (1.40–2.01)	58 (9.6)	2.58 (2.26–2.88)
	Retired	99 (16.5)	1.64 (1.43–1.86)	78 (12.9)	2.19 (1.95–2.43)

Identified factors based on contrast of marginal linear predictions accounting for vitamin D-related knowledge: (1) April 2020 sample: $p < 0.01$ (age); $p < 0.01$ (sex), $p < 0.01$ (financial status), $p < 0.1$ (health status); (2) December 2020 sample: $p < 0.01$ (age); $p < 0.05$ (place of living), $p < 0.1$ (education), $p < 0.1$ (employment). Predictor levels not sharing the same superscript are significantly different at $p < 0.05$ using pairwise comparisons of predictive margins with Sidak's adjustment method.

Vitamin D Supplementation Practices

The penetration of the pre-COVID-19 vitamin D supplementation was 33.7%, and very similar also in the early stage of the COVID-19 pandemic in April 2020 (33.2%) (**Table 5**). Among those participants who reported the amount of vitamin D supplementation they took before the COVID-19 pandemic or during the pandemic in April, 58% did not report any change in their vitamin D supplementation practice, while 21% reported increased vitamin D dosage, and the same percentage (21%) reported reduced vitamin D dosage. Only few subjects reported using daily doses above 100 μg, exceeding the Tolerable Upper Intake Level (UL) of vitamin D (51). The mean pre- and mid-pandemic daily vitamin D supplementation, calculated after the exclusion of these subjects, was 31.0 and 32.2 μg, respectively. Median intake was 25 μg in both cases. Pre- and post-intervention distribution histograms of daily vitamin D dosages are presented in **Figure 3**. It should be noted that we excluded subjects, which did not report daily vitamin D dosage ($N = 41$ in pre-intervention and $N = 58$ in post-intervention), and that the first bar represent subjects taking <5 μg daily (including those not taking vitamin D).

As expected, the distribution is not normal; subjects were typically supplementing vitamin D with standardized pharmaceutical formulations, where most common vitamin D content is 25 μg (1,000 IU) per dosage (capsule, tablet,…) (52). More exact daily dosages are however also achievable if liquid formulations (such as oil drops) are used.

On the other hand, notably different supplementation practices were observed in the later phase of the COVID-19 pandemic, after the educational intervention. Analyses of the post-intervention dataset showed significantly higher penetration of vitamin D supplementation, in comparison to both April and pre-COVID-19 data (**Table 5**). Post-intervention proportion of vitamin D supplementation in December 2020 increased considerably for 65%, in comparison to pre-COVID data. While median intake of vitamin D was not changed (25 μg), daily vitamin D supplementation dosage significantly increased to 41.1 μg. Among participants who reported the amount of vitamin D supplementation before the pandemic, or during the December COVID-19 lockdown, 63% reported increased vitamin D dosage, while 20 and 17% reported no change or decrease of daily vitamin D dosage, respectively. The proportion of supplement users exceeding the UL of 100 μg Vitamin D daily was comparable with April 2020 (5%).

Further we investigated predictors of vitamin D supplementation using multivariable logistic regression analysis,

TABLE 4 | Assessment of intervention-related changes in vitamin D-related knowledge by age, sex, place of living, education, financial status, health status, and employment (analyses on $N = 373$ subjects, included in both April and December 2020 sampling).

Variables	Levels	*N* (%)	Subjects with increase[1] in vitamin-D related knowledge; *N* (%)	Odds ratio (CI)
Overall		373 (100)	274 (73.5)	
Age groups	66 years and above	27 (7.2)	21 (77.8)	1.21 (0.40–3.60)
	50–65 years of age	144 (38.6)	109 (75.7)	1.10 (0.56–2.18)
	36–49 years of age	117 (31.4)	82 (70.1)	0.86 (0.44–1.68)
	18–35 years of age	85 (22.8)	62 (72.9)	1
Sex	Female	177 (47.4)	135 (76.3)	1.36 (0.83–2.23)
	Male	196 (52.6)	139 (70.9)	1
Place of living	Urban	79 (21.2)	60 (76.0)	1
	Intermediate	124 (33.2)	95 (76.6)	1.08 (0.54–2.16)
	Rural	170 (45.6)	119 (70.0)	0.82 (0.43–1.57)
Education	Higher	178 (47.7)	128 (71.9)	5.36 (1.61–17.78)[b]
	Medium	181 (48.5)	141 (77.9)	6.34 (1.93–20.78)[b]
	Lower	14 (3.8)	5 (35.7)	1[a]
Financial status	Above average	60 (16.1)	40 (66.7)	0.71 (0.31–1.62)
	Average	225 (60.3)	170 (75.6)	1.08 (0.59–1.99)
	Below average	88 (23.6)	64 (72.7)	1
Health status	Low	13 (3.5)	10 (76.9)	1
	Average	81 (21.7)	55 (67.9)	0.46 (0.10–2.07)
	High	279 (74.8)	209 (74.9)	0.73 (0.17–3.14)

[1]*Increase in December 2020 vitamin D-related knowledge score, in comparison with April 2020 scoring. Three respondents showed no change in vitamin D related knowledge. Identified factors based on contrast of marginal linear predictions accounting for increase in vitamin D-related knowledge: $p < 0.01$ (education). Predictor levels not sharing the same superscript are significantly different at $p < 0.05$ using pairwise comparisons of predictive margins with Sidak's adjustment method. Area under receiver operating characteristic (ROC) curve: 0.62.*

focusing on age, sex, place of living, education, financial, and health status (**Table 6**). Analyses were done separately for pre-intervention (April 2020) and post-intervention (December 2020) samples. In the model, respondents were classified into two categories (respondents supplementing and not supplementing with vitamin D); model parameters were estimated by the maximum likelihood method. The only two significant predictors were financial and health status. In April 2020, the likelihood for supplementing vitamin D was higher for population with higher financial status and lower health status. Situation changed considerably after the educational intervention, in the December 2020 dataset. Health status was not a significant predictor for vitamin D supplementation anymore, while the financial status was marginally significant ($p = 0.07$). On the other hand, age appear as significant predictor, with the highest vitamin D supplementation rates in the elderly subjects.

To provide further insights into the connection between vitamin D supplementation practices and vitamin D-related knowledge, we used a modeling approach based on the logistic regression method (**Figure 4**). Two models were constructed to investigate the probability of vitamin D supplementation, using all six investigated dimensions of vitamin D-related knowledge. Model 1 examined pre-intervention vitamin D supplementation practices (April 2020), while Model 2 referred to post-intervention supplementation practices in December 2020. The analysis shows that the increase in vitamin D-related knowledge in three of the six dimensions significantly predicted the likelihood of vitamin D supplementation. The increase in knowledge about dietary sources of vitamin D was found significant predictor in post-intervention Model 2 (OR 2.88, 95% CI: 1.20–6.91, $p = 0.02$), while it was close to significant in pre-intervention model (OR 2.55, 95% CI: 0.98–6.65, $p = 0.05$). On the other hand knowledge about the health-related impact of vitamin D (OR 6.16, 95% CI: 2.89–16.56, $p < 0.001$ in pre-intervention, and OR 4.22, 95%CI: 2.36–7.56, $p < 0.001$ for post-intervention) and knowledge about prevalence of vitamin D deficiency in the population (OR 1.64, 95%CI: 1.10–2.44, $p = 0.02$ before the pandemic, and OR 1.56, 95% CI: 1.06–2.29, $p < 0.03$ during the pandemic) significantly increase the probability of vitamin D supplementation in both models.

DISCUSSION

Due to previously established high prevalence of wintertime vitamin D deficiency in populations not taking vitamin D supplements (30, 32–34), an educational intervention was conducted in Slovenia in November 2020, during COVID-19 pandemic. Objectives of this study were to investigate the voluntarily vitamin D supplementation practices, factors, that are affecting these practices, and to evaluate the effects of the educational intervention on vitamin D supplementation practices during the COVID-19 pandemic.

Interestingly, despite the very high prevalence of vitamin D deficiency in many countries, very few studies investigated the penetration of supplementation practices. While some countries introduced policies to implement vitamin D supplementation

TABLE 5 | Vitamin D supplementation practices before and during the COVID-19 pandemic.

Variables	Before COVID 19	During COVID-19 pre-intervention	During COVID-19 post-intervention
Number of subjects *N* (%)	602 (100)	602 (100)	606 (100)
Reporting Vitamin D supplementation *N* (%)	203 (33.7)[a]	200 (33.2)[a]	337 (55.6)[b]
Reporting daily vitamin D dosage *N* (%)	168 (27.9)	159 (26.4)	279 (46.0)
Daily vitamin D dosage [μg/day] (95% CI)*	31.0 (27.3–34.7)[a]	32.2 (28.1–36.2)[a]	41.1 (37.5–44.7)[b]
Std. Err.	1.9	2.1	1.8
Median	25	25	25
Subjects with vitamin D dosage above 15 μg/day; N (%)	125 (74.4)	124 (95.0)	231 (82.8)
Subjects with vitamin D dosage above 100 μg/day; *N* (%)	4 (2.4)	8 (5.0)	14 (5.0)

Before COVID-19 pandemic data and pre-intervention data were collected as part of April 2020 survey (N = 602).
**Daily vitamin D dosage was calculated based on the responses of participants who reported the amount of vitamin D supplementation they took before, and during the COVID-19 pandemic (April, December 2020). Different letters next to numbers denote significant difference determined with independent sample t-test and z-test for proportions.*

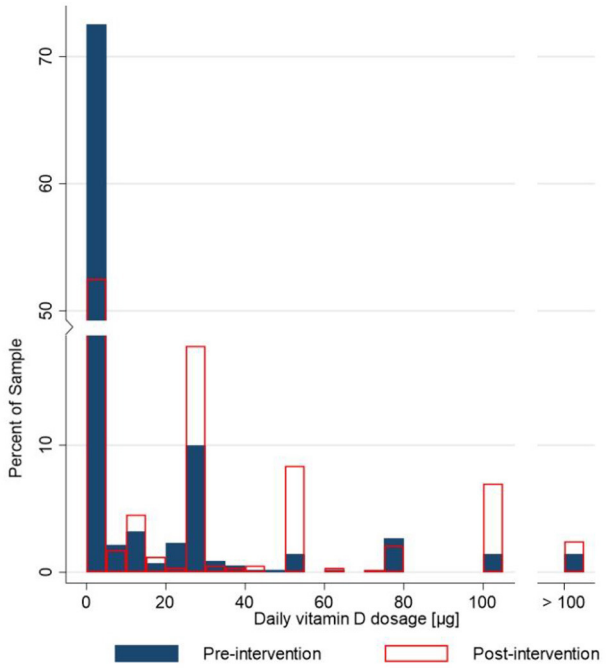

FIGURE 3 | Histogram of pre-intervention (*N* = 573; April 2020: blue) and post-intervention (*N* = 548; December 2020: red) daily vitamin D dosage (μg). The horizontal (x) scale uses daily vitamin D dosage, while the distribution in the population (% of the sample) is represented by the vertical bars. We excluded subjects reporting vitamin D supplementation, which did not report daily vitamin D dosage (*N* = 41 in pre-intervention and *N* = 58 in post-intervention).

in specific and more at-risk groups (i.e., children up to 12 months of age in Slovenia), supplementation is typically voluntary in the general population. Spiro and Buttriss (30) highlighted major differences in the use of food supplements across Europe, with a clear north–south gradient. Typically, intake of food supplements is higher in northern countries. Greater use of food supplements is also commonly reported in women in comparison with men (53). It has been established that, globally, dietary supplementation contributes 6–47% of the mean intake of vitamin D (32). In a recent UK study, 43% of participants (adults) used vitamin D supplements (41); however, the study sample mostly included females and was not representative. Nevertheless, similar penetration of vitamin D supplementation was reported in Pakistani students (42). On the other hand, a nationally representative French study reported the use of vitamin D supplements at a much lower level of 11% (40). Similarly, only about 9% of adults reported year-round vitamin D supplementation in a Slovenian nationally representative dietary Si.Menu/Nutrihealth survey, conducted in 2017/2018 (34). The same study also identified an alarmingly high prevalence of vitamin D deficiency (about 80%) in adults between the beginning of October and the end of April (extended wintertime), but the study design did not allow insights into the seasonal use of food supplements to be captured.

In April 2020, about one-third of our study sample reported extended wintertime vitamin D supplementation, and we did not observe considerable differences before and during the COVID-19 pandemic (33.7 vs. 33.2%, respectively). The observed greater penetration of vitamin D supplementation, in comparison with Si.Menu/Nutrihealth 2017/2018 data, can be partially explained by the fact that our measurements were done during the extended winter period when vitamin D supplementation is usually advised. Although at that time there were no official policy recommendations for vitamin D supplementation in the general population in Slovenia, this topic was addressed by the mass media in March 2020 (**Figure 1**), and greater penetration of the supplementation was expected during

TABLE 6 | The proportion of the population using vitamin D supplements during COVID-19 pandemic by age, sex, place of living, education, financial status, and health status: pre-intervention (April 2020) and post-intervention (December 2020) data.

Variables	Levels	Pre-intervention (April 2020)			Post-intervention (December 2020)		
		N (%)	Subjects supplementing Vitamin D; *N* (%)	Odds ratio (CI)	*N* (%)	Subjects supplementing Vitamin D; *N* (%)	Odds ratio (CI)
Overall		602 (100)	201 (33.4)		606 (100)	337 (55.6)	
Age groups	18–35 years of age	179 (29.7)	57 (31.8)	1	206 (34.0)	101 (49.0)	1[a]
	36–49 years of age	202 (33.6)	64 (31.7)	1.00 (0.64–1.56)	184 (30.4)	94 (51.1)	1.13 (0.75–1.70)[ab]
	50–65 years of age	186 (30.9)	66 (35.5)	1.19 (0.75–1.88)	187 (30.9)	121 (64.7)	1.95 (1.27–3.01)[b]
	66 years and above	35 (5.8)	14 (40.0)	0.71 (0.74–3.35)	29 (4.8)	21 (72.4)	2.66 (1.09–6.47)[ab]
Sex	Male	300 (49.8)	95 (31.7)	1	312 (51.5)	170 (54.5)	1
	Female	302 (50.2)	106 (35.1)	1.21 (0.85–1.73)	294 (48.5)	167 (56.8)	1.21 (0.86–1.69)
Place of living	Rural	272 (45.2)	85 (31.3)	1	281 (46.4)	152 (54.1)	1
	Intermediate	205 (34.1)	71 (34.6)	1.12 (0.75–1.66)	202 (33.3)	117 (57.9)	1.03 (0.71–1.51)
	Urban	125 (20.8)	45 (36.0)	1.19 (0.75–1.89)	123 (20.3)	68 (55.3)	1.00 (0.64–1.54)
Education	Lower	24 (4.00)	7 (29.2)	1	22 (3.6)	14 (63.6)	1
	Medium	308 (51.2)	96 (31.2)	1.04 (0.41–2.65)	279 (46.0)	154 (55.2)	0.54 (0.21–1.39)
	Higher	270 (44.6)	98 (36.3)	1.22 (0.47–3.14)	305 (50.3)	169 (55.4)	0.55 (0.21–1.43)
Financial status	Below average	137 (22.8)	34 (24.8)	1[a]	147 (24.3)	77 (52.4)	1
	Average	363 (60.3)	129 (35.5)	2.00 (1.24–3.22)[b]	361 (59.6)	201 (55.7)	1.47 (0.96–2.24)
	Above average	102 (16.9)	38 (37.3)	2.20 (1.18–4.09)[b]	98 (16.2)	59 (60.2)	1.91 (1.08–3.41)
Health status	High	458 (76.1)	146 (31.9)	1[a]	457 (75.4)	241 (52.7)	1
	Average	121 (20.1)	43 (35.5)	1.35 (0.86–2.13)[ab]	126 (20.8)	80 (63.5)	1.42 (0.91–2.21)
	Low	23 (3.8)	12 (52.2)	3.05 (1.26–7.40)[b]	23 (3.8)	16 (69.6)	2.16 (0.84–5.53)

Surveying was done during the first (April 2020) and second (December 2020) COVID-19 lockdown period. Vitamin D-related educational intervention was done between both measurements in November 2020. We identified predictors based on the contrast in marginal linear predictions accounting for vitamin D supplementation: p = 0.01 (financial status), p = 0.03 (health status) for pre-intervention sample; p < 0.01 (age), p = 0.07 (financial status) for post-intervention sample. Predictor levels not sharing the same superscript are significantly different using pairwise comparisons of predictive margins with Sidak's adjustment method. Area under receiver operating characteristic (ROC) curve: Pre-intervention: 0.60; post-intervention: 0.62.

COVID-19 lockdown in April 2020. At that time some mass media reports were published (44) about the importance of this vitamin for the functioning of the immune system, and about the possible beneficial role of vitamin D during the COVID-19 pandemic. However, there were no notable changes in the prevalence of vitamin D supplementation, or the daily dosages of vitamin D.

A very different situation was observed during the second wave of the COVID-19 pandemic, which affected Slovenia much harder in a greater manner. It should be noted that at the launch of the April 2020 survey, there were cumulatively 1,366 COVID-19 cases and 79 deaths reported in Slovenia, while in December there were already had 95,479 COVID-19 cases and 2,041 deaths (54). This also affected our study. In April 2020 survey, about 9% of participants reported that their household was somehow affected by COVID-19 (i.e., due to illness or quarantine of household member), while in December 2020 this was the case in 25% of subjects (**Table 1**). Furthermore, April 2020 mean score for the reported likelihood of a household member becoming infected with the virus was notably lower (score 2.2/5) in comparison with December 2020 measurement (score 2.7/5). Also, the December 2020 survey was conducted after the educational intervention. A press release (46) about the wide prevalence of vitamin D deficiency in the Slovenian population (34) was sent to all major mass media at the beginning of November 2020, which received a lot of media attention (**Figure 1**).

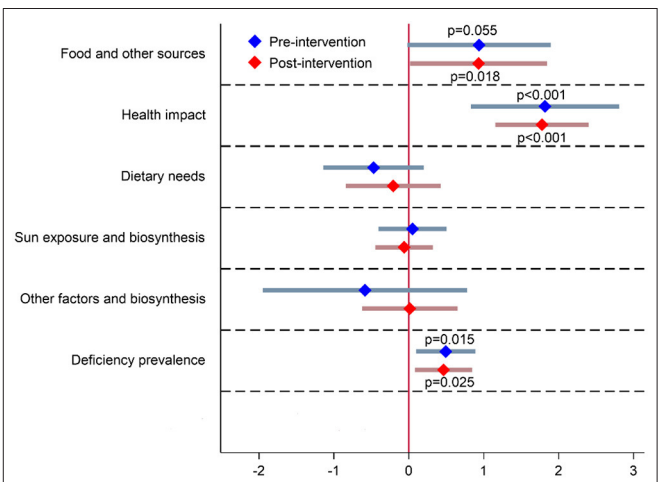

FIGURE 4 | Logistic regression analysis for distinct dimensions of vitamin D-related knowledge in pre-intervention (Model 1: April 2020) and post-intervention (Model 2: December 2020) prevalence of vitamin D supplementation. Area under receiver operating characteristic (ROC) curve: 0.66 (pre-intervention) and 0.67 (post intervention).

Analyses of the December 2020 dataset showed that penetration of dietary supplementation with vitamin D increased to 55.6% (from 33.7% in April), with the majority of supplement users taking a daily dosage of at least 25 μg vitamin D. The proportion of subjects with very high vitamin D intakes (above UL level of 100 μg/day (51) increased during the pandemic, however about 95% of those supplementing vitamin D were still within safe intake levels (<100 μg/day). Nevertheless, the observation that, in some subjects, vitamin D intakes increased drastically during the pandemic highlights the need for very careful communication of vitamin D supplementation practices in relation to specific health-related events, such as the COVID-19 pandemic. It should be also noted that we recently investigated most commonly consumed Vitamin D supplements in the Slovenian population (52). We analyzed 24 food supplements, which were purchased on the market. Median labeled vitamin D (cholecalciferol) content was 25 μg and results of laboratory analyses confirmed expected amount of vitamin in majority (92%) of samples.

Vitamin D supplementation in the general population is likely to stay voluntarily in most countries. To use dietary supplementation as a strategy for lowering the risk of vitamin deficiency in such circumstances, very efficient public awareness programs would need to be implemented. In this study, we therefore focused on the identification of predictors of vitamin D supplementation practices. In April 2020 the most important predictors of vitamin D supplementation were the financial and health status of the participants, and specific dimensions of individual vitamin D-related knowledge. Multivariable logistic regression analysis highlighted the highest odd ratios for vitamin D supplementation in participants with a lower health status and in those with a higher financial status. In April 2020, only 33% of subjects used vitamin D supplements, while in the low health status group this was the case in 52%, and in the below-average financial status group in 25%. This indicates that the lowest supplementation rates were observed in those, who would probably need the supplementation the most. These observations are in line with our expectations that persons with higer financial status can more easily afford to purchase food supplements and that those with a lower self-reported health status more commonly used supplements. Interestingly, we did not observe significant differences between different sexes and age groups, although we would expect a higher penetration of supplementation in older adults (where vitamin D deficiency is commonly more pronounced), and in women, who are typically more frequent users of food supplements (42). But the situation changed after the educational intervention; in December 2020 dataset age became the only strongly significant ($P = 0.01$) parameter, with the highest supplementation rates in elderly subjects (72%). It should be also noted, that 52% of participants in the lower financial status group reported vitamin D supplementation. Study results are indicating that we managed to considerably increase vitamin D supplementation across different population groups, including in the most vulnerable groups, such as the elderly population.

Similar to the observations of O'Connor et al. (41) in the UK and of Boland et al. (39) in Canada, subjects with better vitamin D-related knowledge are more likely users of vitamin D food supplements. Looking into different dimensions of vitamin D-related knowledge, logistic regression analysis highlighted three dimensions as independent predictors of vitamin D supplementation.

- (Q1) Dietary vitamin D sources: only a few foods are natural sources of vitamin D, and therefore dietary intake of vitamin D is typically very low (35). It seems that those who know that their diet is typically very poor in vitamin D are more likely to use vitamin D supplements.
- (Q2) Vitamin D health impact: vitamin D is a pro-hormone and is essential for musculo-skeletal health, normal immune system, and numerous other body functions (1–3). People that are more aware of these health-related functions are more likely to supplement their diet with vitamin D.
- (Q6) Prevalence of vitamin D deficiency: there is a very high prevalence of vitamin D deficiency in the population, particularly during the winter season (34). Those that were aware of this fact can more easily consider themselves as at risk for vitamin D deficiency and are more likely to use vitamin D supplements. We should also note the previously reported strong inconsistency between personal opinions about vitamin D status and actual vitamin D status (40).

Interestingly, some vitamin D knowledge dimensions were not significantly connected to supplementation practices. For instance, knowledge about the (Q3) recommended daily amount of vitamin D, about the (Q4) time needed in the sun to get enough vitamin D, and about (Q5) factors that affect the skin's biosynthesis of vitamin D were not independent predictors of vitamin D supplementation. This was noted both in pre- and post-intervention surveys. The above-mentioned observations are very important for the preparation of key messages that need to be well communicated if we want to increase vitamin D supplementation in the general population.

Our study also provides interesting insights into the overall knowledge about vitamin D in the Slovenian population. Knowledge was scored using a tool developed by Boland et al. (39). The original questionnaire was tested on Canadian students; the results showed poor knowledge and highlighted the need for more efficient health promotion programs. The reported mean total score in the Canadian study was 29%, while in our case it was 27% (1.60/6) before the intervention, and 37% (2.21/6) after the educational intervention. Knowledge about factors affecting vitamin D levels were also comparably low both in the Canadian study and in our pre-intervention April 2020 study (23%), but in our case this score increased to 45% after the educational intervention. On the other hand, in April 2020 we observed notably lower scores for vitamin D health impact than in the Canadian study (26 vs. 37%, respectively), but this factor also notably improved after the intervention (40%). Contrary, about a quarter of our participants (both in pre- and post-intervention survey) correctly identified the amount of time in the sun required to produce adequate vitamin D (only 14% in the Canadian study), while, in both studies, <10% identified the correct recommended vitamin D intakes. It should be noted that other studies also identified serious vitamin D-related

knowledge gaps in various other populations. Deschasaux et al. (40) investigated vitamin D-related knowledge in a very large study in France, highlighting several knowledge gaps related to vitamin D sources and (non-skeletal) health effects. Tariq et al. recently investigated the vitamin D knowledge in Pakistani students (2020). Only 9% of study subjects correctly identified dietary sources of vitamin D, while one-third were aware of the bone health-related effects of vitamin D, and only 36% identified sunlight exposure as a factor influencing vitamin D production. Interestingly, they also observed that those with more knowledge about the health functions of vitamin D were more likely to use vitamin D supplements. We should note, however, that there were considerable differences in the tools used for measuring vitamin D-related knowledge in these studies.

The strength of this study is in the controlled sampling conducted in two short duration periods during very early (April 2020) and late stage (December 2020) of the COVID-19 pandemic. While the use of an online panel could be considered as a study limitation, we should mention that considering pandemic-related restrictions, the use of an online study was the only option in practice. Both data collections were done during national lockdowns when all schools and universities were closed, non-essential workplaces in the public sector were closed, and the private sector was recommended to close or restrict the number of people working; personal movement was restricted to within one's municipality and operation of the public transport was limited. While food stores and pharmacies were open, non-essential stores were mostly closed. There was governmental advice in place to stay at home and to limit contact with others, while gatherings in public places were limited. We should note that, for some people, these circumstances might have limited the access to vitamin D supplements during the COVID-19 pandemic. The quota sampling approach enabled a fair balance between the genders, age groups, and urban and rural areas. However, the approach used is also subject to limitations. The requirements for computer/smartphone use and internet access denied the inclusion of participants of the lowest socio-economic status. On the other hand, Slovenia has a very good internet infrastructure, and most households use computers. According to data from the Slovenian Statistical Office, more than 80% of the Slovenian population (16–74 years) is using internet (55). Also, home-schooling was in place in Slovenia during COVID-19 lockdowns for all elementary/secondary schools and universities, with online lectures. Nevertheless, the sampling approach may partially explain the difficulties in achieving representativeness in the study samples in the terms of educational level.

Another limitation is related to the vitamin D-related knowledge survey used. To provide some international comparability, we used a tool that was previously tested on Canadian students (39), but has not been validated or used in other subject groups. Despite the above-mentioned limitations, the authors believe that the tool used provided reliable predictors of vitamin D supplementation practices. We should also note that some of the study subjects participated both in April and December 2020 data collections. While this strengthens our study, because enabled us to investigate changes in the same subjects, such sampling could also present a limitation. Although study surveys were not conducted in a way to increase vitamin-D related knowledge or to affect vitamin D supplementation practices in study participants, survey questions brought vitamin D topic under attention. A series of control checks were therefore performed to verify, if this had any meaningful effect on the reported study results. For example, we have compared mean vitamin-D knowledge scores in the second survey (December 2020) between new subjects ($N = 233$), and those that already participated in April 2020 survey ($N = 373$), but no significant differences were observed. Furthermore, we compared December 2020 vitamin D supplementation prevalence in both these two groups. No meaningful differences were observed; in both groups vitamin D supplementation rates were above 50%, and median daily vitamin D intake was 25 μ. Therefore, we believe that the reported results were not majorly affected by exposing subjects to vitamin D topics.

CONCLUSIONS, POLICY, AND RESEARCH RECOMMENDATIONS

While most foods are generally quite poor in vitamin D, they can assure adequate intake of this vitamin, particularly in regions with efficient food fortification policies (32). However, in regions without such policies, a considerable proportion of the population is at risk for insufficient vitamin D status, which could be managed with supplementation. Findings of our study suggest that at beginning of 2020 most of the Slovenian population did not supplement their diet with vitamin D, despite the fact that previous studies indicated alarmingly high vitamin D deficiency prevalence between October and April. While we did not observe notable changes in vitamin D supplementation practices early in the COVID-19 pandemic (April 2020), in comparison to pre-COVID-19 observations, a very successful educational campaign using mass media resulted in a major increase in frequency of winter-time vitamin D supplementation. Pre-intervention study highlighted financial status as an independent predictor of vitamin D supplementation, with those with a below average financial status having the lowest penetration of vitamin D supplementation. This indicates that the financial dimensions of vitamin D supplementation also need to be considered by policy makers to ensure the protection of vulnerable groups.

Vitamin D-related knowledge was also found to be a key predictor of dietary supplementation, with some knowledge dimensions being more important than others. The three key dimensions identified as predictors of more likely vitamin D supplementation are knowledge about dietary sources of vitamin D, the health-related impact of vitamin D, and the prevalence of vitamin D deficiency in the population. Considering the study findings, the following key messages would need to be embedded into awareness campaigns in order to increase supplementation with vitamin D:

(a) Vitamin D can be biosynthesized by human skin when we are sufficiently exposed to sunlight, but such biosynthesis is efficient only between May and September (Note: this is geolocation-related information reflecting the situation in Slovenia).
(b) In the absence of efficient biosynthesis, enough vitamin D needs to be provided by the diet. However, only oily fish

and a few other foods are notable natural dietary sources of vitamin D. Therefore, the typical dietary intake of vitamin D with natural foods is much lower than recommended intake for the normal functioning of the human body.

(c) Vitamin D has numerous health functions. It also contributes to the maintenance of normal bones, muscle function, and the function of the immune system.

(d) In particular, between October and April, there is a very high prevalence of vitamin D deficiency in the population (Note: this is nationally specific information reflecting the situation in Slovenia).

These key messages were constructed based on our preliminary results, using April 2020 sampling, and used in the populational educational intervention in November 2020. Herein reported study results showed that the intervention was very efficient, however long-term effects are yet to be determined in future seasons. Additional studies are therefore needed in the future, preferably in a similar calendar season—during the winter. If vitamin D supplementation practices will change in long term, epidemiological data on vitamin D status in key population groups should be also revisited. It should be noted that the above provided communication messages result from data collected in the Slovenian population. While very similar messages might also be applicable in other regions, they should be adapted to address regional and population differences. The efficiency of awareness campaigns should be always carefully evaluated.

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 Bioethical committee at the Higher School of Applied Sciences in Ljubljana, Slovenia. The participants provided their informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

IP and KŽ conceived the study. IP, KŽ, MH, and AK designed the study questionnaire. KŽ, HH, and IP analyzed and interpreted the data. MH and ŽL supported with the data analyses, and HH conducted the statistical analyses. KŽ wrote the first manuscript draft and all authors then made revisions. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

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Conflict of Interest: IP and KŽ are members of a national workgroup responsible for the development of recommendations for assuring adequate vitamin D status among the Slovenian population.

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Energy Balance-Related Behavior Risk Pattern and Its Correlates During COVID-19 Related Home Confinement

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Self-reported weight gain during the COVID-19 shelter-at-home has raised concerns for weight increases as the pandemic continues. We aimed to investigate the relationship of psychological and health markers with energy balance-related behaviors during the pandemic-related extended home confinement. Ratings for stress, boredom, cravings, sleep, self-control, and beliefs about weight control were collected from 1,609 adults using a questionnaire between April 24th–May 4th, 2020, while COVID-19 associated shelter-in-place guidelines were instituted across the US. We calculated four energy balance behavior scores (physical activity risk index, unhealthy eating risk index, healthy eating risk index, sedentary behavior index), and conducted a latent profile analysis of the risk factors. We examined psychological and health correlates of these risk patterns. Boredom, cravings for sweet/savory foods, and high sleepiness ratings related to high risk of increasing unhealthy eating and sedentary behavior and decreasing physical activity and healthy eating. Having greater self-control, control over cravings, or positive mood was related to lowering all aspects of energy intake and energy expenditure risks. Although individuals in risk pattern classes showed similarity in physical activity and healthy/unhealthy eating habits, they exhibited different patterns of positive mood, craving control, food cravings, boredom, and self-control. Psychological and health variables may have a significant role to play in risk behaviors associated with weight gain during the COVID-19 related home confinement. Emerging behavioral patterns may be meaningful in developing targeted weight management interventions during the current pandemic.

Keywords: COVID-19, energy balance, eating behaviors, physical activity, psychological factors

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INTRODUCTION

In March 2020, the novel severe acute respiratory distress coronavirus 2 (SARS-CoV-2) infection emerged as a global COVID-19 pandemic. As a consequence, widespread shelter-at-home was implemented in the US to prevent the spread of this infection, primarily between March 15th and May 7th, 2020. This public health action markedly disrupted everyday activities and increased unstructured time for people, making weight management a concern (1–3) frequently referred to

on social media as "Quarantine 15," "gaining the COVID-19," or "fattening the curve." Indeed, we and others recently showed that 19–28% of adults self-reported gaining 5–10 pounds of body weight during the self-quarantine (3–5). These self-reported weight increases are of concern because literature on holiday weight gain suggests that fluctuations in body weight in a relatively short period can become permanent and lead to a substantial weight gain over decades (6–9). Thus, it is imperative to understand *for whom* self-reported changes in energy balance behaviors categories have a potential to contribute to weight increases during the brief period of lockdown, mainly healthy and unhealthy eating, and physical and sedentary activities.

With shelter-at-home restrictions and inability to practice normal life, numerous possible challenges can affect energy intake and energy expenditure, the two components of energy balance. With regards to energy intake behaviors, COVID-19 disruptions may have introduced multiple influences on people's dietary behaviors which may have produced increased unhealthy eating and/or healthy eating. In particular, during the lockdown people had easy access to snacks and craving inducing energy dense convenience foods (10, 11) and showed greater interest in cooking/baking high-calorie foods (12). Stockpiling and consumption of shelf stable ultra-processed food intake was also frequent (13, 14). Interestingly, increased intake of healthy foods was also reported by many adults (5, 11), possibly due to greater opportunities for cooking at home and a decline in intake if restaurant meals. Attributed to social isolation and restrictions, a decline in physical activity and greater engagement in sedentary behavior, such as increased screen time, has also been reported (11, 15–17). Considering that two-thirds of the US adult population is overweight or obese, it is critical to understand the impact of COVID-19 on energy balance-related behaviors and identify which individuals are most susceptible to altering these behaviors.

COVID-19 lockdown and related social distancing drastically impacted the life of people in the US. People lost their jobs and shifted to work from home schedule while actively taking care of family and dealing with the fear of infection. Travel, social life, and leisure activities were also severely restricted, unlike prior to pandemic. These major life adjustments were accompanied by severe physiological and psychological costs, as reported in multiple studies. In particular, the recent lockdown caused dramatic increases in these state-like psychological variables, such stress, anxiety, low-sleep quality etc. (18–21). Boredom is another psychological consequence of the interruption to work and social routines, which was evident with SARS outbreak related quarantine in 2003 (22), and possibly with the current lockdown. These state-like psychological variables have been known to correlate with greater energy intake (23), more screen time, and low energy expenditure (24). Similarly, stress (25) and high sleepiness (26) are known to promoting cravings for energy-dense foods. Since these state-like psychological variables relate to energy balance behaviors, we expected they might be relevant to explore during COVID-19 lockdown.

Abbreviations: BMI, Body mass index; Mturk, Amazon Mechanical Turk; CoEQ, The Control of Eating Questionnaire.

With regards to the trait-like psychological variables, some of these factors are known to be known to be protective toward these extreme behavioral alterations. For example, lack of self-control (27, 28) and a lack of belief that body weight can be personally controlled (29, 30) are both part of people's motivational systems and influence self-regulatory processes and goal achievement. Not surprisingly, both are also related to food consumption and other weight management behaviors. Therefore, having these psychological traits may counter the possible negative impact of shelter-at-home on energy intake and expenditure behaviors, and adherence to a healthy and active lifestyle requires self-control and beliefs that body weight can be personally controlled (31). While we recently show self-reported shifts in energy intake and energy expenditure behaviors during the COVID-19 shelter-in-place period using cross-sectional survey data (11), whether these trait-like psychological factors will have a similar protective affect toward energy balance-related behaviors during the COVID-19 lockdown, is of great importance.

Overall, this study aimed to investigate the relationship between relevant demographic characteristics, state- and trait-like psychological markers and energy balance-related behaviors, during the pandemic-related shelter-in-place. Specifically, we examined associations between stress, boredom, cravings, sleep, self-control, BMI, and beliefs about weight control. In addition, we evaluated differences in risk behaviors between demographic groups. Using a Latent Profile Analysis, we also aimed to identify and characterize patterns of health behavior change during the pandemic. We hypothesized that sleep time and quality, craving control, self-control, and beliefs that one can control their weight would be negatively associated with energy balance-related behaviors during the pandemic. In contrast, we expected that boredom, stress, and food cravings would be positively associated with energy balance-related behaviors during the pandemic.

METHODS

Study Design

The study design has been described in full detail elsewhere (11). Briefly, we conducted a cross-sectional study where a convenience sample of U.S. adults completed an online survey delivered using Qualtrics (Qualtrics® Software Company Provo UT and Seattle WA). All participants provided online consent before proceeding to complete the questionnaire. The Institutional Review Board at San Diego State University approved the study.

Participants

We recruited 1,779 men (43.38%) and women (56.62%) between the age of 18 and 75 years. Inclusion criteria included: (1) access to the internet, and (2) living in the U.S. The questionnaire was administered through Amazon Mechanical Turk (Mturk, © 2005–2018, Amazon Mechanical Turk, Inc., Seattle, WA) ($n = 1{,}267$), a web service that enables researchers to survey the target population across the US (32). MTurk's workforce tends to be younger, educated, underemployed, with an equal distribution of males and females, a high percentage of Caucasians and Asians, and household incomes below the average US population (33,

34). We also collected data via social media, email, and word of mouth ($n = 511$). With these recruitment methods, we not only targeted the general population but also targeted support groups with persons of higher education on Facebook and Twitter. These two recruitment methods allowed us to include data from a diverse population.

A small compensation ($1.66) was given to eligible participants completing the survey through Mturk. This amount was estimated based on the minimal amount required to complete a similar survey and in line with the median hourly wage earned by an MTurk responder. Participants recruited via social media, email, and word of mouth volunteered to complete the survey and did not receive any monetary compensation. Of note, while the participation using this recruitment method was completely voluntary, it is possible that the compensation offered to Mturk workers for completion of survey may have been a motivational factor for them to participate in our study.

Participant recruitment and data collection occurred during the 11 days from April 24th, 2020 to May 4th, 2020, while shelter-in-place guidelines were instituted across the US. Of the 1,779 participants who initially responded to the call to complete the questionnaire, 1,609 participants were included in the data analysis. Of the 170 people excluded from the analysis (MTurk $n = 112$, Self-promotion $n = 58$), $n = 116$ failed to complete any questions related to behavioral and psychological variables, or analysis, or complete any the questionnaire or answer essential questions, or failed to respond to more than 2 attention check questions. Four attention check questions and one subjective question that asked participants to type a response in a text box were included to ensure responses were not bots. To assess the quality of participant responses, we also asked them to type their height (inches) and weight (pounds) in a text box, and any biologically implausible responses were excluded. Participants with missing body mass index or biologically implausible body mass index of <15 or BMI $\geq$ 57 kg/m^2, calculated from self-reported height and weight were also excluded.

Questionnaire

The Qualtrics questionnaire included the following 7 item categories: demographics, weight behaviors, sleep, and other health behaviors, eating behaviors, physical activity behaviors, psychological factors, and food purchasing behaviors. Questions within these categories were aimed at understanding change in practices and beliefs during the COVID-19 shelter-at-home. Similar to other studies, we asked whether these practices "increased," "decreased," or "stayed the same" during the COVID-19 shelter-at-home (35, 36). Based on the Qualtrics recordings, participants completed the survey in ∼25 min. Cronbach's alpha, a measure of internal consistency reliability with higher values suggesting higher reliability, is indicated for each scale measure where applicable.

Measures

Eating Behavior Measures

Eating behaviors were determined by asking participants if their consumption of the following items increased, decreased, or remained the same during COVID-19 shelter-in-place: fruits (during meals), vegetables (during meals), caffeine, non-diet drinks (includes, Coke, Pepsi, flavored juice drinks, sports drinks, sweetened teas, coffee drinks, energy drinks, electrolyte replacement drinks), and diet soda and other diet drinks. To determine change in consumption of processed and ultra-processed foods, we presented a list of foods as described by the NOVA classification system (37). This system classifies all foods into 4 groups based on the extent and purpose of industrial processing as following: unprocessed foods, processed culinary ingredients, processed foods, and ultra-processed foods (37). NOVA is a food classification system most applied in the scientific literature to identify and define ultra-processed foods (38). Ultra-processed foods are described as pre-prepared ready-to-heat products including pies and pasta and pizza dishes; poultry and fish "nuggets" and "sticks," sausages, burgers, hot dogs, and other reconstituted meat products; and powdered and packaged "instant" soups, noodles, and desserts. We also collected information on the change in the following snack foods: cake, cookie, ice-cream, other desserts; chips, popcorn, pretzels, and crackers; gummy snacks, fruit candy, sour gummy, or other fruity candies; fruit; vegetables; chocolate; yogurt/cheese. Change in consumption of take-out food and alcohol intake was also recorded. Since no validated tool is available collect information of perceptual change in dietary behavior, a validated tool was not used to collect this data.

We also collected information on the change in consumption of snack items (cake, cookies, ice-cream, other desserts; chips, popcorn, pretzels, and crackers; gummy snacks, fruit candy, sour gummy, or other fruity candies; fruits; vegetables; chocolate; yogurt/cheese). Change in consumption of restaurant/take-out/fast food/delivery food and alcohol intake was also recorded. We did not collect data on quantities consumed for the specific food items using the traditional methods of self-reported dietary data collection because they are prone to reporting errors and appears to underestimate energy and nutrient intake (39, 40).

Physical Activity and Sedentary Measures

Change in sitting, walking, moderate physical activity, and vigorous physical activity during the COVID-19 outbreak in their area were assessed using "I am doing more," "I am doing the same," and "I am doing less" options. Change in sedentary behaviors was determined by asking questions on change in time spent on watching television, social media, or other leisurely activities such as video games, computer, email etc. since COVID-19 outbreak. Given the lack of validated questionnaires to capture the perceptual change in behaviors, we developed and used face-valid items for both the physical activity and eating behavior measures. We intentionally wrote these items to target if the energy balance behaviors "increased," "decreased," or "remained the same" to capture self-reported change.

The Control of Eating Questionnaire (CoEQ)

The validated CoEQ comprised 21 items and included questions on general appetite and overall mood (independent of craving), frequency and intensity of general food craving, craving for specific foods (e.g., dairy, starchy, sweet, or non-sweet foods), and individuals' perceived control over resisting craved food items.

Participants responded about their experience over the previous seven days. These items were assessed using a 10-point visual analog scale (VAS). Subscales created form the questionnaire were used to calculate scores for: craving control, craving for sweet foods, craving for savory foods, and positive mood (41) and their α's were 0.91, 0.73, 0.78, and 0.75, respectively.

Sleep Duration and Sleep Quality

To assess sleep duration, participants were asked to report the average number of hours spent sleeping per day since the COVID lockdown in their area. To quantify sleep quality, we used the Stanford Sleepiness Scale (42) to collect ratings on how sleepy participants felt after waking up in the morning since the COVID lockdown in their area. This scale uses a 7-point rating scale to quantify a participant's sleepiness at the moment, where 1 is labeled "Feeling active and vital; alert; wide awake" and 7 is labeled as "Almost in reverie; sleep onset soon; lost struggle to remain awake. Higher values indicate greater sleepiness.

Multidimensional State Boredom Scale

The Multidimensional state boredom scale (43) was used to collect information on boredom during the COVID lockdown. This scale uses eight items to assess boredom in the present moment on a scale of 1 (*strongly disagree)* to 7 (*strongly agree)*. However, to capture boredom during the pandemic, we reframed each item by adding the phrase "since the COVID lockdown in my area" at the end of each statement (e.g., Time is passing by slower than usual, since the COVID lockdown in my area). Higher score indicated higher boredom during the lockdown. The scale has been used in a similar manner by others to measure boredom during the pandemic (44). Internal consistency of the items was high ($\alpha = 0.91$).

Stress

All participants reported report their current stress levels using a visual analog scale. The scale ranged from 1 through 10, with 1 = no stress at all and 10=highest stress possible.

Capacity for Self-Control Scale

The Capacity for Self-Control Scale (45) assesses individual differences in the ability to exercise three forms of general self-control: self-control by inhibition (i.e., the ability to override a pull toward goal-inconsistent behavior), by initiation (i.e., the ability to override a push toward goal-inconsistent behavior), and by continuation (i.e., the ability to continue initiation or inhibition as a self-control challenge in ongoing). The abbreviated measure consists of 9 items (3 items per subscale) scored on a five-point Likert scale, from 1 (*hardly ever*) to 5 (*nearly always*). Responses to the scale items were reverse scored as appropriate and averaged ($\alpha = 0.86$). Higher score indicates greater capacity for self-control trait.

Implicit Theory of Weight Measure

The Implicit Theory of Weight Measure (29) assesses the degree of orientation toward incremental beliefs of weight (i.e., beliefs that body weight is malleable). The measure consists of 6 items scored on a seven-point Likert scale from 1 (*strongly agree)* to 7 (*strongly disagree*). Responses to the scale items were reverse scored as appropriate and averaged ($\alpha = 0.82$); higher scores indicate a higher degree of entity beliefs (i.e., beliefs that body weight is not malleable).

Data Analysis

SAS version 9.4 (Cary, NC) and MPlus version 8.0 with Mixture software (46) were used for statistical analysis, and significance was set two-tailed at $p < 0.05$. We then calculated scale intercorrelations between psychological and health risk/protective factors. We created four energy balance behavior scores reflecting positive energy balance using the items on the Qualtrics survey administered. Items used to estimate a high-sedentary behavior score included change in television watching, change in screen time, and change in sitting time. Items used to estimate a low-physical activity behavior score included change in walking time, change in vigorous physical activity, and change in moderate physical activity. A high-unhealthy eating behavior score was calculated using responses on the soda, processed foods snacks, ultra-processed foods, snacking on sweets, snacking on chips/salty foods, snacking on gummy/fruity candies, snacking on chocolate, drinking alcohol, and eating takeout/fast food. The low-healthy eating behavior score was calculated using responses on fruit and vegetable consumption as snacks or in general during meals. All behaviors included in development of a priori energy balance behavior scores have been extensively reported to contribute to positive energy balance or negative energy balance (see **Supplementary Material**).

For change in each behavior related to energy intake or energy expenditure, we assigned scores to responses "I am doing more," "I am doing the same," and "I am doing less" such that, 1 = healthy change, 2 = no change, and 3 = unhealthy change. The α's for high-sedentary behavior score, low-physical activity behavior score, high-unhealthy eating behavior score, and low-healthy eating behavior score were 0.54, 0.63, 0.74, and 0.86, respectively. Note that scores on low-physical activity behavior and low-healthy eating behavior were calculated such that higher scores reflected less physical activity and less fruit and vegetable consumption.

We first conducted ANOVAs to test differences of health-risk behaviors between demographic groups. We then calculated intercorrelations between energy balance behavior scores and health and psychological risk and protective factors. We then characterized item level changes (increased, decreased, or stayed the same) for each health/psychological risk factor (see **Supplementary Material**). We further conducted a Latent Profile Analysis (LPA) to identify and characterize patterns of health behavior change during the pandemic. LPA is a data-driven approach used to uncover relationships among individuals to create meaningful groups (or classes) of people based on the heterogeneity of their responses; these classes can then be characterized and compared to each other using important demographic, psychological, and behavioral factors (47). Classes of people determined by LPA have been used to describe distinct differences in cognition and behavior among people with regard to a variety of physical and mental health phenomena, such as alcohol use, sleep, occupational stress, resilience, coping strategies etc. (48–50). In the current work, we used LPA to reveal

different classes of people's health-risk behaviors during the COVID-19 pandemic shelter-at-home. We then compared the classes on psychological, behavioral, and demographic qualities to provide comprehensive representations of various groups of people's characteristics, thoughts, and behaviors during the COVID-19 pandemic shelter-at-home. This analysis does not focus on the amount of change within one behavior but instead looks at patterns of change (i.e., increase, decrease, stays the same) across multiple behaviors.

RESULTS

Risk Behaviors by Demographic Groups

ANOVAs were conducted to evaluate differences of risk behaviors between demographic groups. Participants' scores for four energy balance behavior scores are presented for each demographic variable in **Table 1**. Briefly, the score for increasing sedentary behavior was significantly higher among women (vs. men; $p < 0.001$), Asians (vs. White people, Black people, and people who identified as "other" racial category; $p = 0.015$), unmarried (vs. married; $p < 0.001$) participants, and younger (18–39 years old vs. 40+ years old; $p < 0.001$) participants. The score for low-physical activity was significantly higher among Asians (vs. White people, Black people, and people who identified as "other" racial category; $p < 0.001$), unmarried (vs. married; $p < 0.001$) people, and among people in the lowest annual income bracket (< \$30,000 vs. \$30,000+; $p = 0.009$). The score for high-unhealthy eating was significantly higher among women (vs. men) and people in the highest annual income bracket (> \$90,000 vs. < \$90,000; $p = 0.027$), while the score for low-healthy eating was significantly higher among White people (vs. Asian people, Black people, and people who identified as "other" racial category; $p = 0.039$).

Correlations Between Psychological and Health Risk/Protective Factors

Scale intercorrelations were calculated to highlight associations between psychological and health risk and health protective factors. Correlations are shown in **Table 2**. A high level of boredom was associated with lower self-control ($p < 0.01$), positive mood ($p < 0.001$), and control of cravings ($p < 0.001$) and with higher beliefs about weight control ($p < 0.001$), cravings for sweet and savory foods (p's < 0.001), sleepiness ($p < 0.001$), and stress ($p < 0.001$). Higher self-control was associated with lower beliefs about weight control ($p < 0.001$), cravings for sweet and savory foods (p's < 0.001), sleepiness ($p < 0.001$), and stress ($p < 0.001$) and with higher positive mood ($p < 0.001$) and control of cravings ($p < 0.001$).

Latent Profile Analysis

Next, we conducted a LPA to characterize classes of participants' patterns of risky health behaviors during the COVID-19 pandemic using composite variables for physical activity, sedentary behavior, healthy food consumption, and unhealthy food consumption. A model with four classes demonstrated the best fit with the data, Log Likelihood (LL) = −3744.75, degrees of freedom (df) = 23, Aikake Information Criterion (AIC) = 7535.49, Bayes Information Criterion (BIC) = 7659.10, Sample-size adjusted BIC (ABIC) = 7586.03, Entropy = 0.826. The classes' patterns of endorsed risky health behaviors are shown in **Figure 1**.

Examining the characteristics of participants in all risk profiles (**Table 3**), individuals in the highest risk class (Class 4; 10.6% of the sample) had the highest levels of risk across all four indices ($p < 0.001$). They also reported being sleepier upon waking up ($p < 0.001$), being more bored ($p < 0.001$), having less self-control ($p < 0.001$), having less positive mood ($p < 0.001$), and having more cravings for sweet/savory foods ($p < 0.001$). Participants in the low-risk category (Class 3; 5.02% of sample) were generally similar to the medium risk classes, with one exception–they reported having lesser beliefs about the role of personal effort in weight maintenance than did participants in other groups. Classes 1 (43.35% of the sample) and 2 (41.03% of the sample) both reported generally medium-to high risk with one key behavioral difference: Class 2 reported very high increases in sedentary behavior whereas people sorted into Class 1 were more likely to report engaging in about the same amount of sedentary behavior during the pandemic as before. In terms of psychosocial risk factors, Class 2 differed from Class 1 in sleep patterns (Class 2 participants reported waking up less alert despite reporting more hours of sleep), boredom, self-control, and mood. Although people in these classes were similar in physical activity and engaged in a mixed pattern of healthy and unhealthy eating habits, they exhibited different patterns of positive mood, craving control, cravings, boredom, and self-control. Demographic differences also emerged across groups. Participants in Classes 1 and 3 (relatively lower risk) were more likely to be male, married and White.

DISCUSSION

The primary purpose of this paper was to investigate the relationship between relevant psychological markers and energy balance-related behavior scores, during the COVID-19 related shelter-in-place. Generally, we report that increased boredom, higher self-reported cravings for sweet/savory foods, and high sleepiness ratings during the lockdown were related to increased unhealthy eating and sedentary behavior and decreasing physical activity and healthy eating during the lockdown. Whereas, having psychological traits such as greater general self-control, control over cravings, or positive mood was related to lower self-reported energy intake and energy expenditure during the lockdown. Individuals with the highest risk pattern reported having higher sleepiness, more boredom, less positive mood, and more cravings for sweet and savory foods.

Our hypothesis that self-reported change in boredom during the lockdown, a state like-psychological variable, may be related to dietary intake risk was based on prior research suggesting that high boredom increases the desire for and intake of unhealthy foods and snacks (23). Indeed, in a recent survey of French adults, 37–47% of respondents reported to increase eating to reduce stress, boredom, and feelings of emptiness experienced during the COVID-19 lockdown (51). Our data support these

TABLE 1 | Scores for four energy balance behavior categories by demographic profile of participants.

	High-sedentary behavior score mean (SD)	Group comparison	Low-physical activity score mean (SD)	Group comparison	High-unhealthy eating score mean (SD)	Group comparison	Low-healthy eating scor e mean (SD)	Group comparison
Sex								
Males ($N = 684$)	2.42 (0.43)	$F_{1,1559} = 28.65$ $p < 0.001$ $\eta^2 = 0.02$ [0.01, 0.03]	2.13 (0.53)	$F_{1,1557} = 0.38$ $p = 0.538$ $\eta^2 = 0.00$ [0.00, 0.00]	1.97 (0.34)	$F_{1,1590} = 24.55$ $p < 0.001$ $\eta^2 = 0.02$ [0.01, 0.03]	1.97 (0.48)	$F_{1,1576} = 1.65$ $p = 0.20$ $\eta^2 = 0.00$ [0.00, 0.01]
Females ($N = 875$)	2.54 (0.43)		2.11 (0.58)		2.06 (0.38)		1.94 (0.55)	
Race								
White ($N = 1,209$)	2.47 (0.44)	$F_{3,1556} = 3.52$ $p = 0.015$ $\eta^2 = 0.01$ [0.00, 0.02]	2.09 (0.55)	$F_{3,1554} = 10.88$ $p < 0.001$ $\eta^2 = 0.02$ [0.01, 0.04]	2.03 (0.35)	$F_{3,1587} = 1.94$ $p = 0.121$ $\eta^2 = 0.00$ [0.00, 0.01]	1.97 (0.50)	$F_{3,1573} = 2.80$ $p = 0.039$ $\eta^2 = 0.01$ [0.00, 0.01]
Black ($N = 109$)	2.49 (0.42)		2.15 (0.54)		1.96 (0.42)		1.85 (0.52)	
Other ($N = 81$)	2.52 (0.39)		2.08 (0.58)		2.07 (0.42)		1.95 (0.54)	
Asian ($N = 158$)	2.59 (0.39)		2.36 (0.59)		1.99 (0.43)		1.88 (0.59)	
Ethnicity								
Hispanic ($N = 173$)	2.52 (0.42)	$F_{1,1553} = 0.96$ $p = 0.327$ $\eta^2 = 0.00$ [0.00, 0.01]	2.12 (0.58)	$F_{1,1551} = 0.00$ $p = 0.994$ $\eta^2 = 0.00$ [0.00, 0.00]	2.00 (0.41)	$F_{1,1584} = 1.16$ $p = 0.283$ $\eta^2 = 0.00$ [0.00, 0.01]	1.91 (0.57)	$F_{1,1570} = 1.22$ $p = 0.269$ $\eta^2 = 0.00$ [0.00, 0.01]
Not Hispanic ($N = 1,380$)	2.49 (0.43)		2.12 (0.56)		2.03 (0.36)		1.96 (0.51)	
Marital status								
Married ($N = 748$)	2.44 (0.43)	$F_{1,1558} = 18.33$ $p < 0.001$ $\eta^2 = 0.01$ [0.00, 0.02]	2.05 (0.55)	$F_{1,1556} = 26.45$ $p < 0.001$ $\eta^2 = 0.02$ [0.01, 0.03]	2.02 (0.37)	$F_{1,1589} = 0.97$ $p = 0.325$ $\eta^2 = 0.00$ [0.00, 0.01]	1.95 (0.51)	$F_{1,1575} = 0.00$ $p = 0.973$ $\eta^2 = 0.00$ [0.00, 0.00]
Not married ($N = 810$)	2.53 (0.43)		2.19 (0.56)		2.03 (0.36)		1.95 (0.53)	
Age								
18–39 ($N = 967$)	2.53 (0.43)	$F_{2,1558} = 9.32$ $p < 0.001$ $\eta^2 = 0.01$ [0.00, 0.02]	2.13 (0.57)	$F_{2,1556} = 1.21$ $p = 0.300$ $\eta^2 = 0.00$ [0.00, 0.01]	2.03 (0.38)	$F_{2,1589} = 1.26$ $p = 0.285$ $\eta^2 = 0.00$ [0.00, 0.01]	1.95 (0.54)	$F_{2,1575} = 0.37$ $p = 0.691$ $\eta^2 = 0.00$ [0.00, 0.00]
40–64 ($N = 531$)	2.44 (0.43)		2.11 (0.55)		2.02 (0.34)		1.95 (0.48)	
>64 ($N = 61$)	2.34 (0.40)		2.02 (0.38)		1.96 (0.32)		2.01 (0.43)	
Income								
<30,000 ($N = 290$)	2.45 (0.43)	$F_{3,1489} = 2.33$ $p = 0.073$ $\eta^2 = 0.00$ [0.00, 0.01]	2.20 (0.53)	$F_{3,1487} = 3.88$ $p = 0.009$ $\eta^2 = 0.01$ [0.00, 0.02]	2.01 (0.36)	$F_{3,1518} = 3.08$ $p = 0.027$ $\eta^2 = 0.01$ [0.00, 0.01]	1.72 (0.56)	$F_{3,1507} = 0.99$ $p = 0.397$ $\eta^2 = 0.00$ [0.00, 0.01]
30,000–59,999 ($N = 420$)	2.46 (0.43)		2.14 (0.55)		2.01 (0.36)		1.97 (0.52)	
60,000–89,999 ($N = 329$)	2.53 (0.43)		2.08 (0.57)		2.00 (0.39)		1.97 (0.51)	
>90,000 ($N = 452$)	2.50 (0.43)		2.07 (0.56)		2.07 (0.35)		1.93 (0.53)	

All risk scores are calculated such that higher values = less healthy behavior (e.g., more sedentary time, less physical activity). All eta-squared values are presented with 95% CI.

TABLE 2 | Correlations between psychological and health risk/protective factors.

	Mean (SD)	1	2	3	4	5	6	7	8	9	10	11
Boredom (1)	3.74 (1.53)	—										
Self-control (2)	3.39 (0.78)	−0.62**	—									
Beliefs about weight control (3)	2.61 (1.19)	0.22***	−0.21***	—								
Positive mood (4)	5.51 (1.97)	−0.57***	0.53***	−0.14***	—							
Control of cravings (5)	5.52 (2.46)	−0.39***	0.45***	−0.06*	0.25***	—						
Cravings for sweet foods (6)	4.19 (2.33)	0.33***	−0.32***	0.12***	−0.21***	−0.74***	—					
Cravings for savory foods (7)	4.49 (2.03)	0.33***	−0.28***	0.05	−0.16***	−0.65***	0.60***	—				
Sleepiness rating (8)	2.90 (1.45)	0.42***	−0.45***	0.05*	−0.53***	−0.27***	0.17***	0.17***	—			
Hours of sleep (9)	7.31 (1.45)	0.01	0.00	0.09***	0.13***	−0.05	0.06*	0.03	−0.08**	—		
Body mass index (10)	25.99 (5.95)	−0.02	−0.06*	−0.03	−0.01	−0.17***	0.07**	0.12***	0.05*	−0.11***	—	
Stress (11)	4.59 (2.50)	0.46***	−0.36***	0.19***	−0.63***	−0.28***	0.27***	0.23***	0.40***	−0.09***	0.03	—

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

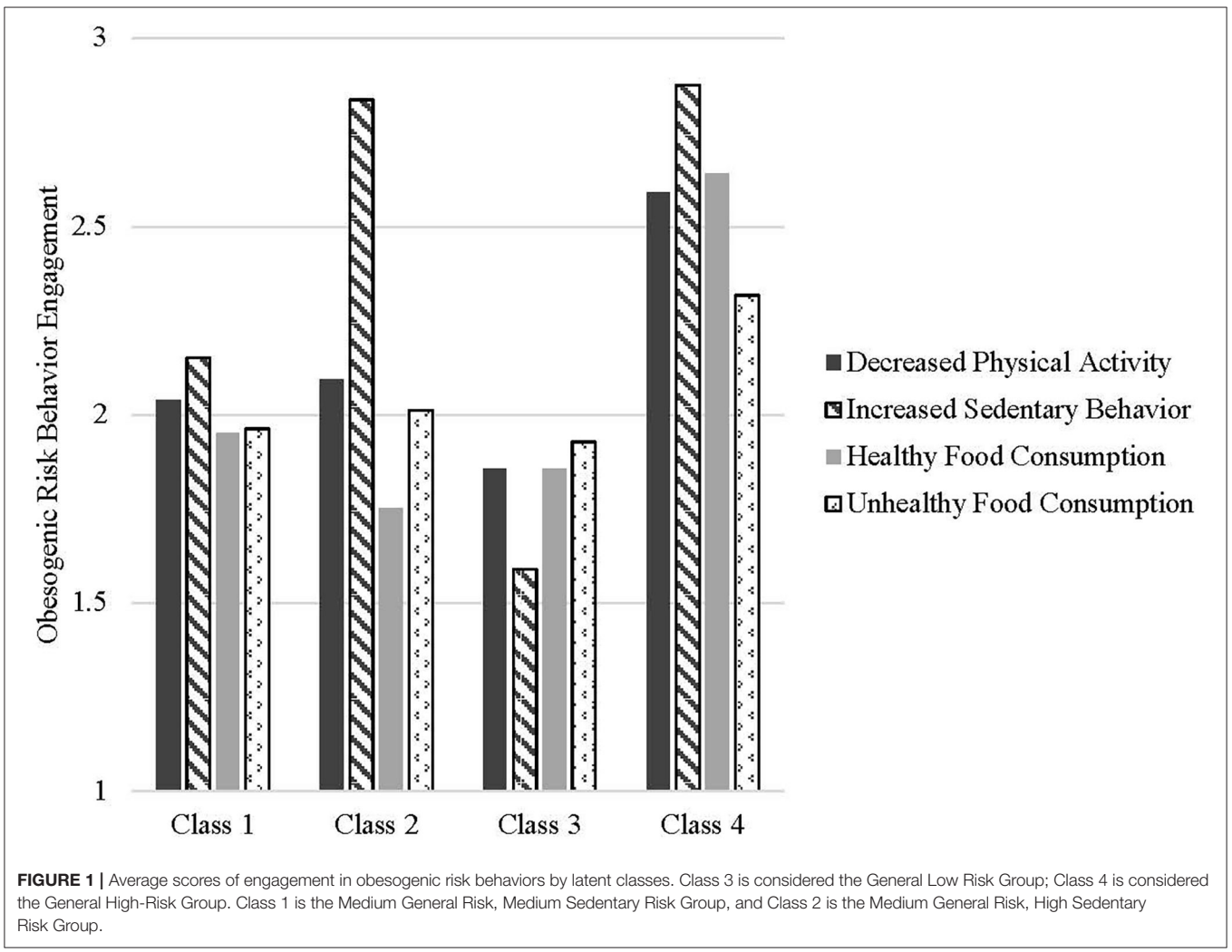

FIGURE 1 | Average scores of engagement in obesogenic risk behaviors by latent classes. Class 3 is considered the General Low Risk Group; Class 4 is considered the General High-Risk Group. Class 1 is the Medium General Risk, Medium Sedentary Risk Group, and Class 2 is the Medium General Risk, High Sedentary Risk Group.

findings by showing that boredom was related to the increased risk of consuming unhealthy foods (energy-dense sweet and savory snacks, sugary drinks, etc.) and lowering healthy food intake (fruits and vegetables) during the pandemic. Boredom is shown to encourage people to seek sensation (52); hence, we speculate that exciting options, such as sugary and fatty foods,

TABLE 3 | Psychosocial risk factors across class determined by latent profile analysis.

	Class 1 medium general risk, medium sedentary risk (N = 671–689)	Class 2 medium general risk, high sedentary risk (N = 643–654)	Class 3 general low risk (N = 80)	Class 4 general high risk (N = 165–169)	Comparison across class (Omnibus F)	η^2 [95% CI]
Low-physical activity score	2.04[a]	2.10[a]	1.89[b]	2.64[c]	63.85***	0.11 [0.08, 0.14]
High-sedentary behavior score	2.16[a]	2.84[b]	1.58[c]	2.89[d]	2918.05***	0.85 [0.84, 0.86]
High-unhealthy eating score	1.96[a]	2.02[b]	1.94[a]	2.33[c]	51.69***	0.09 [0.06, 0.12]
Low-healthy eating score	1.95[a]	1.74[b]	1.88[a]	2.80[c]	284.24***	0.35 [0.32, 0.38]
Boredom	3.38[a]	3.99[b]	3.33[a]	4.42[c]	32.52***	0.06 [0.04, 0.08]
Self-control	3.53[a]	3.35[b]	3.43[a]	2.94[c]	27.32***	0.05 [0.03, 0.07]
Beliefs about weight control	2.64[a]	2.57[a]	3.00[b]	2.46[a]	4.17**	0.01 [0.00, 0.02]
Positive mood	5.81[a]	5.44[b]	5.66[ab]	4.44[c]	21.81***	0.04 [0.02, 0.06]
Control of cravings	5.93[a]	5.43[b]	5.76[ab]	4.06[c]	26.21***	0.05 [0.03, 0.07]
Cravings for sweet foods	3.85[a]	4.35[b]	4.01[ab]	5.07[c]	13.68***	0.03 [0.01, 0.04]
Cravings for savory foods	4.12[a]	4.67[b]	4.34[ab]	5.48[c]	21.68***	0.04 [0.02, 0.06]
Sleepiness rating	2.65[a]	2.96[b]	2.78[ab]	3.68[c]	24.70***	0.04 [0.03, 0.06]
Hours of sleep	7.23[a]	7.41[b]	7.24[ab]	7.26[ab]	2.04	0.00 [0.00, 0.01]
Body mass index	26.20[a]	25.67[a]	25.59[a]	26.45[a]	1.38	0.00 [0.00, 0.01]
Stress	4.29[a]	4.70[b]	4.31[ab]	5.49[c]	11.61***	0.02 [0.01, 0.04]
Demographics					**Chi square comparison across group**	**Cramer's V**
Age	40.14[a]	36.31[b]	39.09[abc]	35.75[bc]	F = 12.17***	η^2 = 0.02 [0.01, 0.04]
Male	51.23%	37.77%	43.75%	33.73%	32.12***	0.14
Married	51.66%	44.65%	57.70%	36.89%	15.34**	0.10
Hispanic	10.30%	12.40%	8.97%	11.31%	1.90	0.03
Race						
White	79.45%	74.92%	88.61%	72.78%	18.10*	0.06
Black	6.51%	7.80%	6.33%	5.92%		
Asian	8.54%	11.93%	5.06%	15.38%		
Other	5.50%	5.35%	0.00%	5.92%		
Income						
<$30,000	22.36%	17.71%	15.79%	16.36%	14.84	0.06
$30,000–59,999	29.00%	25.93%	34.21%	29.09%		
$60,000–89,999	20.85%	23.35%	14.47%	25.45%		
>$90,000	27.79%	33.01%	35.53%	29.09%		

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$. Different superscript letters indicate statistical significance when testing between group differences.*

may have served as a potent distractor of self-regulation by providing intense appearance or taste. Another common reaction to boredom is to give up on a task because of decreased attention and/or greater perceived task difficulty (53). As a result, people gravitate toward easier tasks that require less cognitive load, such as the use of smartphones, the internet, or online socializing (54, 55); this may explain the relationship observed between increased sedentary behavior, low physical activity and boredom, in our dataset.

The relationship observed between self-reported sleepiness ratings, sleep duration, and diet quality in the current study confirms results from prior studies. We, and others, have previously shown that higher sleepiness (26, 56) and reduced sleep duration (57) are both related to food cravings and intake of energy-dense savory and sugary foods that may manifest in positive energy balance. The relationship of sleep time with sedentary activity is more complex, with long and short sleep durations both shown to impact sedentary behaviors in previous studies. In particular, reduced sleep duration (<7 h/night) correlates with increases in self-reported sitting minutes (58) and spending more time in front of the television (59), thus adding to sedentary time. In contrast, long sleep duration lowers daytime activity levels and increases screen-based sedentary behaviors (60). These data suggest that the reported positive correlation between sleep duration and sedentary activity is possibly related to a decline in overall wake time activity. We further speculate that lethargy after a long sleep duration and having less time available in the day may have added to increased sedentary behavior. It is equally possible that spending more sedentary time, especially in front of the screen, may reduce sleep quantity and quality (61). Given the cross-sectional design of this study, it is difficult to determine the directionality of the relationship between sleep duration and sedentary behavior in our participants during the shelter-at-home.

Similar to the findings by Buckland et al. where lower craving control predicted high energy dense sweet and savory food intake during COVID-19 lockdown, we also showed that greater control on food cravings, representing a state-like psychological characteristic, was related to unhealthy eating score (62). Intense food craving is often accompanied with lower mood and anxiety levels, and commonly reported with high BMI (63). Accordingly, we demonstrated that high craving control correlated with positive mood score and healthy food selection. Our data also shows a relationship between craving control and low reduction in physical activity. Interestingly, physical activity interventions can reduce cravings for high-caloric foods as well as mood (64). While we cannot confirm directionality in our cross-sectional data, it is possible that maintenance of high physical activity contributed to better mood and low boredom, thus supporting control over cravings.

In everyday life, general self-control, a trait psychological characteristic, is associated with positive weight management behaviors, including healthier eating, successful weight loss, and increased physical activity, as well as with better psychological well-being (65–67). The current study extends previous research on the personal benefits of self-control by highlighting the potentially protective aspects of self-control during a time when typical lifestyles have been majorly disrupted—in the context of a global pandemic. Because uncertainty increases the desire for indulgence (68), having high self-control may buffer temptation engagement during COVID-19 shelter-in-place. Notably, in this study, people who reported the least engagement in energy balance-related behaviors had the highest self-control. Those with relatively higher self-control also reported feeling in control of their food cravings, had fewer cravings for sweet and for savory foods, believed that body weight is malleable, and had lower average BMI. It could be that people who have higher self-control are better able to continue their established physical activity routines and habits of inhibiting unhealthy food consumption in times of uncertainty (69, 70) and to initiate new lifestyle adjustments in the face of necessary change (45). People with high self-control may also be adept at avoiding tempting situations (71, 72), which may happen frequently during shelter-in-place (e.g., ordering restaurant food to be delivered to one's house, watching more hours of television). In addition, people with higher self-control experienced several positive emotional benefits during shelter-in-place: on average, they felt less bored, reported higher positive mood, more alertness after waking, and less stress. Being able to successfully navigate temptation, resolve self-control conflicts, and pursue their goals, even in an unpredictable time, likely has a beneficial effect on mental well-being (66). Taken together, trait self-control may be a protective factor against the negative effects of COVID-19 shelter-in-place.

One predictor of weight management behaviors is the belief that a person's body weight is malleable (29–31, 73). In contrast to previous work, however, people in the current study who were classified as engaging the least in energy balance-related behaviors (vs. people in the higher risk classes) reported stronger beliefs that body weight is not malleable. Replicating previous correlational findings (30, 74), in the current study, participants' beliefs about weight malleability were unrelated to their BMI. Surprisingly, people who had stronger entity beliefs about body weight reported less sedentary behavior and less unhealthy eating; beliefs about weight control were unrelated to physical activity risk and healthy eating risk. One possible explanation for this finding might be that people who believed they can control their weight felt like they might be able to regain energy balance after the pandemic—that they could manage their weight well when they had the time and resources to do so. Counterintuitively, their health behaviors during the pandemic may have slipped because they thought they might be able to make up for it later. Alternatively, it may be that self-efficacy—which is a mechanism by which beliefs about weight control influence health behaviors (29, 74)—was interrupted during the COVID-19 pandemic. It could also be the case that during this unprecedented time, people may have generally low beliefs that if they were to experience setbacks in their weight management pursuits, they would be able to successfully cope with those challenges. Although we did not directly measure self-efficacy nor expectations of future success, people who reported having weaker incremental weight beliefs also reported lower positive mood, less control over their food cravings, higher cravings for sweet foods, less alertness after waking, and higher stress. Participants' negative mood may signal to them that they are

making poor progress on their goals and will subsequently be less successful in the future (75), which may be indicative of their engagement with weight-management behaviors. In our study, people with more positive mood had a lower risk of less physical activity and unhealthy eating. Along the same lines, feelings of control of one's food cravings predict lower risks of unhealthy and healthy eating. These negative psychological factors experienced during shelter-in-place may attenuate the otherwise positive effect that incremental beliefs usually have on weight management behaviors.

Given the heterogeneity in energy balance-related behaviors, an assessment of risk profile groups gave us a better insight into the unique characteristics of individuals who may be more prone to weight gain during the pandemic. Not surprisingly, individuals with the highest risk not only engaged in all energy balance-related behaviors but also reported to have psychological and health markers known to promote obesity. Although similar in risk level, we observed subtle but unique differences between the two moderate risk groups. The most striking difference between the two groups was sedentary behavior. As theorized by previous work, a complex interplay between personal circumstances, environmental variables, and social factors determines sedentary behavior (76). A large percentage of high sedentary risk group (Class 2) individuals belonged to a high-income bracket. High income groups are more likely to hold sedentary jobs (77) and are known to engage in prolonged sedentary behavior, as compared to lower income groups. Occupational sitting and screen time, along with the closure of all outdoor avenues and added pressure of being *always on* when working from home, may have put the higher income group at higher risk. We also noticed that a large percentage of adults in this group were married or living with a partner. While we did not measure it directly, there is a plausibility of higher perceived modeling of sedentary behavior in presence of a partner, especially if the partner spends more time engaged in screen time (78). Additionally, perceived behavioral control is likely to be protective of sedentarism (79), which was prevalent in the Class 2 risk group. By contrast, studies also show that when it comes to sedentary behaviors, self-control beliefs may be ineffective in influencing the decision to be sedentary. Rather it is the discriminant motivational structure, high access, and ease of use among people who wish to perform these behaviors (80). This lack of motivation with high boredom and negative mood may have been the differentiating factor for sedentary behavior in the two groups during the pandemic.

The results of this study must be interpreted in light of several limitations. This study was cross-sectional and non-experimental; thus, causality and temporality cannot be inferred. As such, we cannot conclude if reported alterations in behaviors truly lead to weight gain. Additionally, while there is evidence of behavior changes with body mass index status, due to the self-reported nature of height and weight data collected, we did not test the difference in health behaviors between BMI groups. We also asked participants to report their perception of behavior change (increased, decreased, remained the same), rather than asking them to report behaviors before and during the lockdown period and calculating the change score for each variable. While we did this to minimize self-reporting bias and/or recall bias, the data is still self-reported, and our results may be subject to biases. Moreover, a recent report demonstrated that perceptual increase in physical activity is driven by the amount of vigorous physical activity performed, suggesting that an increase in intensive physical activity is important for perceiving a change in one's physical activity (81). In contrast, smaller changes may need to be sufficient for change to be perceived as such (82). Thus, the self-reported change scores in our study may not be accurate. Furthermore, with possible differences in perception of individual behavioral component of score categories, our aggregate scores for these categories may be subject to biases. While pandemic related restrictions limited our ability to collect data on energy balance behaviors subjectively, the importance of using objective measures cannot be denied. Recall bias, especially with using non-validated tools, may confound self-reports reflecting a *perceived* rather than *actual* change behaviors during the lockdown (83). This should be taken into consideration when interpreting our findings.

Additionally, while we did not disclose the specific purpose of the study to the participants, our results could also be driven by participant's expectation and not their actual behavior. With regards to the questionnaires, while validated instruments were used as possible, some necessary questions were developed by the investigators to capture the current unique environment. Moreover, we did not use a validated tool for dietary intake, such as food frequency questionnaires. Thus, care should be taken to integrate these findings with the broader literature. For our psychological and health behavior constructs, some variables were contextual or state like, while some were trait like. However, this should not have impacted our findings because whether it is a state like characteristic or trait like characteristic, we were interested in how it influenced energy-balance-related behaviors and how they differed between the risk classes. Moreover, despite the diversity and size of our sample, a convenience sampling approach was used, which may limit generalizability. Furthermore, the degree of shelter-in-place guidelines and the number of COVID-19 cases in participants' area of residence likely differed, creating differences in flexibility with stepping outside the house. The time frame of data collection may have influenced our results as well. As such, at the time of data collection, although most states had implemented shelter-in-place guidelines, a few states were considering lifting the restrictions. This one snapshot of time also assumes that thoughts and behaviors were static throughout the entire shelter-in-place time, which is likely an oversimplification.

Altogether, this study describes state- and trait-like psychological factors that relate to energy balance-related behavior categories during the COVID-19 shelter-at-home restrictions in the U.S. Our analysis provides important insights into the complex interplay of factors related to risk of increasing unhealthy eating and sedentary activities and decreasing healthy eating and physical activity. These results also contribute to improving our understanding of the patterns of risk groups and their unique characteristics, specifically highlighting that the lockdown did not adversely impact energy balance behaviors in all individuals. Our risk classes identified risk groups that represented 15–20% of our sample population. Health entities

such as World Health Organization have several nutritional and lifestyle recommendations to follow during lockdown for the general public Thus, based on our findings, such public health efforts may be better spent targeting at-risk population subgroups in need of weight management interventions during the current pandemic rather than targeting people who are already managing the transition well. Our results also suggest that self-reported changes in state-like psychological variables impacted energy balance behaviors in a similar manner during COVID-19 lockdown, as they did during pre-COVID time. Thus, an effort to reduce stress and boredom, improve sleep hygiene, and strategies to control food cravings (all state-like psychological variables) using public health platforms may be beneficial in addressing a potential negative impact of lockdown on energy balance behaviors. Additional research is also needed on collecting longitudinal data to understand whether the high-risk behaviors revert back to normal as the pandemic crisis is passed.

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 protocol (HS-2020-0105, HS-2020-0100) was reviewed and approved by the Institutional Review Board at San Diego State University, California. All participants gave an online informed consent before initiating the study questionnaire. The ethics committee waived the requirement of written informed consent for participation.

AUTHOR CONTRIBUTIONS

SB, JC, and MD conceived and designed the experiment and acquired the data. MD and LH analyzed the data. SB, JC, LH, and MD interpreted the results and wrote the paper. All authors contributed to the article and approved the submitted version.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fnut.2021.680105/full#supplementary-material

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REVIEW
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Delivering the Multisensory Experience of Dining-Out, for Those Dining-In, During the Covid Pandemic

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In many parts of the world, restaurants have been forced to close in unprecedented numbers during the various Covid-19 pandemic lockdowns that have paralyzed the hospitality industry globally. This highly-challenging operating environment has led to a rapid expansion in the number of high-end restaurants offering take-away food, or home-delivery meal kits, simply in order to survive. While the market for the home delivery of food was already expanding rapidly prior to the emergence of the Covid pandemic, the explosive recent growth seen in this sector has thrown up some intriguing issues and challenges. For instance, concerns have been raised over where many of the meals that are being delivered are being prepared, given the rise of so-called "dark kitchens." Furthermore, figuring out which elements of the high-end, fine-dining experience, and of the increasingly-popular multisensory experiential dining, can be captured by those diners who may be eating and drinking in the comfort of their own homes represents an intriguing challenge for the emerging field of gastrophysics research; one that the chefs, restaurateurs, restaurant groups, and even the food delivery companies concerned are only just beginning to get to grips with. By analyzing a number of the high-end fine-dining home food delivery options that have been offered (in the UK and in the US) in this narrative review, we highlight a number of promising directions for those wanting to optimize the at-home multisensory dining experience, wherever in the world they might be.

Keywords: takeaway, COVID-19, dining-in, dining-out, fine dining, gastrophysics

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INTRODUCTION

The home food delivery business has been expanding rapidly in recent years, spanning everything from the delivery of takeaway meals, through part-prepared meals to boxes of raw ingredients (Moore, 2017; Kang and Haddon, 2020; Pearson-Jones, 2021). In no time at all, or so it would seem, brands such as Just Eat and Deliveroo, have become household names in those countries where they have successfully managed to establish a presence (Feehan, 2021). Over the last few years, in the UK market in particular, Just Eat, Domino's Pizza, and RooFoods (parent company of Deliveroo) were the three largest players by turnover (see Lock, 2020). Other companies such as Blue Apron, Gousto, UberEats, Hello Fresh, Serious Eats, GrubHub, Swiggy, Postmates, DoorDash, foodpanda, Zomato, etc., have also managed to develop a successful foothold in many of the countries in which they operate.

One important distinction to highlight at the outset is between takeaway meals and food boxes. Takeaway food is fully prepared and ready to eat on arrival (save for perhaps, warming up in the microwave, stove, or oven, and plating on your own crockery)[1]. McDonald's and KFC have both jumped on the home delivery bandwagon (Evans, 2017). Boxes, or meal kits (Anon, 2021), on the other hand, imply that the food has only partially been prepared, meaning that the customer is also involved in the process of preparing/finishing the meal. This may potentially result in them feeling a part of the process of making, which might itself be expected to convey certain benefits in terms of the latter's enjoyment of the food (Dohle et al., 2014; Spence, 2017a). Many fine dining restaurants have opted for the latter option (i.e., meal kits), given that high-end cuisine typically does not travel well, nor is it likely to be well-presented on delivery (which is, of course, often what makes the difference with high-end dishes; Elliott, 2015; see Spence et al., 2016, for a review).

As a case in point, consider only the difficulty of trying to preserve/recreate some of the beautiful dishes served at n-naka in California, at home (see https://n-naka.com/). The challenge perhaps explaining why the restaurant pivoted to bento boxes instead (see **Figure 1A**). Bento (弁当), which is very popular in Japan, describes a single-portion home-packed or take-out meal. The way fine dining dishes are designed (with freshness in mind, never forgetting the concept of service *á point*) makes delivering these foods more challenging, and also means the food is less likely to travel well. Meanwhile, world-famous Michelin-starred modernist restaurant Alinea, in Chicago, known for dishes such as its edible green apple balloon (Forbes, 2012), would presumably be very difficult, if not impossible, to transport to the home environment. Intriguingly, Alinea now offers their patrons the opportunity to make a number of their famous table-top desserts (see Spence and Piqueras-Fiszman, 2014) at home. What is more, social media also increasingly allows for the possibly of showing off one's personal creations online too (Olsen, 2020a).

At the same time, however, it is also worth noting how the majority of consumers have been spending much more time at home during lockdown (Spence, 2020c), and home-cooking/baking has become noticeably more popular (e.g., see The National Trust, 2020). For instance, according to Kraterou (2020), half a billion more meals were cooked at home during the first 6 months of lockdown in the UK alone. What is more, there would also appear to be growing interest from many consumers in learning from chefs with cooking classes etc., held over Zoom or some other internet platform. The Covid-19 pandemic has undoubtedly also changed the face of fine dining in many countries, such as for example, in the UK (where the majority of restaurants were closed for many months; see Clay, 2021), and in the US, where many cities have had periods of only allowing very limited outdoor dining.

Perhaps unsurprisingly, the hospitality sector is in freefall in many parts of the world. To give some sense of the scale of the problem, according to a survey from the National Restaurant Association, more than 110,000 restaurants in the US, or one in every six, had either closed permanently, or else on a long-term basis, during the first 6 months of the pandemic (see Gonzalez, 2020; Singh and Gonzalez, 2020). Given such a challenging operating environment, many of those restaurants and restaurant groups that are still in operation have pivoted to offering food for home delivery or takeaway. This raises a number of important questions about how to recreate the restaurant experience at home, which is something that a growing number of consumers apparently crave (Kraterou, 2020). Here, it is worth noting that the challenges associated with recreating the experience of dining-out amongst those forced to dine-in during the Covid-19 pandemic is presumably just going to be that much harder for those trying to deliver a high-end, or immersive, experiential meal than for those offering mainstream takeaway food (e.g., burgers, pizza, etc.).

ON THE GROWING POPULARITY OF HOME FOOD DELIVERY

First, though, before taking a closer look at the high-end food delivery market, it is perhaps worth briefly summarizing some of the dramatic changes that have been documented over the last 5–10 years in the takeaway sector. According to The Takeaway Economy Report (2015), in the UK in 2014, 1.2% of the total weekly spend was already going on takeaway meals, with Just Eat processing 45.5 million food orders that year. The takeaway sector was worth an estimated £9 billion to the UK economy in 2014, representing a 25% increase since 2009 (when the sector was valued at £7.2 billion). The estimated 35,000 takeaway restaurants that were operating in the UK in 2014 were already supporting a wide variety of different cuisines (especially in urban centers), including everything from South African to Mongolian, Peri Peri to Polish, and from Kurdish to Iranian cuisine. Long gone, in other words, are the days (e.g., in the 1970s) when more than 70% of all takeaway spending in the UK was on fish and chips (The Takeaway Economy Report, 2015)[2]. By 2014, that figure had dropped to just 30%, and was continuing to decline. While part of this change in the public's tastes can simply be put down to a growth of interest in more exotic takeaway fayre (The Takeaway Economy Report, 2015), the steadily increasing price of fresh fish, and the growing perception of what was once the UK's most popular takeaway food, as being unhealthy have undoubtedly also contributed to its declining popularity (see Robineau, 2016; Timmins, 2017).

Perhaps the most important change in the takeaway market over the last 5–10 years or so, though, has been the rise of home delivery services. These companies promise to connect the consumer (i.e., the home diner) with a range of takeaway options. A host of new ordering platforms have come online over the last decade, such as UberEats, Caviar, Postmates, and DoorDash. Indeed, according to a blogpost by Allen (2016), these four platforms alone were already processing $400 million orders (in the US) in 2014, with that figure expected to quadruple to

[1]Though, of course, takeaway pizza, etc., is often served/eaten direct from the cardboard box in which it is delivered.

[2]The first shop selling fish and chips opened in 1860 in the East End of London (see also Spence, 2021c).

FIGURE 1 | (A) n/naka's New Year's Eve hot pot + bento box; **(B)** n/naka's collaboration with Susan Yoon; (**C)** n/soto bento box.

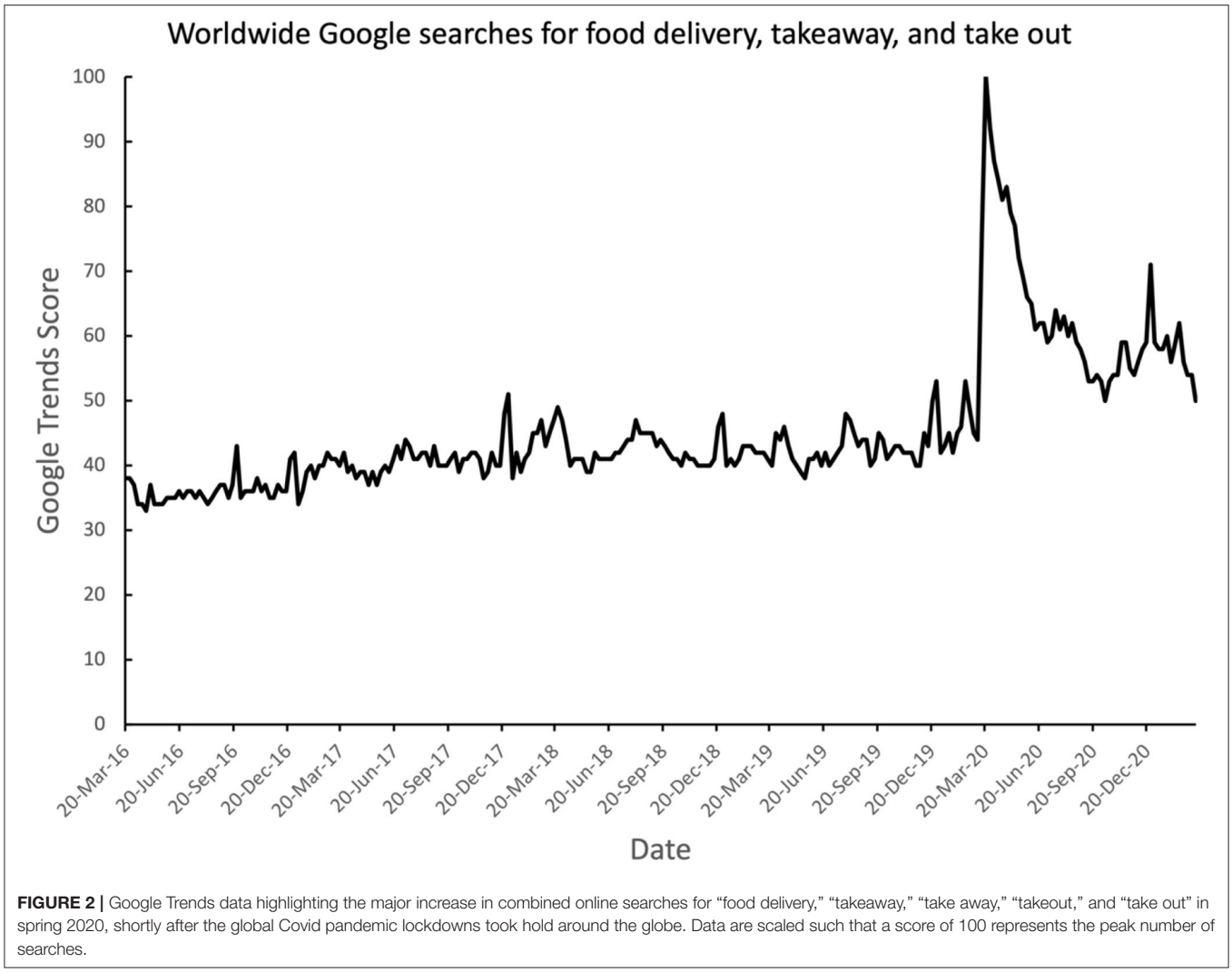

FIGURE 2 | Google Trends data highlighting the major increase in combined online searches for "food delivery," "takeaway," "take away," "takeout," and "take out" in spring 2020, shortly after the global Covid pandemic lockdowns took hold around the globe. Data are scaled such that a score of 100 represents the peak number of searches.

$1.6 billion by 2016. Allen highlights how the problem for many independent restaurants is their lack of a dedicated mobile app and/or a dedicated online ordering platform. The danger is that the deleterious consequences of this digital neglect are likely to become increasingly apparent, given Allen's (2016) further claim that: *"Digital online ordering is growing 300% faster than dine-in ordering."* The recent spike in online searches for home food delivery and takeaway certainly supports the explosion of consumer interest resulting from the Covid pandemic (see **Figure 2**). To give some sense of the history here, ordering food online is thought to have started in Northern California in 1995 and later expanded throughout California. The company was called World Wide Waiter and is now known as Waiter.com. The market for mobile food ordering on smartphones via smartphone and mobile apps was estimated to become a $38 billion industry and make up nearly 11% of all quick-service restaurant sales by 2020 (Wasilefsky, 2017).

With the pandemic, therefore, the use of food delivery apps has surged, bringing in billions in revenue. That said, profitability in the sector remains elusive (Sumagaysay, 2020), in part due to the rapid expansion in the major players in the area (e.g., Just Eat and Deliveroo; Witherow, 2021), as they try to dominate the market (e.g., in Europe), thus meaning that in the UK such companies that expand rapidly while posting annual losses do not have to pay any corporation tax (Walters, 2020). In certain cases, these companies also receive substantial digital enterprise grants from the UK government (Walters, 2020). Bear in mind here only that Deliveroo is backed to tune of £500 million by Amazon (Walters, 2020)[3].

Some restaurants ship food across the US; currently for example, one can order the famous turtle soup from New Orleans' Commander's Palace either alone or as part of a multi-course dinner with spiced sugarcane quail and pecan pie, or signature dishes from New York City's Momofuko, such as their Bo Ssäm or Ko Foie foie gras (both available via https://www.goldbelly.com/). However, assembly may be required; while

[3]Indeed, it has been suggested that the key asset Roofoods Ltd., Deliveroo's parent company, has is its consumer data (which, crucially, is not shared with restaurants; Walters, 2020).

some dishes only require reheating, others involve some pretty extensive preparation on the part of the consumer.

On the Rise of the "Dark Kitchen"

The phenomenal growth in the popularity of home food delivery, facilitated by the rise of online platforms, has led to increasingly vocal concerns being raised around the rise of so-called "dark kitchens" (e.g., Butler, 2017a,b; Walters, 2020), also known as "ghost kitchens" (cf. Robertson, 2013; Isaac and Yaffe-Bellany, 2019). For instance, in the US, a single restaurant might serve dishes associated with as many as 10 different brands (Wiener, 2020). Oftentimes, the food offerings are highly specialized (e.g., breakfast burritos, specific styles of pizza, or grilled cheese) in order to draw in those customers with a specific craving, and the concepts are designed to optimize visibility in the relevant food apps (Conrad, 2021). Even some fine dining restaurants have gotten on board (Krader, 2021), while some celebrities have now even formed their own "franchises," where different kitchens prepare meals to particular specifications (Conrad, 2021).

In the UK, meanwhile, commentators have started to draw attention to the fact that an increasing percentage of branded takeaway food offerings are now being prepared not in a branch of the namesake restaurant (as the consumer might expect), but rather in one of Deliveroo's dark kitchens (otherwise known as Rooboxes). A large number of such typically-windowless shipping containers, or other temporary buildings, have been placed in anonymous industrial estates or car-park across the UK (e.g., Butler, 2017a,b; Walters, 2020). Deliveroo makes meals for famous brand name restaurants such as MEATLiquor, Busaba Eathai, Indian chain Dishoom, popular burger joints, Honest Burger, Shake Shack, and Patty And Bun, and curry house Moto. These are then delivered from Roobox outlets. Some more exclusive/expensive, restaurants such as Hakkasan in Mayfair, London have also started to offer high-end Chinese food at home as a result of Covid, including their signature Chinese dishes such as Peking duck (£110) and roasted silver cod in champagne and honey for £52. Yet much of the food in this case turns out to be prepared in a dark kitchen (Walters, 2020)[4]. Given that such dark kitchens often bypass planning regulations and give rise to noise disturbance from all of the delivery vans and mopeds coming and going to those living nearby, Deliveroo has been facing a growing chorus of complaints from local authorities/councils in the UK (e.g., Butler, 2017a).

While it presumably should not really matter where exactly one's meal is made (providing, that is, that the end result tastes as expected), one might nevertheless want to question whether it is still worth paying a premium for the "brand," especially for what might essentially be considered a commodity takeaway item such as a burger, say. At the same time, however, it is interesting to note that the question of where exactly it was made never seems to arise in the mind of the consumer when enjoying processed foods (cf. Laudan, 2001). So what, exactly, is different in the case of branded takeaway meals dispatched from dark kitchens rather than the namesake restaurant? Of course, it is a separate question as to whether this should, or does, change, the consumer's experience of a meal, and, if so, how. At the same time, however, concerns about the source, or location, of food preparation do not seem to have been raised in the context of fine-dining. Perhaps this is because the quality of the food is supposed to speak for itself. What is more, diners often have to pick up the meal kit from the restaurant itself, rather than having it delivered to the home, thus reinforcing the notion that the food was actually prepared there[5].

High-End Meals At-Home

Launched in 2015, Supper (https://supper.london/home) has been delivering Michelin-starred restaurant cuisine direct to the door of those living in central London for more than 5 years now (e.g., Editorial Staff, 2015; Anon, 2020). According to a recent press report (Vincent, 2020), they currently service customers in the Home Counties as well (i.e., the range of delivery has expanded over the years). In line with what we have seen so far in this review, the company reported a 700% increase in orders since the start of lockdown. The company apparently has some clients who regularly pay £1,500 for Michelin-starred restaurant meals to be brought from London (Vincent, 2020). The latter example, assuming that it is more than just an isolated instance, could then be taken to support the claim that the most expensive home-delivery option may constitute a successful business opportunity for high-end restaurants (Vincent, 2020), that is, a high-end meal offering with a financially-viable take-up amongst consumers. Supporting such a suggestion, Deliveroo also reports that it has been delivering some increasingly expensive meals to its customers (Scott, 2017).

To those of us who may be unaccustomed to paying such astronomically high prices for a meal, never mind a takeaway, or meal kit, one might be tempted to wonder whether such experiences represent a one-off indulgence, or else a genuine and sustainable shift in dining patterns. The alternative here is to consider only whether the exceptionally high prices might be promoted in order to help maintain perceived exclusivity of the food brand without the restaurant necessarily expecting much of a take-up (Wharton, 2008; Poundstone, 2010). If this sounds unlikely, consider only how pre-Covid, excessively expensive options were sometimes put on restaurant menus seemingly in order to elicit outraged press interest (at the expense) and/or to make the other options on the menu look cheaper (Spence and Piqueras-Fiszman, 2014)[6].

However, despite this interest in the delivery of high-end food to the home, many chefs and restaurateurs have realized that it is difficult to reproduce the multisensory experience of a high-end restaurant meal at-home. It certainly requires far more than simply just ordering the suitably-expensive home-delivery meal kit direct to one's door, or else picking it up from the

[4]In the UK, the phrase "Deliveroo Editions" is key. It is code for the fact that your meal may actually have been prepared in a dark kitchen.

[5]Of course, in a non-food context, many top clothes brands fabricate their merchandise in sweatshops in the Third World, so perhaps the case of branded takeaway food is not so very different after all.

[6]For instance, the "Zillion Dollar Frittata" at Norma's in New York City, a decadent $2,000 egg dish including lobster and caviar is ordered by less than a dozen customers a year, but its inclusion on the menu is meant to evoke a feeling of extravagance and playfulness (Haviland-Blunk, bib48).

restaurant itself. The question to be addressed in the remainder of this review, therefore, is how chefs, restaurateurs, and restaurant groups have adapted in light of the dramatic changes in behavior that have been brought about by COVID. We also highlight a number of promising directions for those wanting to deliver an enhanced multisensory dining experience at home that goes well beyond merely providing the food (and drink) itself.

IS IT POSSIBLE TO DELIVER A HIGH-VALUE, OR EXPERIENTIAL, MEAL AT HOME?

The expectations of takeaway/fast food are typically not that high (Cowen, 2012). What is more, takeaway meals likely do not deteriorate much in transit. In fact, it has even been suggested that the flavor or certain takeaway meals improves on reheating (see Pass Notes, 2020). By contrast, one might wonder whether it is actually possible to deliver a high-value meal, or even one of the increasingly-popular immersive (or experiential) meals, for those dining at home. For example, just take the five-course New Year's takeaway menu from high-end London hotel The Connaught in Mayfair that cost £415. The meal, in this case, was prepared by Michelin-starred chef Hélène Darroze (McCarthy, 2020), with diners presented with a number of distinctive features/elements, including beautiful origami packaging (see **Figure 3**), a point to which we will return later. But can the culinary experience at-home ever really justify the expense (or live up to the experience of dining-out)?

Many other high-end restaurants in the UK and US have also jumped on the meal kit bandwagon since the start of Covid. They include Alinea in Chicago (one of the first to do so—and at a reasonable price; Olsen, 2020b); and, in the UK, Restaurant Hyde in London (https://hydeandco-delivery.co.uk), Core by Clare Smyth (https://www.corebyclaresmyth.com/core-at-home/), La Gavroche (https://www.hot-dinners.com/2020111110026/Gastroblog/Latest-news/michel-roux-jr-jason-atherton-restaurant-box-le-gavroche), Sketch, Simon Rogan and many, many others (https://luxurylondon.co.uk/taste/food/home-deliveries-restaurants-london; e.g., Anon, 2020; Chomka, 2020; West and Henderson, 2020). While some restaurants have opted for ongoing offerings, with regular menu changes, others only offer menus for special occasions.

While the focus of this narrative review is squarely on high-end dining in the UK/US, it is worth noting that similar trends have been reported in a number of other countries including Australia (Amin, 2020; Wilden, 2020), Canada (Bell, 2020), and Japan (Kyodo, 2020).

However, can an expensive takeaway meal or meal kit ever really come close to a delivering what one expects from a high-end experience when dining-out if consumed in the customer's own home? After all, the atmosphere etc. is an important factor influencing the dining experience (e.g., see Anon, 1965; Spence and Piqueras-Fiszman, 2014; Spence, 2020a). Indeed, legendary French chef Paul Bocuse is once rumored to have said that more than half the experience of fine dining is comprised of "the everything else" (i.e., beyond the food and drink offering itself; see Spence and Piqueras-Fiszman, 2014). And while one might well be tempted to question what the appropriate percentage should be in this case, there can be little doubting that the service element is critical to the customers' experience of fine dining (e.g., Matthews, 2017)[7]. One might also wonder how important the music is (Wilson, 2003; Fiegel et al., 2014; Spence et al., 2019b), or the scent, the flower arrangements, the napkins, or even the lighting (see Spence, 2021a, for a review)?

In a way, the appreciation of food, in particular, high-end cuisine is much like art, being rated more highly when experienced in the appropriate context (see Brieber et al., 2015). Here, it is interesting to note how the same meal is sometimes rated very differently by participants depending on where it happens to be served—five-star hotel restaurant or institutional cafeteria, for instance (e.g., Bell et al., 1994; Edwards et al., 2003). In such cases, however, it is important to stress that the location/venue may have been the only product-extrinsic cue that the diners had to go on when it came to rating the quality of the food. Contrast this with the situation when eating an expensive meal kit at home. In the latter case, the diner is presumably acutely aware of the brand that is supposedly providing the food and hence the atmosphere/location might be expected to matter less (i.e., branding matters, while the means by which that branding information is conveyed, does not).

THE COVID PANDEMIC AND THE CHANGING FACE OF HIGH-END HOSPITALITY

According to the many articles that have appeared in the UK press, there have been a number of sometimes dramatic changes in the foods that people are choosing to buy/eat during Covid lockdown (e.g., Hargreaves, 2020; Pearson-Jones and Poulter, 2020). Changes have been reported both in terms of what people choose to consume and how we choose to prepare it (if at all). Home cooking/baking was also much more evident in the initial periods of lockdown than has been the case in the later ones (The National Trust, 2020). According to one report in the British press, for instance, sales of trifle were up by 700%. While there was marked panic buying (e.g., of pasta) during the initial periods of lockdown (e.g., in the UK, see Bekiempis, 2020; Lufkin, 2020)[8], it is worth stressing that somewhat different patterns of consumer behavior have been documented during each period of lockdown. Note here also that tension and stress (e.g., associated with Covid-related stresses and strains) have been shown to lead toward greater desire for, and consumption of, fast food and sweet/carbohydrate-dense foods (Leow et al., 2020). There would also seem to be an increasing use of food rituals amongst

[7]It has even been suggested that the quality of the bathroom fittings might play a role in the Michelin guides rankings (Sharp, 2013). As Steinberger (2010, p. 75) put it: "*The Michelin Man, they came to believe, had a yen for luxury and wanted his surroundings to be as sumptuous as his food*." Not too far removed from this suggestion is the claim that one should never eat at a restaurant where the facilities are of questionable cleanliness (see Markwell, 2017).

[8]Dickins and Schalz (2020) have even put forward an explanation couched in terms of evolutionary theories of foraging, to explain the panic buying (e.g., of foods such as pasta).

FIGURE 3 | £415 takeaway meal for two from Hélène Darroze at The Connaught Hotel, London (McCarthy, 2020). Figure copyright Hélène Darroze, The Connaught.

consumers to help deal with Covid-related stress (Randall, 2021; Wang et al., 2021a), as well as a rise in consumption of nostalgia foods (Morrissy Swan, 2020; see also Cereceda, 2020). Here, though, it is worth noting that often what is called a food ritual turns out, on closer inspection to be more of a food habit, or stereotypical food behavior, meaning that it lacks the traditional/symbolic element of true rituals (see Spence, inpress; Visser, 1991).

But have our tastes/preferences as far as high-end, or immersive experiential dining, also been changed as a result of Covid? Furthermore, there is a very real question here as to whether diners will still be interested in experiential/molecular/modernist dining in the post-Covid era (see Spence and Youssef, 2018; Spence, 2020c)[9]. Here, though, it should be noted that it is currently difficult (i.e., during Covid) to predict which of the Covid-related trends in food and drink consumption will stay post lockdown, and which may revert to their former patterns of food behavior/preference (Plata et al., submitted). Intriguingly here, Some restaurants have been encouraging their former customers to buy vouchers for future dining-out meals in anticipation of when the hospitality industry opens up (Lutrario, 2020).

Changing High-End Food Offerings

Intriguingly, the chefs in a number of the most famous restaurants, have chosen to adapt their menus and pricing to be much more accessible during Covid. There has also been a change in what is served in many venues. For example, Noma, in Copenhagen, formerly judged to be the world's best restaurant, served what can perhaps best be described as experimental Nordic cuisine prior to the Covid pandemic. However, on reopening in May, 2020, the offering consisted of a much more homely combination of burgers and wine/beer (Hosie, 2020). These items can be enjoyed in the restaurant's garden or else be taken-away for only $18. Note that this is just 1/20th of the cost of the usual Noma experience (excluding drinks). Meanwhile, at another of the world's former top restaurants, The Fat Duck (in the UK) has started offering two-course lunches again after more than a decade of only serving a set menu. By contrast, at the start of the pandemic, Alinea began by offering beef Wellington, then started serving French comfort food. However, as the various periods of lockdown have progressed, it has been reported that the food has grown increasingly "Alinea-like" (Kludt, 2020).

The atmosphere is so much a part of the total experience at restaurants such as Vespertine in LA (http://vespertine.la/), from chef Jordan Kahn. A meal for two will set one back upwards of $1,000. A 5-h dinner comes with bespoke soundscape that plays pervasively throughout (from the car park through to the roof where your meal service begins and back down to the garden), scents[10], and the most other-worldly, and beautiful plateware that the diner has likely ever seen (see Scattergood, 2017; Spence,

[9]Note here also how trends in aesthetic preference are cyclical (Carbon, 2010, 2011).

[10]Indeed, guests are sent home from Vespertine with a small bottle of the restaurant's bespoke scent.

2020b)[11]. How, then, to offer a meal that does not compromise the essence of the in-person person experience of a meal at Vespertine? How to capture the scents, the sounds, and the ubiquitous black of the interior (not that everyone would want to; see Baum, 2017)? Much the same problem faces other (typically high-end) multisensory experiential dining concepts such as chef Jozef Youssef's Gastrophysics Chef's Table that involve everything from projection mapping on the dining table though sonic accompaniments to match certain of the dishes (Spence and Youssef, 2020; see also Pigott, 2015; Abend, 2019; for a number of other experiential multisensory immersive dining concep).

Kahn, like many other chefs wisely does not try to deliver the full restaurant experience for takeaway at home. Instead, the chef creates a completely new menu every few weeks, designed around a particular theme (Addison, 2020). While some of the themes reflect Kahn's own family heritage (Cuban, Southern US, Sicilian, and Yucatán), others are linked to his own culinary lineage (namely the French Laundry, and Alinea). Crucially, however, the price point is far different than dining in (at the restaurant), with most of the offerings starting at <$100/person.

At many restaurants, frequently changing themes/menus provide a reason for customers to return. And yet, at the same time, there is also a sense in which, there should be something constant (so that the customer has something tangible to look forward to when ordering again; see Poundstone, 2010; Spence and Piqueras-Fiszman, 2014). Limited-time themes can help to create both variety and scarcity. At David Kinch's Manresa, based in Los Gatos, California) the at-home menu changes daily (https://www.manresarestaurant.com/menus/). Kinch's well-known New American eatery offers extravagant farm-to-table tasting menus, and relevant to one of the themes that we will return to shortly, it is noticeable how the stress is on the social family meal element of the offering (just take the following from the Google search page: "MANRESA FAMILY MEAL TAKE OUT. We have released our Daily @manresafamilymeal menus for the entire week"). Given that museums, galleries, and musical venues are closed in so many major cities, and travel is heavily restricted in much of the world, food has become a way to experience art, and to at least get a taste of being somewhere else (All the more relevant when it is realized that according to a pre-Covid survey of young British holidaymakers, one in five reported that they were choosing the destination based on the food that they expected to find at their destination (Amey, 2015; see also on the desire to travel being linked to meal box delivery; Thornhill, 2021).

In some cases, there have been intriguing culinary collaborations and innovations with the move to takeaway food provision at the high-end. While n/naka (in California, this a restaurant that we came across earlier) is normally a kaiseki restaurant, they offered a bento box created by chef Susan Yoon that included Korean-inspired flavors (see **Figure 1B**)[12]. Given the popularity of such collaborations, the team behind n/naka ultimately decided to open a second restaurant, n/soto (see **Figure 1C**), specifically focused on such collaborations (Wang, 2021). In San Francisco, the chefs of Michelin-starred restaurants Lord Stanley and Mister Jiu's came together to create five-course meals (Guerrero, 2020). In other cases, restaurants have chosen to reference each other; For instance, Melisse x Citrin in Los Angeles had a series of "tribute" menus including to chefs David Kinch, Jean-Georges Vongerichten, Daniel Boulud, and Alice Waters (https://www.instagram.com/melisserestaurant/?hl=en). Meanwhile, Alinea in Chicago and Eleven Madison Park in New York City teamed up late in 2020 to collaborate on a meal offering (Krader, 2020).

ON THE ECONOMICS OF FINE-DINING AT HOME

While the consumer might well expect to pay less for a meal when delivered direct to their door (rather than served in the context of the restaurant; for instance, Cosme in New York City offers some of its food items for less on Caviar than they charge in person; see Adams et al., 2020), it is worth noting that the likes of Deliveroo demand around 35% of the cost of the meal to deliver and VAT and £3–5 delivery fee to customers (Walters, 2020; see also Merriman, 2021). That means that Deliveroo takes £42 of every £100 charged by the restaurant. By contrast, big chains, including the likes of McDonald's (Evans, 2017), Starbucks, and Wagamama, meanwhile, are charged much less (c. 20%). As such, it is really the big brands who can afford to use these dark kitchens, more than the independent restaurant[13]. Some cities have pushed back on such fees, capping them at 15% (e.g., Allyn, 2020), but this still represents a substantial hit to revenue streams. What is more, the cost of packaging pushes up the price of the at-home food delivery still further (e.g., see Mahe, 2015). Luke Johnson, the owner of Gail's Bakery as well as the former chairman of Pizza Express, had the following to say: *"I can't see how restaurants can make a profit if they have to hand over 35 per cent. And I don't really want to eat meals cooked on industrial estates that have been on the back of a moped for 20 minutes."* (Walters, 2020). The expense may be even harder to justify to consumers given that they already appear to have an unrealistic sense of the true costs involved in preparing and serving a meal in the context of a restaurant (Peters, 2016).

There is an important question here about the economics of providing a high-end meal experience at home. Bear in mind only that many restaurateurs find that their profits derive primarily from the sale of alcohol (Cowen, 2012), whereas producing the food itself tends to be more-or-less done "at cost" (Markwell, 2017). However, if dining at home, the wily customer might rightly question why they should be expected to pay the normal 300% mark-up for a wine or drink that they can likely acquire at a

[11] As Scattergood (2017) puts it: "Kahn's dishes, though expertly orchestrated from seasonal ingredients, are sometimes indistinguishable from the ceramics they're presented with, resembling not so much food as *objets d'art*."

[12] Notice also how the format of the bento box is perfectly adapted to remote consumption, with all of the elements served at room temperature, and tightly segmented in the sections of a molded tray, meaning that contents stay in place even when bento box is carried around.

[13] Indeed, the question has been raised in the press as to whether dark kitchens will do to independent restaurants what Amazon has already done to small local shops in UK and North America?

fraction of the price elsewhere. Such mark-ups may all too easily strike at-home diners as excessive, and diners can Google/buy wine much cheaper (e.g., Chung, 2008; Spence and Piqueras-Fiszman, 2014, p. 56). What is more, the food/wine pairings that are such a feature of many high-end dining experiences (see Spence, 2020e, for a recent review) are obviously going to be very difficult to deliver at home, given the standard 750-ml packaging of wines.

At the same time, however, craft cocktails have been rapidly emerging in the US, with many states changing their laws in order to allow for the delivery of home cocktail. With alcohol consumption increasing during the pandemic (Pollard et al., 2020; Zipursky et al., 2021; though see also Plata et al., submitted). As such, the impact of shifting to take-away are context-specific. Even beyond alcohol sales, though, the economics of take-away are highly variable. Alinea's highest revenue day ever occurred during the pandemic—though note that one of their co-owners is also a founder of Tock, a reservations and ordering website used by many high-end restaurants, which, or so it has been argued, may have given them an edge in rapidly pivoting their business model (Kludt, 2020). It may be that some high-end restaurants will opt to continue with some take-away options even post-COVID; special holiday events, especially when they require pre-order, can allow for restaurants to reach far more customers than they could possibly accommodate in-house, and with reduced front-of-the-house staffing. Now that many people have had the opportunity to try a Michelin-starred holiday dinner at home, will they want to go back to cooking such "event meals" themselves?

OPTIMIZING THE EXPERIENCE BY DELIVERING MORE THAN JUST DINNER

It is important to stress that the atmosphere is only a part of what makes a meal at a top restaurant so special (see Spence and Piqueras-Fiszman, 2014, for a review). Indeed, it has often been suggested that eating out is as much a social activity as anything else (see Spang, 2000; Julier, 2013; Spence, 2017a). Given the epidemic of loneliness that has resulted from lockdown (Klein, 2020), those offering food for home should really be thinking about how they can also offer hospitality[14]. For instance, Nick Kokonas, co-owner of Alinea, has talked about hospitality being "extended to the curb," by making sure to greet the customer by name when they come to pick up their meal (Kludt, 2020)[15]. Some restaurants include thank you notes in appreciation of support during difficult times.

Facilitating Digital Commensality

Given the growing social isolation, even before Covid struck (Spence, 2017a), it would seem that there is likely to be an important opportunity for those offering high-end dining to deliver company (perhaps digitally), and not just "sushi for one," say (see Spence et al., 2019a). After all, a number of commentators have predicted an epidemic of loneliness caused by the Coronavirus crisis (Klein, 2020)[16]. It would likely make sense to consider how the meal kit (or takeaway) can be used as a vehicle to deliver a social encounter.

As mentioned already, the pandemic and associated lockdown has seen a marked increase in solo dining. As such, there is a growing need for digital commensality (see Spence et al., 2019a, for a review). Indeed, given that dining is fundamentally a social activity, it is the shared social interaction that has been one of the most obvious casualties of the current series of lockdowns (see also Holmes et al., 2020). As such, this is what is most obviously missing currently for so many at mealtimes.

Various studies had already documented the dangers for those dining alone in terms of lowered mood, and impaired food behaviors—either consuming more (given how few foods are portioned for just one person) through to not eating enough as a result of the negative mood that can be associated with loneliness (see Spence, 2017b). In response to this enforced (and, by now, increasingly prolonged) social isolation that so many of us have been facing, there has been a growth in digital surrogates: Everything from Zoom cocktails (of which the authors have partaken, never having done so previously; Bernard and Bastone, 2020; Smith, 2020; Tilley, 2020; see also the concept of the Quarantini cocktail, Hubbard, 2020), Zumba classes (Barr, 2020), Skeating meals online (i.e., Skyping while eating; Bernard and Bastone, 2020), which was already predicted by Spence (2017b). More people are now cooking and sharing meals together online with friends and family using platforms like Zoom or Google Hangouts (Heil, 2020). Though our sense is that drinking together online is more popular than dining together.

Note also the role that social media can play, with Steak-umm, a frozen meat company, having established a following on Twitter for their scientific literacy and critical thinking advice (Bogomoletc and Lee, 2021). Some restaurants are directly engaging with the general public on platforms such as Facebook and Instagram. Diners can now preview their meals on Instagram, seeing the photos others have taken, building a sense of anticipation, and sharing images of their food can also help to facilitate connection (though envy can also be a consequence). For many, part of the joy of creating Alinea's desserts is the aesthetic experience, as much as merely just the gustatory satisfaction (Olsen, 2020a), as each creation is unique.

In social psychology, there is emerging evidence for "enclothed cognition:" the idea that what one wears can influence one's state of mind (Adam and Galinsky, 2012). For instance, wearing a tunic identified as nursing scrubs leads to greater empathy and altruism (López-Pérez et al., 2016), while people wearing police uniforms were more likely to shoot unarmed targets in a video-game simulation (Mendoza and Parks-Stamm, 2020). Might restaurants therefore encourage at-home diners to dress for the meal? One could imagine providing an apron or toque for some of the more DIY experiences, or suggesting colors

[14]Note also here how pre-Covid a number of restaurants were already targeting their offering to the solo diner (see Spence, 2017a).

[15]This, note, a version of the in-restaurant personalization that the restaurant is so famous for.

[16]Mukbang can perhaps be considered one of the solutions to digital commensality which has become surprisingly popular in the Far East over the last 5 years or so (e.g., in Korea; see Pereira et al., 2019).

or styles for the eating experience. Relevant here, according to the latest evidence, the clothing that people wear can exert an influence on their choice of healthy food (Wang et al., 2021b). Even the color of the napkins and the presence vs. absence of tablecloths has been shown to make a difference to the experience (see Spence, 2017a, 2021a).

Cooking Class/Advice

While restaurants simply cannot offer the at-home dining experience of being served, they can nevertheless potentially offer their guests the opportunity to become engaged in the creation, or at least the assembly, of their meals, which can lead to a greater appreciation of the food (e.g., Dohle et al., 2014; Spence, 2017a)[17]. Note that there has anyway already been growing interest in online cooking classes in recent years (e.g., Peters, 2020). For instance, Eleven Madison Park, in New York City, offered a foie-gras stuffed chicken to be roasted at home[18] as well as a $200 "truffle and eggs" dish consisting of six raw eggs, truffles, and instructions concerning how to cook an omelet (Goldfield, 2020). Meanwhile, the Vespertine x Alinea collaboration offered diners the chance to "Be the Chef" with a dedicated hotline that patrons could call should they require some culinary assistance (Hochman, 2020). A number of other top restaurants have also created videos designed to guide the customer through the process of proper heating/assembling/plating of the food as well as to give context about the courses/the ingredients. For example, at San Francisco's Atelier Crenn, each course has its own video. One can see gloved experts using tweezers to precisely arrange the component ingredients/elements (https://ateliercrenn.getbento.com/crenn-kit-luxe-menu/; https://vimeo.com/user115409838)[19]. Los Angeles's Providence's videos all feature their chef Michael Cimarusti, and, at times, become a little playful; for instance, a menu featuring black truffles from the Southern hemisphere was accompanied by a video that opens with Men at Work's song, "Down Under" (https://www.youtube.com/watch?v=ybomgEQN7AE).

In the UK, Kitchen Theory offered a complete home multisensory experience; For instance, in February, 2021, they offered Valentine's Day boxes incorporating a four-course meal, wine, scented candle and a curated Spotify playlist (https://kitchen-theory.com/valentinesday/). In March, there was a Mother's Day box with full afternoon tea, glass cake stand, rose atomiser, luxury tea selection, and another Spotify playlist (https://kitchen-theory.com/mothers-day-afternoon-tea/). Note here how both meal boxes came with a written guide for the recipient of the meal box on how to have a more multisensory experience at home and a zoom call with the chef ahead of the experience to help them with any questions that they might have.

Hence, rather than seeing the need for the end consumer to have to do some of the preparatory work on the food in a meal kit as a disadvantage, some chefs/restaurateurs have managed to turn their interaction with their customers to their own advantage.

Packaging, Cutlery, and Other Atmospheric Enhancements for In-Home Dining

Simply packaging high-end food in paper/cardboard or Styrofoam, like regular takeaway, and then instructing the consumer to stick it in the microwave/oven is obviously not going to set expectations of a high-end multisensory tasting experience in the mind of the customer. There is ample research demonstrating that packaging and serving/serviceware influence the meal experience (e.g., Iggers, 2007; Robinson et al., 2007; Field et al., 2009; Spence and Piqueras-Fiszman, 2014). Some restaurants have explicitly brought in multisensory aspects to the serviceware. At o.d.o. (a kaiseki speakeasy opened by Chef Hiroki Odo in New York's Flatiron District, https://www.odo.nyc/), the Valentine's Day meal came in a reusable box made of mulberry bark along with Japanese glassware and a playlist (Wiener-Bronner, 2021)[20]. Meanwhile, one of Vespertine's meals came with hand-crafted flatware made from coconut shells, handmade incense, a cedar spray, and even a selenite crystal[21]. Meanwhile, Niki Nakayama and Carole Iida-Nakayama of n/naka developed a cook-at-home meal kit that included a candle artwork and a musical playlist (Stueven, 2020).

The added extras are often what improves the offering, as in the case of the UK's Petersham Nurseries. According to one online source: *"The food is hearty and substantial, but what really elevates this particular offering is the added extras. As standard, it comes with a pair of beautiful gastro green candles to illuminate proceedings. But you can go the whole hog, with matching wine and premade cocktails—all the way up to a Petersham-inspired tablescape including Bertozzi tablecloths and napkins and Murano glassware."* (Anon, 2021). Meanwhile, at one point during the evolving series of lockdowns in the UK, The Fat Duck was, offering its diners a basket of goodies to take away to complete their meals, given the Government stipulation that all venues had to be closed, or stop serving food, by 10 p.m., before banning indoor dining altogether once again (cf. https://thefatduckgrouphampers.co.uk/).

Food tastes better if consumed with heavier cutlery (Michel et al., 2015). Furthermore, given the growing interest amongst some chefs and food designers in novel forms of food interaction. Novel forms of cutlery are not unusual, such as Kitchen Theory meals served without a fork. Consider only the opening jellyfish dish that was served wrapped around tweezers as part of the Gastrophysics chef's table (Youssef et al., 2019). At the other

[17]Note here that there is a whole line of gastrophysics research to be conducted around ascertaining the minimum conditions necessary to make the diner/consumer feel that they have contributed substantively to the creation, or finishing, of a dish (without their having to work too hard). Though, see also the long history on the role of adding fresh eggs to the powdered cake mix, which was supposed to be an essential part of making the North American homemaker really feel that they were making something for her family with love (Park, 2013).

[18]Roast chicken presumably an especially good choice as it may count as a comfort food (Spence, 2017b; see also Coppin, 2020).

[19]There is a sense in which this starts to come close to the immensely-popular Chef Steps (https://www.chefsteps.com/), or other chef-teaching apps or experiences, such as Masterclass (see also Peters, 2020; Pigott, 2020).

[20]Though, as of 15th March, 2021, the website states only that the restaurant is currently closed.

[21]If you were wondering about the Selenite Charging Crystal, according to the accompanying text: *"The gemstone of purification: This variety of gypsum stone can be amazing for shifting through energy blocks, bringing peace and purity to one's head and heart, and generally just ensuring that you stay protected and connected to the world around you."* So now you know!

end of the food spectrum, recognizing the importance of cutlery to the dining experience, McDonald's France have taken the decision when serving their "signature" gourmet burger (coming in at twice the price of their ordinary burger) to provide a knife and fork at all 1,400 of its French restaurants[22]. While much of the mainstream takeaway food is eaten with the hands, this approach is just much rarer in the context of high-end dining. Note here only how the provision of cutlery (e.g., in an Asian restaurant) can help to frame a meal.

In the world of product design, many companies have become aware of the power of unboxing (e.g., Kim et al., 2018). Apple, for instance, is well-known for taking great care to ensure consumers would have a positive emotional experience when opening up their new products (Lashinsky, 2012). These days there is even a YouTube genre of unboxing videos (Mowlabocus, 2020). Vespertine has managed to maintain continuity with the physical restaurant's black aesthetic by providing the food in sophisticated black boxes complete with black tissue paper that provides for a pleasurable unveiling experience (https://www.instagram.com/p/CMgJuWPJ0x-/). Meanwhile, n/naka's boxes are customized to each theme, but care is taken to ensure they are as visually appealing as possible (https://www.instagram.com/p/CExvlngBHLY/). By using higher-quality materials, restaurants can communicate the expectation that the ensuing food experience will also be a quality offering too. It is perhaps worth bearing in mind here that even the color of the napkins have been shown to affect the diner's impression/emotion (Navarro et al., 2020).

There has been growing interest at the high-end of more experiential dining to help the diner curate the multisensory atmosphere at mealtimes. This has involved everything from matching musical playlists through providing scented candles and aromatic scent sprays, and could, potentially at least, incorporate intelligent illumination recommendations too. After all, color-changing remote control lightbulbs are now cheap enough to be included, and ambient color has been shown to influence our food choice and flavor perception (see Robson, 1999; Spence et al., 2014; Cho et al., 2015; Robinson, 2016). That said, curated playlists and scent are perhaps the easiest elements to transfer from the restaurant to the home dining environment (cf. Fulberg, 2003; Guéguen and Petr, 2006).

However, by far the most widespread use of multisensory atmospheric elements, such as curated music to complement the experience of food, has been promoted by the big brands, including everyone from British Airways (Victor, 2014) through to Häagen-Dazs, and from Munchery to Just Eat. Krug champagne have also paired their Champagnes with "matching" musical playlists to help enhance the multisensory tasting experience of a high-end drink (Spence, 2017c). Meanwhile, Starbuck's Japan recently introduced the idea of simply by scanning a provided QR code, the consumers can have a sakura (cherry-blossom) latte under an AR-blooming tree (Tanquary, 2020). As such, there would seem to be great potential for home food delivery services, where the take-away, or meal, is delivered together with a curated music selection (e.g., a Spotify playlist) designed to enhance, or modify, the consumer's tasting experience: Relevant in this regard, just take Munchery and Google Play Music (e.g., Roncero-Menendez, 2015; Samuely, 2021) who teamed up to turn a simple meal into a dining experience. Twice a week from August 17th through September 11th, 2015, as part of the daily menu offering incorporated website custom playlists paired with specific dishes (e.g., "Coffee Shop Indie Radio" paired with chocolate cake, while "Sunny Patio Vibes" paired with a lightly grilled chicken dish). Here, it is worth highlighting the fact that this more experiential approach to the delivery of takeaway food was designed to be paired with mainstream (i.e., not high end) food offering.

Having realized just how important the atmosphere is to the experience of eating and drinking (see Spence and Piqueras-Fiszman, 2014), food and drinks brands are increasingly doing everything in their power to optimize the sonic backdrop when the consumer tastes their products. It really can make all the difference (see Spence, 2020d, 2021b, for a couple of recent examples).

In a project commissioned by Just Eat in 2017, one of your authors (C.S.) and his colleagues had more than 700 people evaluate of a range of styles of food (Indian, Italian, Thai, Japanese, and Chinese) while listening to one of 19 different music tracks, designed to cover a diverse range of popular musical styles (e.g., including jazz, pop, opera, etc.). The participants were invited to estimate the spiciness of the dish, how much they thought it was worth, and how appealing it looked. Amongst a number of other findings, the results showed that jazz music resulted in the takeaway dishes being rated as significantly more expensive (a 4% lift on average). In particular, across these different styles of takeaway food, the top tracks in terms of food evaluation were Feeling Good (Nina Simone) and One for my Baby (Frank Sinatra). There is also a role for matching the music to the cuisine. Nessun Dorma sung by Pavarotti gave rise to the highest ratings for the Italian food, there would also seem to be an element of ethnic matching too. By contrast, Justin Bieber's song Baby, and the absence of music, led to the lowest ratings for the takeaway meal options viewed online. Intriguingly, classical music has often been reported to increase food and drink sales in both stores and restaurants (see Spence et al., 2019, for a review). Taken together, such results support the suggestion that taking time to intelligently select an appropriate soundtrack may help to enhance the meal experience at home—assuming, that is, that those dining at home choose to access the recommended playlists (see Sanderson, 2015; Spence, 2015). In 2015, researchers were already predicting that CDs might be thrown in with take-away delivery (see Spence, 2017c)[23].

However, beyond simply using music to match, and hopefully enhance, the diner's experience of the meal, it might also be worth considering delivering an emotional experience. That is, it might pay off to determine whether the diners are interested in a romantic, an experiential, a comforting meal experience, and

[22]It has been suggested that this was, in part, in response to stiff competition from burger franchises, such as Five Guys (Barnes, 2017).

[23]While the format (CD) seems quaintly outdated nowadays, the emergence of curated playlists to match the food/drink is a rapidly expanding enterprise (Spence, 2019, 2020d).

thereafter coordinating the everything else to match. Relevant here, the first author (C.S.) has also been involved in a project to coordinate home delivery of meals with top TV shows offered by Sky Atlantic (Russell, 2017), partnering with a leading chef. So, for example, this led to Deliveroo serving a Game of Thrones themed meal. Meanwhile, other shows that were airing at the time, and for which a matching meal was designed included Riviera and Twin Peaks. However, in all these cases, the short-term nature of the pairing offering suggested that the companies concerned may have been more interested in the associated press headlines (that can result from pairing the senses in unexpected ways) than necessarily with long-term improvement of their customers dining experience.

CONCLUSIONS

It would seem that the most successful examples of high-end restaurant home food-delivery have not attempted to simply reproduce the dining-out meal experience for which they are best known in the context of dining-in. Rather they have used their brand to develop and deliver something that works given the constraints of food that will need to be finished at home (e.g., see Vespertine, Kitchen Theory Gastrophysics chef's table). Some of the more successful examples have obviously put a great deal of thought into the design of the packaging and presentation (e.g., see Vespertine). Ultimately, however, the challenge for high-end chefs, restaurants, and restaurant groups is one for gastrophysics (e.g., Robinson, 2015; Miari, 2020; Spence, 2020a). By adding more elements to the total multisensory tasting experience, such as music, scented candles, bespoke cutlery, culinary instruction, etc., it also offers the opportunity for chef to engage in a little Sensploration (Leow, 2015), which is itself becoming increasingly popular.

While the majority of examples have been taken from high-end meal box offerings, it should be remembered that several of the examples that have been discussed came from attempts to enhance regular takeaway offerings. Recognizing how lonely many people may be feeling during Covid also likely represents an important opportunity for restaurateurs. At the same time, however, it is also noticeable how the food has come down in price in many cases, and the offering has often been more oriented toward comfort foods. In closing, we should highlight the (narrow) focus of this review on UK/US fine dining scene. However, we also believe that the solutions to enhance experiential high-end dining would also be appropriate in other countries where there is an appetite for such experiential dining, and we have highlighted how the same approaches have been reported in Australia, Canada, and Japan as but three examples.

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All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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BRIEF RESEARCH REPORT
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Quarantine During COVID-19 Outbreak: Eating Behavior, Perceived Stress, and Their Independently Associated Factors in a Brazilian Sample

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The study aimed to assess the eating behavior [uncontrolled eating (UE), emotional eating (EE), and cognitive restraint (CR)], the perceived stress, and independently associated factors among Brazilians during the COVID-19 pandemic. An online survey was conducted and data about 1,368 participants were evaluated. Multivariate logistic regression models were performed to identify factors independently associated (socioeconomic, lifestyle, and eating habits data) with eating behaviors and perceived stress. Working in the COVID-19 frontline (OR = 2.19), increased food delivery (OR = 1.49), increased food intake (OR = 1.48), increased number of meals (OR = 1.13), and EE (OR = 1.05) were factors independently associated with UE. Variables that were independently associated with EE were: increased food intake (OR = 2.57), graduation in a non-health-related course (OR = 1.78), perceived stress (OR = 1.08), UE (OR = 1.07), and CR (OR = 1.02). Reduced snacking (OR = 2.08), female gender (OR = 1.47), having a higher degree (OR = 1.44), increased homemade meals (OR = 1.31), the higher difference in the frequency of instant meals and snacks intake (OR = 0.91), EE (OR = 1.01), not increased alcohol dose intake (OR = 0.57), and increased physical activity (OR = 0.54) were independently associated with CR. Perceived stress was independently associated with changes in the way of working or studying (OR = 2.48), worse sleep quality (OR = 2.22), younger age (OR = 1.06), and EE (OR = 1.02). This study indicates that socioeconomic variables, lifestyle, and eating habits were independently associated with the eating behaviors of Brazilians and perceived stress during the quarantine.

Keywords: feeding behavior, habits, pandemics, quarantine, life style, stress

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INTRODUCTION

The acute respiratory disease caused by the SARS-CoV-2 virus (COVID-19) has already affected individuals in 220 countries, areas, or territories (1). Globally, there have been more than 175 million confirmed cases and more than 3 million deaths (1). The spread of SARS-CoV-2 led health officials worldwide to take several measures, such as complete city locking down, building hospitals,

performing strict social distancing, and implementing sanitary measures. Despite the important effect against COVID-19, social distancing can lead to changes in the daily life of the population. There may be changes in access to food, in the habit of eating out (2), and even changes in food purchases by families due to the possibility of losing their jobs or having reduced income during this period (2). Food markets have access restricted and restaurants and bars have been closed, which may affect the food buying and consumption behavior (3, 4). It may further affect the choices of an individual to prepare their meals or buy premade food more often. Social distancing can affect eating patterns (5), promoting snacking, eating palatable meals, and increased alcohol consumption (6). People reported snacking more frequently (7), increased consumption of sweets and snacks rich in calories has been found in studies carried out during the quarantine in different countries (3, 5, 8).

Additionally, facing excessive daily information about the pandemic may cause stress (9). Most people usually change their eating behaviors when stressed, resulting in under or overeating, depending on the stressor severity (10). Furthermore, interruption of the work routine caused by the quarantine could result in boredom, which in turn is associated with a greater energy intake (11).

Some studies have focused on identifying eating habits change (2, 12), but information about the impact of the COVID-19 pandemic on eating behavior and perceived stress is still limited, especially in Brazil. It is believed that the pandemic has resulted in increased food delivery, food intake, number of meals, and emotional eating (EE) behavior in Brazilians. This study aimed to assess the eating behavior, the perceived stress, and their independently associated factors among Brazilians during the pandemic. These results may be useful to define strategies to minimize the problems observed and to encourage healthy behavior during the period of social distancing.

MATERIALS AND METHODS

Study Design

A cross-sectional online survey, based on a sample for convenience, was conducted from August 14, 2020, to September 9, 2020, approximately 5–5.5 months after the beginning of the social distancing measures in Brazil. At that time, Brazil showed the highest number of cases and deaths in Latin America, and it was the third country with the most cases in the world, behind only the United States of America and India. The lockdown measures implemented in Brazil included: suspension of non-essential activities (closing of restaurants, bars, shopping malls, and gyms), suspension of the activities of schools and universities and with the implementation of emergency remote education, the incentive to adhere to social and physical distance measures, among other issues addressed in Federal Law No. 13,.979, of February 6, 2020. Brazilian residents aged 18 years of age or older were invited to enroll in the study. Pregnant women, individuals under 18 years of age, and residents of other countries were excluded (**Figure 1**). The study was conducted according to the Declaration of Helsinki. The protocol was approved by the Research Ethics Committee of the Federal University of Viçosa, Minas Gerais, Brazil (Protocol number 35516720.5.0000.5153).

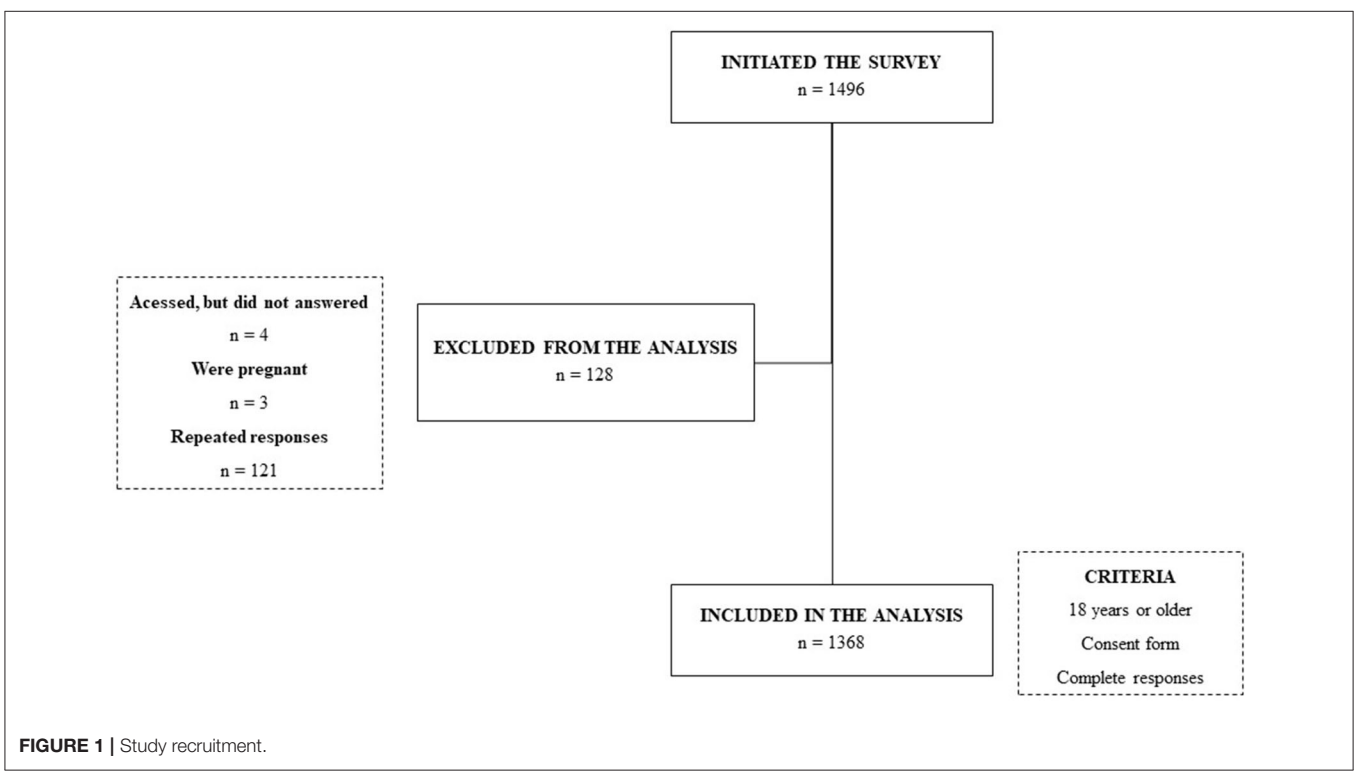

FIGURE 1 | Study recruitment.

Instrument and Procedure

The survey was created on Google Form Platform® and the link was shared *via* emails, university websites, and social media. The first part of the survey included the consent form. The answers of the participants were anonymous (only the emails of the participants were available), and they were able to stop their participation in the study at any stage before submitting the answers.

Eating behavior was assessed using the Brazilian version of the Three-Factor Eating Questionnaire (TFEQ-R21) translated into Portuguese and validated by Natacci and Ferreira Júnior (13). TFEQ-R21 measures eating behavior based on uncontrolled eating (UE), EE, and cognitive restraint (CR). The TFEQ consisted of 21 questions (a 4-point response format for items 1 to 20, and a numerical rating scale of 8 points for question 21). Responses to each of the questions were given a score between 1 and 4. Before calculating the scores, items 1–16 were reverse coded and item 21 was recorded as follows: 1–2 scores as 1, 3–4 as 2, 5–6 as 3, 7–8 as 4. The CR scale was composed of items 1, 5, 11, 17, 18, and 21. The UE scale was composed of items 3, 6, 8, 9, 12, 13, 15, 19, and 20. The EE scale was composed of items 2, 4, 7, 10, 14, and 16. The mean of each was calculated and transformed into a scale from 0 to 100 points as recommended in the score instruction (13). Perceived Stress (PS) was measured by a 10-item version of the Perceived Stress Scale (PSS) validated for the Brazilian population (14).

The other variables were divided into three sections: socioeconomic data, lifestyle, and eating habits. Socioeconomic data included questions about home state, gender, age, per capita income, the composition of home residents (posterior divided into groups of living with sons vs. others and living with parents vs. others), an education level (divided into groups of complete graduation course vs. incomplete graduation course or less, postgraduation or not, and graduation in a health-related course or not), current occupation (divided into professors or not, students or not, healthcare professionals or not, and workers in the line of the front of COVID-19 or not), working schedule during pandemic (perception of lower, unaltered, or greater time spent in work, including domestic activities), labor situation (alteration in the way of working or studying during a pandemic period or not, to study or work remotely full-time or part-time), and social isolation (total and partial or not).

As for lifestyle habits, participants were also asked about time and quality of sleep, amount of time of physical activity/week, smoking habit, alcohol consumption (dose and frequency), screen time (smartphones, computer, tablet, and TV) before and during the pandemic, and the differences were calculated. These variables were evaluated numerically and dichotomized into greater or not and lower or not about such habits.

Eating habits included differences in the number of meals (before and during a pandemic), the type of meals consumed (breakfast, morning snack, lunch, afternoon snack, dinner, evening snack, and other meals), amount of food, snacking (eating between meals), using food delivery service, habits of cooking at home, and food frequency (times a week) related to the periods before and during the pandemic.

A food frequency questionnaire based on the Food and Nutritional Surveillance System (SISVAN) protocol was used (15), with the following groups: legume (beans, soybeans, lentils, and chickpeas), cereal (rice, corn, and oats), bakery products (bread, cakes, and cookies), milk and dairy, fruit, meat, hamburger or canned products (hamburger, bologna, salami, and sausage), vegetables (except potatoes, cassava, and yams), sugary drinks (soft drink, canned or powdered juice, canned coconut water, guarana/blackcurrant syrup, and fruit juice with sugar), instant foods and snacks (instant noodles, packaged snacks, or crackers), candies (chocolate, pies, lollipops, gum, caramel, and jelly), and fast-food (pizza, sandwich, and finger food). The volunteers filled in information related to the time before and during pandemic for groups of foods and the differences were calculated. The frequency of consumption of the food groups was set to 0 for those who reported never consuming such food, 0.5 for those who reported consuming rarely, 1 for those who consumed once a week, 2.5 for consumption 2–3 times/week, 5 for consumption 4–6 times/week, 7 for consumption once a day, and 10 for more than once a day, and the differences between the frequency of consumption before and during the pandemic were calculated. When the differences were positive, they were classified as increased consumption and when they were negative, they were classified as decreased consumption. The consumption frequencies before and during the pandemic may be found in another study of the team (16).

Questions about lifestyle habits and eating habits were based on other online surveys performed during the COVID-19 pandemic (2, 5). To verify the adequacy and the response time of the questions, a pilot study was carried out with about 30 respondents.

Data Analysis

Data were analyzed using the software Statistical Package for Social Sciences® (SPSS® Inc., Chicago, IL, USA) version 21.0. Data are shown as median, minimum, and maximum values for independently associated factors and interquartile intervals for UE, EE, CR, and PS. Assumption of normality was checked using the Kolmogorov-Smirnov test. The correlations between eating behaviors and PS were obtained by Spearman's correlation test. To evaluate the factors independently associated with the eating behaviors and PS, univariate (by Chi-square and Mann-Whitney) and multivariate logistic regression models, respectively, were performed. The score obtained in each questionnaire was divided into the cutoff point of the third quartile (UE: 48.1, EE: 61.1, CR: 61.1, and PS: 28.0). The highest quartile was chosen because it represents 25% of the most extreme data. The same was performed by other authors that used some scales related to eating behavior (17, 18). The models were obtained by the backward method. The fit of the models was tested by the Hosmer-Lemeshow test ($p > 0.05$). The level of significance adopted was 0.05.

RESULTS

A total of 1,368 individuals were enrolled in this study (1,496 answers were computed, but four individuals submitted the

TABLE 1 | Socioeconomic factors, lifestyle, and eating habits of a Brazilian sample during the COVID-19 pandemic period.

Variables	% (*n*)[a] Median (min-max)[b]
Gender	
Female	80.0 (1,094)
Male	19.7 (269)
Age (years)	31.0 (18.0–87.0)
Per capita income ($)[c]	334.6 (15.9–3059.0)
Home residents	
Living with children	25.1 (344)
Living with parents	38.3 (524)
Education level	
Graduate or above	65.9 (902)
Undergraduate or below	33.9 (464)
Post-graduation	46.5 (636)
Health-related graduation course	49.6 (679)
Profession	
Student	45.3 (620)
Healthcare worker	19.4 (265)
Professor	17.3 (237)
COVID-19 frontline worker	6.1 (83)
Time spent at work (including household chores)	
Reduced	12.8 (175)
The same	21.3 (291)
Increased	65.9 (902)
Labor situation	
Full-time work/study	89.0 (1218)
Full/part-time work or study	40.6 (555)
Changes in the way of working or studying	70.7 (967)
Social isolation	
Total	57.2 (783)
Partial	39.8 (544)
No	3.0 (41)
Sleep time difference (hours)	0.0 (−5.5 to 8.0)
Increased sleep hours	43.1 (590)
Reduced sleep hours	31.1 (425)
Improved sleep quality	13.3 (182)
Worsened sleep quality	46.3 (634)
Screen time difference (hours)	3.5 (−8.0 to 14.0)
Increased screen time	64.6 (883)
Reduced screen time	2.0 (28)
Alcoholic beverage difference (times/week)	0.0 (−7.0 to 7.0)
Increased frequency of alcoholic beverage intake	17.9 (245)
Reduced frequency of alcoholic beverage intake	18.6 (254)
Difference in dose of alcoholic beverage intake	0.0 (−6.0 to 6.0)
Increased dose of alcoholic beverage intake	20.3 (275)
Reduced dose alcoholic beverage intake	11.7 (159)
Difference in number of cigarettes	0.0 (−10.0 to 32.0)
Increased number of cigarettes	1.2 (16)
Reduced number of cigarettes	0.5 (7)
Difference in physical activity (min)	0.0 (−280.0 to 280.0)
Increased physical activity	20.8 (285)
Reduced physical activity	43.3 (593)
Use of medication	40.4 (552)
Difference in number of meals	0.0 (−6.0 to 5.0)
Increased number of meals	23.1 (316)
Reduced number of meals	26.6 (364)
Increased food intake	58.6 (802)
Reduced food intake	16.2 (221)
Increased snacking	51.5 (704)
Reduced snacking	8.0 (110)
Increased using food delivery service	50.1 (686)
Reduced using food delivery service	13.5 (185)
Increased homemade meals	67.3 (921)
Reduced homemade meals	5.8 (80)

(Continued)

TABLE 1 | Continued

[a] *Chi-square was used in univariate analyses in category variables.*
[b] *Mann-Whitney was used in univariate analyses in continuous variables.*
[c] *R$1 = $0.18 (current value).*

questionnaire and did not answer, three women were pregnant and there were 121 repeated answers). The responders were from the five regions of Brazil, but most participants (89.6%) reside in the southeast region.

Socioeconomic, Lifestyle, and Eating Habits Status

The median age of volunteers was 31 years old (varying from 18–87), and most responders were female (80%). Regarding the profile of home residents, 38.3% lived with parents and 25.1% lived with children. Most of the responders were graduates (65.9%), 46.5% attended postgraduation courses, and 49.6% were graduates in a health-related course. Most participants of the study reported increased time spent at work (65.9%), to be working or studying remotely full or partial-time (70.7%), and changes in the way of working or studying during the pandemic (89%). Furthermore, 57.2% related total social isolation during the pandemic.

Many respondents reported decreased sleep time (31.1%) and worsened sleep quality (46.3%) during quarantine. There was a positive difference in screen time with a median of 3.5 h, and 64.6% of participants showed longer screen time during the pandemic. The frequency of alcoholic beverages intake was increased by 17.9% of individuals, but 18.6% reported reduced frequency consumption and 20.3% increased the dose of alcoholic beverages consumed. Only 1.2% of the respondents related to increasing cigarette use and 43.3% reduced the physical activity time.

Regarding eating habits, food intake increased in 58.6% of the participants, and 51.5% reported snacking more frequently. The use of delivery food and homemade meals increased by 50.1 and 67.3%, respectively (**Table 1**).

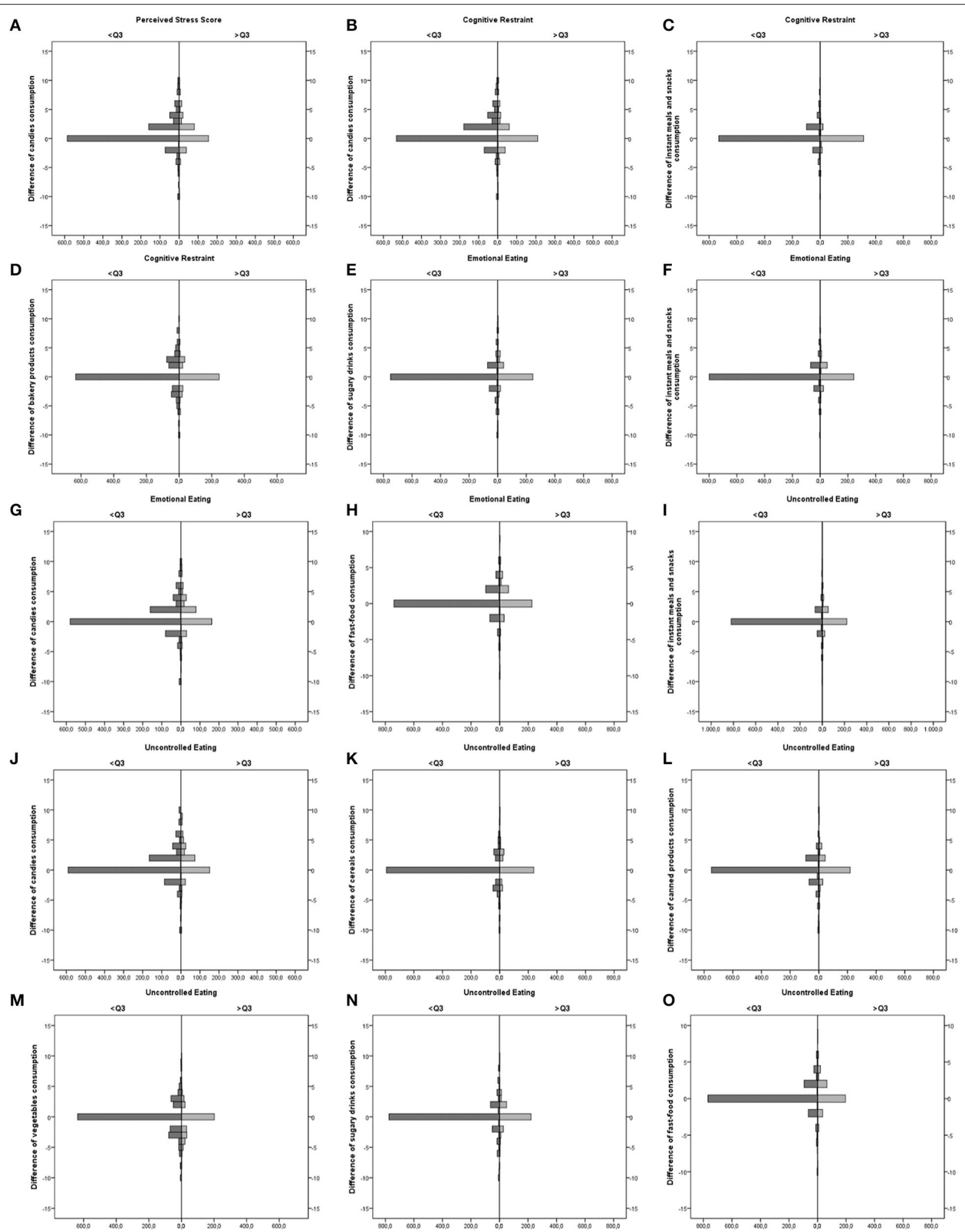

FIGURE 2 | Difference of food consumption among Brazilians who were under and above the third quartile of perceived stress, cognitive restraint (CR), emotional eating (EE), and uncontrolled eating (UE) scores. **(A)** Difference of candies consumption among Brazilian who were below and above the 3rd Quartile of Perceived

(Continued)

FIGURE 2 | Stress score; **(B)** Difference of candies consumption among Brazilian who were below and above the 3rd Quartile of Cognitive Restraint score; **(C)** Difference of instant meals and snacks consumption among Brazilian who were below and above the 3rd Quartile of Cognitive Restraint score; **(D)** Difference of bakery products consumption among Brazilian who were below and above the 3rd Quartile of Cognitive Restraint score; **(E)** Difference of sugary drinks consumption among Brazilian who were below and above the 3rd Quartile of Emotional Eating score; **(F)** Difference of instant meals and snacks consumption among Brazilian who were below and above the 3rd Quartile of Emotional Eating score; **(G)** Difference of candies consumption among Brazilian who were below and above the 3rd Quartile of Emotional Eating score; **(H)** Difference of fast-food consumption among Brazilian who were below and above the 3rd Quartile of Emotional Eating score; **(I)** Difference of instant meals and snacks consumption among Brazilian who were below and above the 3rd Quartile of Uncontrolled Eating score; **(J)** Difference of candies consumption among Brazilian who were below and above the 3rd Quartile of Uncontrolled Eating score; **(K)** Difference of cereals consumption among Brazilian who were below and above the 3rd Quartile of Uncontrolled Eating score; **(L)** Difference of canned products consumption among Brazilian who were below and above the 3rd Quartile of Uncontrolled Eating score; **(M)** Difference of vegetables consumption among Brazilian who were below and above the 3rd Quartile of Uncontrolled Eating score; **(N)** Difference of sugary drinks consumption among Brazilian who were below and above the 3rd Quartile of Uncontrolled Eating score; **(O)** Difference of fast-food consumption among Brazilian who were below and above the 3rd Quartile of Uncontrolled Eating score.

Eating Behaviors and Perceptive Stress: Independently Associated Factors

The respective median scores for UE, EE, and CR were 33.9 (interquartile interval: 18.5–48.1), 44.5 (interquartile interval: 27.8–61.1), and 39.5 (interquartile interval: 11.1–61.1) points. PS showed a median of 22.9 (interquartile interval: 19.0–28.0) points. The UE behavior was significantly and positively correlated to all the other behaviors and PS (EE: $r = 0.098$; CR: r = 0.714; PS: $r = 0.257$; $p < 0.001$ for all) and so the EE behavior (CR: $r = 0.171$ and PS: $r = 0.334$). However, the correlation between CR behavior and PS was significantly negative ($r = -0.030$). Variables associated with UE, EE, CR, and PS above the third quartile by univariate analyses are found in the **Supplementary Material**.

The significant difference in the frequency of food consumption (before and during the pandemic period) among the respondents who were under and above the third quartile of PS, CR, EE, and UE scores are shown in **Figure 2**.

The multiple logistic regression analysis is summarized in **Table 2**. Factors that independently increased the probability of being in the highest quartile of UE score were: being a COVID-19 frontline worker (OR: 2.196; CI: 1.233–3.911), increased food delivery (OR: 1.498; CI: 1.105–2.031), increased food intake (OR: 1.483; CI: 1.049–2.097), increased number of meals (OR: 1.483; CI: 1.049–2.097), and emotional eating (OR: 1.054; CI: 1.047–1.061). Increased food intake (OR: 2.579; CI: 1.817–3.660), graduation in another non-health-related course (OR: 1.785; CI: 1.305–2.443), PS (OR: 1.080; CI: 1.052–1.108), UE (OR: 1.078; CI: 1.068–1.088), and CR (OR: 1.020; CI: 1.012–1.028) increased the probability of being in the highest quartile of EE score. Finally, factors positively and independently associated with CR were: reduced frequency of snacking (OR: 2.080; CI: 1.376–3.144), female gender (OR: 1.468; CI: 1.447–2.053), graduate status (OR: 1.443; CI: 1.097–1.893), increased frequency of homemade meals (OR: 1.314; CI: 1.004–1.722), increased difference in the frequency of ultra-processed food intake (OR: 0.91; CI: 0.849–0.981), and EE score (OR: 1.007; CI: 1.003–1.012). On the other hand, unincreased alcohol dose intake (OR: 0.573; CI: 0.405–0.811) and increased physical activity time (OR: 0.537; CI: 0.402–0.711) decreased the chance of being in the highest quartile of CR score. About PS, factors independently associated were: changes in the way of working or studying during quarantine (OR: 2.480; CI: 1.470–4.183), worsened sleep quality (OR: 2.222; CI: 1.700–2.904), younger age (OR: 1.069; CI: 1.053–1.085), and EE (OR: 1.016; CI: 1.012–1.021).

TABLE 2 | Factors independently associated with the last quartile of the eating behaviors and stress among Brazilians during the pandemic period in multivariate analyses.

Behaviors	OR	CI (95%)		*P*-value
		Lower	Upper	
Uncontrolled eating (82.0% of prediction; Hosmer Lemeshow test = 0.278)				
Frontline worker	2.196	1.233	3.911	0.008
Increased using food delivery service	1.498	1.105	2.031	0.009
Increased food intake	1.483	1.049	2.097	0.026
Increased number of meals	1.135	1.003	1.284	0.044
Emotional eating	1.054	1.047	1.061	<0.001
Constant	0.016			<0.001
Emotional eating (83.2% of prediction; Hosmer Lemeshow test = 0.356)				
Increased food intake	2.579	1.817	3.660	<0.001
Graduation in a non-health-related course	1.785	1.305	2.443	<0.001
Perceived stress	1.080	1.052	1.108	<0.001
Uncontrolled eating	1.078	1.068	1.088	<0.001
Cognitive restraint	1.020	1.012	1.028	<0.001
Constant	0.001			<0.001
Cognitive restraint (72.7% of prediction; Hosmer Lemeshow test = 0.099)				
Reduced snacking	2.080	1.376	3.144	0.001
Female gender	1.468	1.447	2.053	0.024
Graduate or above	1.443	1.097	1.893	0.009
Increased homemade meals	1.314	1.004	1.722	0.047
Higher difference in ultraprocessed food	0.916	0.849	0.981	0.017
Emotional eating	1.007	1.003	1.012	0.001
No increase in alcohol dose intake	0.573	0.405	0.811	0.002
Increased physical activity (hours practiced)	0.537	0.402	0.711	<0.001
Constant	0.323			<0.001
Perceived stress (75.4% of prediction; Hosmer Lemeshow test = 0.851)				
Change in the way of work or study during pandemic period	2.480	1.470	4.183	0.001
Worsened sleep quality	2.222	1.700	2.904	<0.001
Younger age	1.069	1.053	1.085	<0.001
Emotional eating	1.016	1.012	1.021	<0.001
Constant	0.412			0.020

DISCUSSION

The findings revealed that many respondents showed altered habits during the COVID-19 pandemic. Sleeping changes and physical activity reduction were observed, as found by Ammar et al. (12). Increased number of daily meals, increased food intake, snacking, increased use of food delivery, and homemade meals were also verified. Likewise, changes in diet during the pandemic have also been previously reported (2, 5). Studies carried out with Brazilian samples also found negative changes in eating habits (19, 20).

Furthermore, people during quarantine might experience severe disturbances in eating behavior, such as extremely reduced food intake or overeating, which could increase body weight and shape concerns (21). The lack of data about the eating behavior of Brazilians during the COVID-19 pandemic and the use of different questionnaires in other populations during quarantine limit comparisons. However, volunteers of the present research reported similar scores of EE [44.5 (27.8–61.1)] and lower scores of UE [33.9 (18.5–48.1)] and CR [39.5 (11.1–61.1)] in comparison to the study of de Medeiros et al. (22), performed before the pandemic, with healthy adult Brazilians (EE: 45.8 $\pm$ 29.2; UE: 55.6 $\pm$ 25.0, and CR: 70.8 $\pm$ 25.0). However, Papandreou et al. (23) found higher scores of eating behaviors in the Spanish and Greek population than other pre-COVID-19 data, supporting the idea that these behaviors may be affected during quarantine. Elmacioglu et al. (24), in a study that evaluated the eating behavior during the social isolation in the COVID-19 pandemic, found an increase in the EE and UE of individuals, but no significant changes in CR occurred.

In this study, the number of meals, food intake, and use of food delivery increased the chance to have UE scores in the highest quartile in 13.5, 48.3, and 49.8%, respectively. Increased food consumption and changes in eating behaviors are frequent in subjects ordered to follow stay-at-home during the pandemic (5). In the present study, the highest quartile of the behaviors studied was associated with differences in the frequency of candies (PS, CR, UE, and EE), instant meals and snacks (CR, UE), bakery products (CR), sugary drinks (EE, UE), cereals (UE), canned product (UE), vegetables (UE), and fast-food (EE, UE) consumption (**Figure 2**).

Furthermore, COVID-19 frontline workers showed a 2.2 higher chance to have greater UE scores. Beyond the risk of exposure to COVID-19 by contact with patients and coworkers, healthcare workers are under increasing stress and mental health risks due to higher workload, shortages of protective equipment (25), death of their colleagues after exposure to the virus, and fear of spreading it to their families (26). The context experienced by these workers may probably have contributed to the higher UE scores observed in this study.

Individuals with higher scores of EE showed higher chances to have UE scores above the third quartile. Studies have attempted to identify the influence of emotions on food consumption (27, 28). Humor and emotions can influence food choice, in the same way, that consumption of certain foods can change a mood or emotional state (27). People who have EE seem to be more susceptible to the effects of stress and may try to obtain comfort through food (29). Stress may promote irregular eating patterns and strengthen networks toward hedonic overeating, choosing more pleasurable, and palatable foods irrespective of caloric intake changes (30). In an Italian study (9) carried out during the COVID-19 pandemic, almost half of respondents felt anxious about their eating habits, consumed comfort foods, and increased food intake to feel better.

Emotional eating is related to the tendency of individuals to overconsumption of food in response to negative emotional stimuli (13). Increased food intake and UE, CR, and PS were associated with higher scores of EE. These results indicate that EE is determined by other eating behaviors and by PS, and probably affected food choice, as the strong association among EE and an increase in food intake during quarantine. Emotional factors probably impede the control of food intake in situations of stress. The EE behavior can occur as a coping strategy concerning negative emotions (31). Other authors reported the association between stress and eating behavior of EE (30, 31). In a study carried out during the COVID-19 outbreak, in which the majority (73.6%) of the participants reported moderate to high levels of perceived stress, the EE was significantly correlated with four of the nine reasons for food choice: mood, convenience, price, and familiarity (32). In a study conducted with mothers from Los Angeles, California, the authors observed that the most common strategy that mothers indicated to deal with stress related to COVID-19 was to eat comfort foods (e.g., sweets and snacks) (58.7%). The PS related to COVID-19 was positively associated with the BMI of the mother and emotional eating (33).

In the present study, EE was a factor independently associated with CR, increasing the chance of individuals to show a higher CR score. A positive correlation between CR and EE was also previously observed in a cohort study (34), reporting that the CR impairment can leave the individual vulnerable to emotional eating and more reactive to sensory or cognitive exposure linked to food. The cognitively restricted individual imposes a set of dietary obligations and prohibitions to maintain or lose weight, but many of them, when exposed to certain situations, such as stress, tend to overeat (28). Restrained eaters may become hypervigilant to threat stimuli, accentuated by having to remember these during eating, at the expense of maintaining self-awareness or monitoring dietary concerns and goals (35).

In this study, individuals who practiced more physical activity and those who did not increase their alcohol dose intake showed 46.3 and 42.7% less probability of being CR scores above the third quartile, respectively. CR has been previously associated with higher cortisol levels which can activate the stress response (36). It is well-recognized that sustained exercise may influence basal cortisol levels (37) and might affect the response to stressors (38). Although, high restraint scores have been associated with more hours of weekly exercise (39), these findings have not been shown in the study. The relation between alcohol intake and CR has been reported previously, as restrained behaviors of individuals show disinhibition/impulsive episodes of food eating as the binge drinking ones (40). Hunt and Forbush (41) found that CR predicted the presence of alcohol misuse and drunkorexia in college students.

In contrast to what was expected from the pandemic, increased food intake was not associated with CR. Other factors such as female gender, graduation, reduced snacking, and increased frequency of homemade meals to the period before the pandemic increased the probability of individuals having higher CR scores. On the other hand, a higher frequency of ultra-processed food intake reduced the probability of higher CR scores. Regarding gender, studies have shown that many young women are motivated to both obtain and maintain their perceived ideal body shape (42). Furthermore, women who constantly monitor their bodies tend to put an extreme emphasis on outward appearance and weight and are also more likely to be motivated in adopting stressful behaviors to obtain a body that meets societal expectations (43).

In relation to PS, the multivariate model indicated that changes in the way of working or studying in relation to the period prior to the pandemic showed a 2.48 higher chance to produce PS scores above the third quartile. The results showed that most participants related changes in their way of work or study and increased time spent at work. During the pandemic, corporations and governments encouraged the practice of working from home to reduce exposure to COVID-19 (44). However, the responsibilities of people were amplified, including teleworking, doing domestic activities, minding their children, and facilitating homeschooling (44).

Sleep quality, younger age, and higher EE score were also factors independently associated with PS. Sleep deprivation is a common chronic stressor that may contribute to an increased risk of obesity and metabolic diseases (45). However, long-term studies that may assess the relationship between stress during the pandemic and the outcomes of chronic disorders have not yet been published. Additionally, the social isolation necessary to flatten the epidemic curve restricts young people from having physical contact with friends, causing increased feelings of loneliness, and stress (46). The relationship between stress and emotional eating has been discussed previously in this study.

PS showed a median of 22.9 (interquartile interval: 19.0–28.0) points. During the pandemic, other studies showed moderate (total mean scores between 14 and 26) or high- stress levels (total mean scores between 27 and 40) in most participants (32, 47). Considering these cutoff values, 88% of the volunteers showed moderate or high-stress levels, and 26.1%, high levels. COVID-19 is a stressor with great impact and unknown long-term implications, but may not be stressful or cause the same degree of stress for everyone (48).

The main limitation of this study is related to the lack of data about the eating behavior of participants and PS before the pandemic or the lack of a comparison group that has not been through isolation during the COVID-19 outbreak. Longitudinal studies are necessary to explain better the association of the pandemic between eating behavior and perceived stress. The studied sample may not be representative of the entire Brazilian population since the number of respondents was higher in the Southeast region and most participants were women. Also, other limitations may involve the self-reported data and the fact that only individuals who had access to a computer and were technically savvy may have taken this study. Despite these limitations, this research contributes to a better understanding of pandemic effects on eating behavior and stress.

We observed that many individuals experienced modification of their habits, manifested by reduced sleeping time, worsened sleep quality, increased frequency in consuming alcoholic beverages, reduced physical activity, and increased food intake. Working in the pandemic and increased food delivery were some of the factors associated with the eating behaviors. Perceived stress was associated with changes in the way of working or studying and by worse sleep quality.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because the database is being used for other studies by the research group that has not yet been published. Requests to access the datasets should be directed to Ceres Mattos Della Lucia, cmdellalucia@ufv.com.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Research Ethics Committee of the Federal University of Viçosa, Minas Gerais, Brazil (Protocol number 35516720.5.0000.5153). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

JL, LA, LF, LO, and CD participated in the design of the project, analysis, and interpretation of the data. The orientation and critical review of the content were carried out by JL, LA, LF, and CD. All the authors were responsible for the final approval of the version to be published.

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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.2021.704619/full#supplementary-material

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Food Consumption Behavior of Pakistani Students Living in China: The Role of Food Safety and Health Consciousness in the Wake of Coronavirus Disease 2019 Pandemic

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The emergence of coronavirus disease 2019 (COVID-19) has considerably changed global food production, processing, and consumption at different levels. Sojourners are among those who have experienced a higher level of food insecurity during the crisis of the COVID-19 outbreak. The current research aimed to investigate the immediate consumption behavioral intentions of the Pakistani international students in the People's Republic of China (PRC) during the wake of COVID-19 pandemic. This study applied the Theory of Planned Behavior (TPB) and background factors of food safety and health consciousness that influence the consumption behavioral intention of Pakistani students toward unfamiliar local food in China. A relational model was analyzed where food safety and health consciousness were hypothesized to serve as background variables associated with TPB components. Moreover, the indirect effects of food safety and health consciousness on behavioral intentions were assessed. The data were collected through convenience samples from 462 Pakistani international students and were analyzed through partial least square structural equation modeling (PLS-SEM). The results confirmed that food safety and health consciousness were positively associated with attitude (ATT), subjective norm (SN), and perceived behavioral control (PBC). However, food safety and health consciousness were indirectly associated with the behavioral intention only through ATT and SN. The results highlighted the role of food safety and health consciousness as important antecedents of classical TPB components that affect intentions and behaviors to avoid unfamiliar local food in a migrated context. The present study provides enlightenment to those who aim to investigate the consumption behavioral intentions of sojourners in the wake of the pandemic situation based on food safety and health consciousness. The findings of the current study are also applicable to general consumption patterns in the food sector.

Keywords: COVID-19, sojourners in China, food safety, health consciousness, Theory of Planned Behavior, PLS-SEM

INTRODUCTION

Coronavirus disease 2019 (COVID-19) is an infectious disease caused by the novel coronavirus, severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2). It is a highly contagious disease identified in late December 2019 and declared as a global pandemic by WHO on 11 March 2020 (COVID-19 Dashboard, 2020). Initially identified in the city of Wuhan (Hubei, China), the ongoing COVID-19 has spread globally, and as of 21 February 2021, caused 110,749,023 confirmed cases and 2,455,131 deaths worldwide (COVID-19 Dashboard, 2021). Based on some evidence (not the firm), the first infections of the disease were linked to Hunan Seafood Market, located in Wuhan city (Laborde et al., 2020). The sequencing technology of genes showed that the SARS-COV-2 poses a similarity in gene sequence with the bat coronavirus up to 96.2%, thus suggesting bats as the possible source of the disease (Zhou et al., 2020).

The emergence of COVID-19 has considerably changed global food production, processing, and consumption at different levels. The concerns for individual hygiene and consumer behavior have been significantly shifted with the prevalence of COVID-19 (Olaimat et al., 2020). The increasing health and food safety concerns have turned the behavior of the consumers toward a healthier and more sustainable direction, resulting in the avoidance of unfamiliar food products (Butu et al., 2020). For instance, the results of Qi et al. (2020) revealed that the COVID-19 crisis had influenced the perceptions and attitudes of consumers toward green foods. Shreds of evidence suggest that the ongoing pandemic crisis has a considerable influence on the life and consumption behavior of the sojourners (Liyanage, 2020; Morales et al., 2020). However, none of the studies have systematically investigated the food consumption behavior of the sojourners in the context of the COVID-19 pandemic. Sojourners are among those who have experienced a higher level of food insecurity during the coronavirus outbreak. Recently, researchers have attempted to explore the food patterns of the sojourners, which provide a comprehensive description of motivational factors of the food preferences of the sojourners during their sojourning (Brown et al., 2010; Wu et al., 2016; Xuhui et al., 2018; Yu et al., 2019). Research attention toward food consumption of the sojourners during COVID-19 is yet limited, rendering it a challenge for the destination marketers, tourism and hospitality businesses, and policymakers. The current research contributes to the scarce literature on the food preferences of the sojourners during the COVID-19 pandemic, concerning food safety and health consciousness. This research significantly aims to investigate the consumption behavioral intention of Pakistani students living in People's Republic of China (PRC) during the COVID-19 pandemic.

The PRC has become a hot corner for an increasing number of expatriates and is ranked as a highly attractive destination for foreigners in 2017 (HSBC Holdings plc, 2017). Besides, the Chinese Ministry of Education has enrolled enormous academic sojourners, which created a reputation as a regional center for education (Global Times, 2020). In 2019, there were 492,185 international students from 196 countries studying in PRC, where Pakistan was ranked as the second-highest number of international students (TRIBUNE, 2019). The strong bilateral relations between the two countries and China Pakistan Economic Corridor (CPEC), has set China as the top education destination for Pakistani international students. With the increasing number of Pakistani academic sojourners and their contribution to the economic and education sector of China, it is crucial to clearly understand the challenges they face during their stay in PRC. Their move to the new Chinese cultural environment with key communication barriers, cultural and social disparities, economic imbalance, and consumption differences represent the most traumatic situation they can experience. In this situation, some level of food shock is unavoidable. To the best of our knowledge, none has attempted to investigate the consumption behavior of Pakistani students living in China, particularly during the COVID-19 pandemic, leaving a knowledge gap to understand this potential market segment.

The traditional Pakistani culture is food-centered (Usman et al., 2020). Pakistani foods form part of the collectivistic cultural and religious identity, where group membership is essential (Sadia et al., 2021). Given its religious and robust cultural importance to Pakistani food, it is not surprising that Pakistani consumers have stronger ethnic and food retention when traveling abroad (Kamran, 2021). Mirza (2020) investigated that the second and even third-generation Pakistani immigrants living in the UK, daily consume Pakistani food and prefer to choose Pakistani restaurants when eating outside. Despite being strongly attached to the traditional Pakistani food, most young Pakistani consumers prefer to consume global food brands on several occasions (Sadia et al., 2021). However, due to the scant research on Pakistani students living in China, it remains uncertain if they are inclined to show similar interest in the local Chinese or global food brands after their initial arrival in China. Besides, with the emergence of COVID-19, consumers today are more resistant to consuming unfamiliar food, specifically in a migrated or expatriated context where they have less information regarding the safety of local foods (Morales et al., 2020). The current situation leads to increased health and safety concerns that negatively affect local or unfamiliar food consumption (Leone et al., 2020; Olaimat et al., 2020; Qi et al., 2020). Therefore, due to the increasing number of Pakistani students, food uncertainties, and recent scandals in the Chinese food market, diverted the intentions of the authors to conduct contemporary research that is more predictable and pertinent to the new circumstances.

THEORETICAL BACKGROUND

During the last decades, the food choices of consumers have been thoroughly investigated. The literature has acknowledged several socio-psychological theories which act as foundations to investigate food consumption patterns. Based on the intricacy of food choices, this research approaches to employ the Theory of Planned Behavior (TPB) as a theoretical basis to investigate the intended consumption behavior. The TPB emphasizes on precise interested behavior which offers a complete model

that explains/understands the factors determining the interested behavior. The TPB proposes that specific behavior (BEH) is evaluated through the intention to perform it (Ajzen, 2002). The intention is the direct precursor of the actual behavior, which captures motivations and cognitive planning. The intention is further determined by three main variables, such as personal attitude (ATT), subjective or social norm (SN), and perceived behavioral control (PBC) (Ajzen, 2012). Over the decades, the TPB has played a vital research role in various disciplines. Many studies have demonstrated the relationship of the prediction power of TPB with the consumption behavior of individuals (Bonne et al., 2007; Singh and Verma, 2017; Soon and Wallace, 2017; Ting et al., 2017; Ali et al., 2018; Giampietri et al., 2018; Mohd Suki and Abang Salleh, 2018; Canova et al., 2020) that justify its application in the current research.

AIMS AND HYPOTHESIS

Subsequent to TPB, firstly, the current research aims to predict and explain the consumption behavioral intentions of young Pakistani international students to retain Pakistani food in a migrated context, particularly during the crisis of COVID-19. Secondly, the study aims to investigate how concerns about food safety influence the behavioral intentions of Pakistani students to avoid unfamiliar or local food during their sojourning during the period of COVID-19. Thirdly, based on the prime reason for health concerns, this study aims to investigate the influence of health consciousness on the behavioral intentions of Pakistani students to avoid unfamiliar food products.

Attitude refers to the psychological tendency that describes the self-performance evaluation of an individual, which predicts intentions and, consequently, the actual behaviors. It implies the degree of positive or negative evaluations toward a behavior (Ajzen, 2002). Numerous studies have reported the positive associations between attitude and intentions to perform the behavior of interest (Azam, 2016; Singh and Verma, 2017; Xu et al., 2020). Similarly, several studies have reported significant positive relationships between intentions and attitude toward consuming ethnic food (Leung, 2010; Arvela, 2013; Ayyub, 2015; Ting et al., 2019). Chang et al. (2010) investigated that Chinese tourists have a positive attitude toward consuming Chinese food when traveling abroad. Based on the previous results, we argue that local Chinese food can be attractive to Pakistani students, but their unfamiliarity is also an obstacle for consumption; therefore, we hypothesize that:

> H1. Attitude has a significant positive effect on the intentions of Pakistani students to avoid unfamiliar local food and retain Pakistani food consumption during their sojourning in China, particularly during the period of COVID-19.

Apart from the attitudinal effect, social influence also plays a vital role in the specific food consumption behavior. The said influence is termed as SN in TPB. It reflects the perceived external pressure on individuals either to perform the behavior or not to perform the behavior (Ajzen, 2011). Park (2000) defined SN as the sentiment of the individuals with regard to the social pressure received from important referents. Mohd Suki and Abang Salleh (2018) argued that the social/religious groups form the foundations of community life, eventually leading them to grasp strong social values with other individuals living in the same communities. In this case, those who highly consider themselves as a part of the social group will be highly motivated to comply with the group members (Ali et al., 2018). Wu et al. (2016) investigated that the social pressure on the Chinese tourists to avoid unfamiliar local food negatively affects their intention to consume unfamiliar food. Consequently, we hypothesize that:

> H2. Subjective norm has a significant positive effect on the intentions of Pakistani students to avoid unfamiliar local food and retain Pakistani food consumption during their sojourning in China, particularly during the period of COVID-19.

Behavioral control means "the perceived easiness/difficulty to conduct the behavior of interest" (Ajzen, 2002). The PBC predicts both intention and actual behavior; however, the strength of the relationship between the behavioral control and intention differs across studies (Canova et al., 2020). In many cases, PBC has a substantial positive effect on the intention to consume a specific kind of food (Moser, 2016; Carfora et al., 2019; Lim and An, 2021); whereas, in some cases, the relationship was insignificant (Ayyub, 2015; Wibowo and Ahmad, 2016; Ali et al., 2018). Similar deliberations were found in the context of several ethnic foods (Bonne et al., 2007; Ting et al., 2016, 2019). The conflicting arguments of researchers may be associated with the availability of the investigated food for a specific group (Mohd Suki and Abang Salleh, 2018) which helps them to grasp control over the desired behavior. Conversely, individuals who fail to grasp control will not be able to perform the behavior. Based on the above discussion, we hypothesize as follows:

> H3. PBC has a significant positive effect on the intention of Pakistani students to avoid unfamiliar local food and retain Pakistani food consumption during their sojourning in China, particularly during the period of COVID-19.

Suggested by academic literature, TPB allows some background variables (e.g., self-identity, risk perception, trust, perceived attributes, and past experiences) which can act as potential factors to influence the belief of an individual. The integrated TPB model proposed in the current research (**Figure 1**), considered food safety and health consciousness as background variables. In fact, food safety and health consciousness are the behavioral determinants whose nature and importance in a migrated context may be relevant for all TPB constructs (Wu et al., 2016; Singh and Verma, 2017; Hansen et al., 2018), particularly in the current situation of COVID-19 (Olaimat et al., 2020; Qi et al., 2020).

In the migrated context, food safety and health concerns are major issues. Unhygienic food practices and consuming unfamiliar/local food can be a potential threat to the health of the sojourners (Wu et al., 2016; Yen et al., 2018). Mostly, not even after the consumption of unfamiliar local food, the sojourners can verify whether the food was hygienic, safe, and healthy (Xuhui

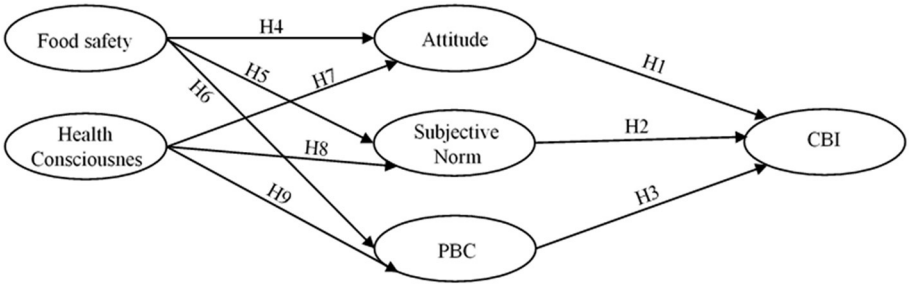

FIGURE 1 | Hypothesized model.

et al., 2018). The food safety concerns in the migrated context can act as a potential barrier for sojourners to consume unfamiliar local and non-ethnic food. Consequently, in situations like COVID-19 outbreaks, it is important to thoroughly investigate the role of food safety and health consciousness with its strength to influence food consumption behavior.

Food safety describes the handling, processing, preparing, and storing the food in ways that help in preventing food-borne diseases (Gerard Fitzsimmons, 2012). The frequent food safety incidents and scandals in the Chinese food market, including the emergence of COVID-19, have increased the greater concerns of the sojourners with regard to food safety during their sojourning in China (Leone et al., 2020). During the emergence of COVID-19, the foodservice operators were among those who experienced the direct impact of the pandemic, which caused the potential source of infection (Aday and Aday, 2020). These types of concerns are consistent with food safety and are very important for food preferences. For instance, when the Avian flu (from birds to humans) erupted in Asia, the majority of Asian countries noticed a decrease in the tourists and in the consumption of poultry food (Chmielewski and Swayne, 2011).

Health consciousness is the perceived tendency to pay attention to one's health (Xu et al., 2020). More precisely, health consciousness is the self-awareness of an individual regarding his lifestyle, including seeking health information, natural environmental concerns, and food consumption (Hong, 2009). Several scholars argue that health concerns have a significant positive influence on the behavioral intentions of the consumers to consume healthy food (Hong, 2009; Singh and Verma, 2017; Qi et al., 2020). Hee and Jae-Eun (2011) identified health awareness as the most influential factor for food consumption behavior.

Some of the previous studies considered food safety and health consciousness as additional predictors of the behavioral intentions to purchase organic food when TPB was incorporated as a theoretical basis (Singh and Verma, 2017; Hansen et al., 2018; Ismael and Ploeger, 2020; Qi et al., 2020). Explaining the additional variables of intention variance within the classical TPB components, it was found that food safety and health consciousness are significant antecedents of intention. None of the studies have explored the extent to which relationships among food safety, health consciousness, and behavioral intentions were mediated by classical TPB components to avoid unfamiliar local food in the migrated context. **Figure 1** summarizes the proposed mediated relationships between food safety, health consciousness, and consumption behavioral intentions of Pakistani students, where food safety and health consciousness are proposed as predictors of TPB components.

Previous studies found that food safety is an important predictor of the attitude of consumers when living abroad (Nevin and Ece, 2012; Lee et al., 2017). Employing TPB as a theoretical basis, food safety was recognized as an important precursor of attitude (Wu et al., 2016; Qi et al., 2020). Based on an extensive literature review, since the emergence of COVID-19, none of the studies in the field of the food preferences of sojourners have examined the associations among food safety, ATT, SN, and PBC. Few studies on the literature of tourism and hospitality (Maclaurin, 2004; Yeung and Yee, 2019) and on organic food consumption (Lobb et al., 2007; Alam et al., 2020; Qi et al., 2020) highlighted that food safety through attitude has a positive relationship with intentions and behavior. Capitalizing on the mentioned results concerning the link between food safety and attitude, we hypothesize that:

> H4. Food safety has a significant positive effect on the attitude of Pakistani students to choose Pakistani cuisines over unfamiliar local food during their sojourning in China, particularly during the period of COVID-19.

According to Ajzen (2011), SN refers to the individual's perception of the belief of their important referents about a specific behavior. In our study, we argue that the positive association between food safety concerns and SN means that Pakistani students living in China and who have a higher level of food safety concerns will depend more on the beliefs of their referent. Confidence in important other beliefs plays an important role in determining the SNs (Canova et al., 2020). More precisely, we argue that China has a complex society, with the second-highest number of Pakistani international students who have a collectivistic cultural and religious identity, forms a social influence on each other. In fact, due to the increasing food safety concerns in the local Chinese food market, Pakistani students will comply more with the belief of their important others. Consequently, we hypothesize that:

H5. Food safety has a significant positive effect on the SN of Pakistani students to choose Pakistani cuisines over unfamiliar local food during their sojourning in China, particularly during the period of COVID-19.

Concerning PBC, food safety concerns in the local Chinese food market will motivate Pakistani students to gain control over consuming Pakistani cuisines and avoid unfamiliar local food products through self-efficacy. Self-efficacy is related to "an individual's perception of *being able* to perform the behavior." Hence, we argue that the pure, safe, and healthy characteristics tethered to Pakistani cuisines dominate over the preferences for local food products and increase the self-efficacy of Pakistani students to consume only their cuisines. Based on this logic, we developed the following hypothesis:

H6. Food safety has a significant positive effect on the PBC of Pakistani students to choose Pakistani cuisines over unfamiliar local food during their sojourning in China, particularly during the period of COVID-19.

Similarly, previous researchers found health consciousness as an important predictor of consumer ATTs. Qi et al. (2020) investigated that during the COVID-19 pandemic, health consciousness is an influential factor of consumer attitude to consume green food. Singh and Verma (2017) found that health benefits have a significant positive impact on the attitude of Indian consumers to purchase organic food products. Similar deliberations were found in the study of Canova et al. (2020). With reference to ethnic food consumption, Ting et al. (2017) investigated that health considerations have a significant positive effect on the attitude of the Malaysian consumers to consume Dayak-food occasionally. Consequently, we argue that highly health conscious Pakistani students also prefer to avoid unfamiliar food products, particularly in the migrated context. Therefore, our next hypothesis is stated as follows:

H7. Health consciousness has a significant positive effect on the ATT of Pakistani students to choose Pakistani cuisines over unfamiliar local food during their sojourning in China, particularly during the period of COVID-19.

The key challenges these sojourners face in the host Chinese environment are the communication barrier, cultural and social disparities, and food consumption. The majority of the ethnic consumers of today are more interested in trying new foods but at the same time, they remain sensitive to their health benefits (Ma, 2015). In this situation, the motivation to comply with significant others is considered to be highly important to stay safe and healthy. The positive associations between health consciousness and SN mean that highly health conscious individuals will rely more on the belief of their important referent to avoid the possible risk associated with the consumption of unfamiliar local food. Therefore, our next hypothesis concerning the link between health consciousness and SN is as follows:

H8. Health consciousness has a significant positive effect on the SN of Pakistani students to choose Pakistani cuisines over unfamiliar local food during their sojourning in China, particularly during the period of COVID-19.

Health consciousness evaluates the readiness to perform healthy actions (Michaelidou and Hassan, 2008). Health conscious consumers are usually involved in maintaining their health and quality of life through healthy nutrition and physical fitness (Chmielewski and Swayne, 2011). Michaelidou and Hassan (2008) argued that health conscious consumers avoid unhealthy food; therefore, they have relatively higher control to opt for healthy and natural food. Similarly, health consciousness can act as a potential resource that will influence the control of Pakistani students to avoid unfamiliar local food during their sojourning in China. The positive attributes of Pakistani cuisines as being familiar, safe, and of better quality increase the control of Pakistani students to retain their cultural food and self-cooking, particularly during the crisis of COVID-19. Consequently, our next hypothesis is as follows:

H9. Health consciousness has a significant positive effect on the PBC of Pakistani students to choose Pakistani cuisines over unfamiliar local food during their sojourning in China, particularly during the period of COVID-19.

Finally, and as mentioned earlier, the three antecedents of behavioral intention (ATT, SN, and PBC) are assumed to mediate the structural relationships between food safety and consumption behavioral intention. Based on an extensive literature review, none of the studies on the area of food choices of the sojourners have analyzed that food safety and consumption behavioral intentions are mediated by classical TPB components. Some recent studies on organic food choices (Canova et al., 2020), the online service industry (Wu and Chen, 2005), and transport management (Madha et al., 2016) have analyzed that the classical TPB components mediate the relationships between consumer trust and intentions. Therefore, we proposed the following hypothesis.

H10a. Food safety has a positive and indirect relationship with behavioral intentions of Pakistani students to choose Pakistani cuisines over unfamiliar local food during their sojourning in China, through ATT.

H10b. Food safety has a positive and indirect relationship with behavioral intentions of Pakistani students to choose Pakistani cuisines over unfamiliar local food during their sojourning in China, through SN.

H10c. Food safety has a positive and indirect relationship with behavioral intentions of Pakistani students to choose Pakistani cuisines over unfamiliar local food during their sojourning in China, through PBC.

Similarly, some studies on the field of transport management (Hsiao and Yang, 2010), and (Madha et al., 2016) analyzed that the relationship between variety seeking and intentions to take high-speed rail are mediated *via* classical TPB components. As evident from the mentioned literature, we assume that the classical TPB components will also mediate the structural relationships between health consciousness and behavioral intentions of Pakistani students to retain the consumption of

Pakistani cuisines and avoid unfamiliar local food in China. Consequently, we hypothesized as follows.

H11a. Health consciousness has a positive and indirect relationship with the behavioral intentions of Pakistani students to choose Pakistani cuisines over unfamiliar local food during their sojourning in China, through ATT.

H11b. Health consciousness has a positive and indirect relationship with the behavioral intentions of Pakistani students to choose Pakistani cuisines over unfamiliar local food during their sojourning in China, through SN.

H11c. Health consciousness has a positive and indirect relationship with the behavioral intentions of Pakistani students to choose Pakistani cuisines over unfamiliar local food during their sojourning in China, through PBC.

In conclusion, the current research aims to investigate the consumption behavioral intention of Pakistani students using the TPB model, along with extended measures of food safety and health consciousness, particularly during the COVID-19 crisis. Based on the available literature, we believe that our study is innovative for three reasons. First, the emergence of COVID-19 has considerably changed the global food production, processing, and consumption at different levels, but none of the studies, except the current research, has investigated the food preferences and consumption behavioral intention of sojourners during the COVID-19 crisis, particularly in China. Most of the studies (Butu et al., 2020; Laguna et al., 2020; Qi et al., 2020) have limited the investigations to organic and green food consumption during the crisis of COVID-19. Second, the role of food safety and health consciousness is examined, given its potential heuristic importance in the social-cognitive process occurring behind the creation and execution of behavior. Third, to the best of our knowledge, none of the studies on the field of food consumption have investigated that food safety and health consciousness have a positive and indirect relationship with behavioral intentions through the mediation of ATT, SN, and PBC. The results of our study will offer suggestions to different stakeholders concerned with the relationship between cognition and behavioral processes associated with food consumption, particularly in a migrated context.

MATERIALS AND METHODS

Participants and Sampling Procedure

In this study, a quantitative approach was applied to examine the proposed model. All the data were collected with the help of organized, self-administered questionnaires distributed among Pakistani international students/Post-Doctoral Fellows registered as full-time students and living in different cities of China. The questionnaire was administered at the time when the pandemic situation was in a serious condition between July and August 2020. The respondents were those who were living in China since the COVID-19 outbreak and were highly concerned about the safety and health benefits of the food they consume. All the respondents signed a written consent and were briefed through an instruction document. Due to the lockdown and restrictions on free movement to combat the spread of coronavirus, a random sampling technique was applied online to directly approach all the respondents who took part in the study. Along with the consent letter, participants were provided with an instruction letter that informed them about the aim of the study. To ensure that the sample was not biased by a specific group of Pakistani students and to strictly follow the epidemic control and prevention policies, the questionnaire was spread *via* different social platforms (WeChat and QQ) of Pakistani international students through Questionnaire Star (online data collection software), where all the respondents have an equal chance of being selected. The targeted population completed 462 usable questionnaires, where all the respondents participated voluntarily.

TABLE 1 | Characteristics of survey sampling ($n = 462$).

Demographics	Specifications	Statistics	
		N	%
Gender	Male	265	57.35
	Female	197	42.64
Age	Under-25	179	38.74
	25–35	253	54.73
	36–45	27	5.89
	45–55	3	0.64
Qualification	Undergraduate	107	23.16
	Master	223	48.26
	PhD	129	27.92
	Others	3	0.64

The demographic profile of the respondents in the current study is mentioned in **Table 1**. The majority of the respondents were Pakistani students/Post-Doctoral Fellows who have registered in different disciplines and who have spent 2–5 years in China. Considering the Covid-19 pandemic facts, health consciousness, communication barrier, and cultural and social disparities, the respondents of the current study were expected to be less assimilated to the host Chinese culture. Regarding the gender distribution of collected survey data, it was found that 57.35% of the respondents were men, whereas 42.64% were women. With regard to the age of the respondents, it was found that 38.74% were under the age of 25, while 54.73% were aged 26–35 years, and 5.89% and 0.64% were between 36–45 and 46–55 years, respectively. A total of 23.16% were undergraduate students, whereas 76.82% were postgraduate or Ph.D. students.

Measures

The measures of the TPB construct adopted in the current research were those used by previous researchers in different contexts, which comply with the guidelines for the construction of the TPB questionnaire. All the classical TPB model constructs along with the background constructs shown in **Figure 1** were regarded as latent variables. The questionnaire used for the data collection comprised of two portions. The demographic information of the participants was placed in the first part. In the second part of the questionnaire, the food consumption behavioral intention of the targeted population during Covid-19

TABLE 2 | Convergent validity assessment ($n = 462$).

Constructs and items	Items	CL	CR	AVE
Attitude				
The Pakistani food is important to me.	ATT1	0.82	0.90	0.70
Consuming Pakistani food is a reasonable action for me.	ATT2	0.84		
Eating Pakistani food is a positive activity for me.	ATT3	0.82		
I feel worried if Pakistani food is not available to me.	ATT4	0.78		
Subjective norm				
My close friends/family consume our ethnic food.	SN1	0.62	0.86	0.54
My loved ones expect me to consume my ethnic food only.	SN2	0.83		
People who are important to me think I should eat my food.	SN3	0.84		
My referents pressurize me to consume Pakistani food only.	SN4	0.64		
The institutions I follow encourage me to eat Pakistani food.	SN5	0.74		
Perceived behavioral control				
I have enough control over eating Pakistani food.	PBC1	0.84	0.84	0.62
Pakistani food is easily available in the market.	PBC2	0.87		
I can buy Pakistani food online.	PBC3	0.62		
Food safety				
The pandemic has increased my food safety concerns.	FS1	0.86	0.90	0.70
I am concerned about the safety of the local Chinese food.	FS2	0.82		
I am convinced about the safety of Pakistani food.	FS3	0.85		
I am being panicked by food safety issues during the pandemic.	FS4	0.81		
Health consciousness				
The pandemic has hyped the level of my health consciousness.	HC1	0.86	0.89	0.67
I carefully choose food to ensure good health.	HC2	0.84		
I believe that Pakistani food is healthy.	HC3	0.80		
I am very concerned about my health during the pandemic.	HC4	0.77		
Consumption behavioral intentions				
I always prefer to eat Pakistani food.	CBI1	0.85	0.92	0.72
I am always more interested in consuming Pakistani food.	CBI2	0.87		
I intend to consume Pakistani food in the future.	CBI3	0.82		
I will make special efforts to consume Pakistani food.	CBI4	0.84		
I would choose to eat Pakistani food even if it costs more.	CBI5	0.84		
Given a choice between two, I intend to choose Pakistani food.	CBI6	0.82		

CL, cross loadings; CR, composite reliability; AVE, average variance extracted; ATT, attitude; SN, subjective norm; PBC, perceived behavioral control; CBI, consumption behavioral intentions; FS, food safety; HC, health consciousness.

based on the classical TPB components was measured. The ATT of the participants was evaluated through four items derived from the proposed scale by Qi et al. (2020) and Alam et al. (2020), whereas the adoption of five items from the proposed scale by Ali et al. (2018) and Singh and Verma (2017) measured the SN. The PBC was measured by seven items adapted from Bonne et al. (2007) and Ting et al. (2016). The consumption behavioral intention (CBI) to consume Pakistani food was measured with the help of six items proposed by Yen et al. (2018) and Qasim et al. (2019). The food safety (FS) concern of the consumers was measured by four items derived from Wu et al. (2016) and Qi et al. (2020). Four items from the study of Hong (2009) and Hansen et al. (2018) were used to measure the health consciousness (HC). All the items were measured through a seven-point Likert Scale ranging from "strongly disagree" (1) to "strongly agree" (7). To ensure the response format and reliability of the responses of the sojourners, the questionnaire was piloted with 50 respondents.

Common Method Variance

The current research contributes to the data obtained from the same participants for both variables (independent and dependent). Therefore, there is a possibility for the existence of method biasness. To reduce method biasness, our study ensures that all the participants were briefed properly; this helped them to completely understand the questionnaire. The main approaches adopted for this reason include the variance inflation factor (VIF) and tolerance (TOL) test. The results shown in **Table 4** suggest that the TOL values are >0.1, and the observed values of the VIF are <10, indicating no collinearity issue in the study.

Model Assessment

The proposed relationships of the current research model were converted into structural equation modeling (SEM) for a further analysis comprising an outer model and an inner model. The PLS-SEM was used *via* Smart PLS 3. This study opted for PLS-SEM as an appropriate multivariate technique,

TABLE 3 | Discriminant validity assessment ($n = 462$).

Hetrotrait-Monotrait Ratio (HTMT)					
Attitude					
Consumption behavioral intention	0.839				
Food safety	0.779	0.795			
Health consciousness	0.773	805	0.743		
Perceived behavioral control	0.498	0.428	0.539	0.519	
Subjective norm	0.82	0.772	0.745	0.731	0.456

Source: Estimated results based on Henseler et al. (2015) heterotrait-monotrait (HTMT) criterion.

which is used for understanding the relatively complex models and the multivariate relationships among them. In the field of management, the PLS-SEM has relished its attractiveness as a useful multivariate analytical technique. The flexibility and adequacy of the model have been recognized by the strategic management research to analyze multiple relationships among variables (Sarstedt et al., 2014).

RESULTS

Partial Least Square Structural Equation Modeling

The study used a two-step approach to evaluate the proposed research model. Initially, the outer model (measurement model) assessment was carried out, which evaluated the validity and reliability of the scale adopted in the study. The next step assessed the inner model (structural model) to measure the fitness of the model and the proposed relationships among variables. For this purpose, the PLS-SEM version 3 was used.

Measurement Model

For the evaluation of the reflective measurement model, the convergent and discriminant validity assessment was considered. **Tables 2**, **3** depict the specific results of the assessment. Convergent validity states that the items which measure the same construct should be highly correlated (Hair et al., 2019). It was assessed through factor loading and composite reliability along with the average variance extracted (AVE). The factor loadings for all the items ranged from 0.621 to 0.876 (above 0.5), which are satisfactory. The values of the composite reliability (CR) also ranged from 0.842 to 0.928, which are greater than the required range (0.7), thus demonstrating a good proportion of internal consistency. Finally, the AVE for the item loading was examined. The AVE is calculated by adding all the squared factor loadings of items in the construct divided by their numbers. The results demonstrated that the AVE for all of the constructs ranged from 0.548 to 0.721, which is higher than the minimum threshold value of 0.5, thus ensuring that all the items explain a variance of more than 50% in the constructs (Hair et al., 2017).

Discriminant validity was assessed through the criterion, Henseler's heterotrait-monotrait (HTMT) (Henseler et al., 2015). The results of HTMT are depicted in **Table 3**. Following the suggestions of Henseler et al. (2015), the obtained values of HTMT ratios mentioned in **Table 3** were lower than 0.85. Therefore, the results of the discriminant validity for each of the constructs in the proposed model are satisfactory.

TABLE 4 | Collinearity assessment.

IVs	**Tolerance**	**VIF**
ATT	0.410	2.591
FS	0.523	2.094
HC	0.539	2.081
PBC	0.619	1.402
SN	0.449	2.29

IVs, independent variables; ATT, attitude; SN, subjective norm; PBC, perceived behavioral control; FS, food safety; HC, health consciousness; VIF, variance inflation factor.
Source: Estimated results based on the collinearity assessment by Latan and Noonan (2017).

Structural Model Assessment

Before the structural model assessment, it is necessary to make sure that the structural model does not pose any problems of collinearity. The result of the collinearity assessment is presented in **Table 4**, which depicts that in each of the constructs, the values of VIF are smaller than the offending value of 10, whereas the TOL values are >0.1, which indicates no multicollinearity issues in the current study.

For the assessment of the proposed structural model **(Figure 2)**, the dimensions and values of standardized path coefficients with other related *t*-statistics, including the calculation of R^2 (coefficient of determination) were considered important. The study applied the resampling technique (i.e., bootstrapping) to 5,000 resamples for measuring the path coefficients and their relative importance in the proposed model. The study also considered measuring the effect sizes (f^2) for the proposed structured paths as suggested by Hair et al. (2017). Moreover, to measure the predictive ability of the proposed model, Stone–Geisser's Q^2 was also taken into consideration.

The results of β-coefficients, t-values, and f^2-values for each of the respective structural paths obtained from the bootstrapping procedure are illustrated in **Table 5**. All of the proposed relationships, except one, were found to be significant at the confidence level of 99.0 percent. Attitude (ATT→CBI, $\beta = 0.615$, $t = 11.053$, LL = 0.417, UL = 0.609, $P \leq 0.01$) showed

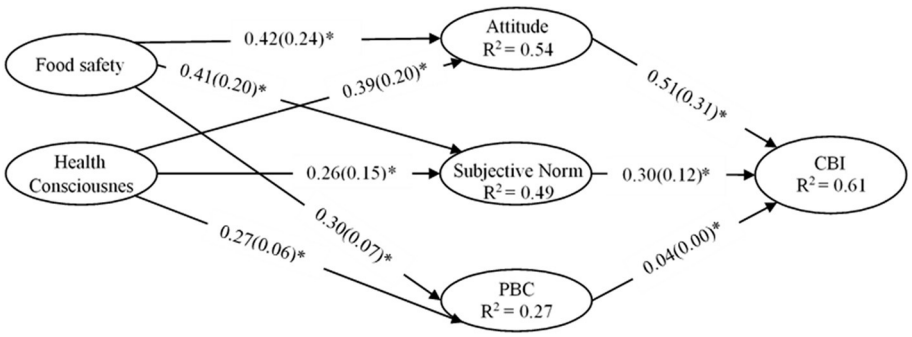

FIGURE 2 | Structural equation modeling (SEM) results of complete data ($n = 462$), PBC, Perceived Behavioral Control. The * indicates p-values <0.01. The figure presents the effect sizes (f^2) in the parentheses next to each path coefficient (β).

the strongest positive effect on the consumption behavioral intentions of Pakistani international students to retain Pakistani cuisines when living in China. Subjective norm (SN→CBI, $\beta = 0.319$, $t = 6.648$, LL = 0.219, UL = 0.412, $P \leq 0.01$) was also positively associated with the consumption behavioral intention. Hence, H1 and H2 were supported by the results. However, PBC (PBC→CBI, $\beta = 0.040$, $t = 0.978$, LL = −0.037, UL = 0.125, $P \geq 0.05$) does not affect the consumption behavioral intentions to retain Pakistani cuisines, thus rejecting H3. With regard to background factors, food safety concern was positively associated with ATT (FS→ ATT, $\beta = 0.427$, $t = 9.421$, LL = 0.337, UL = 0.514, $P \leq 0.01$), PBC (FS→PBC, $\beta = 0.306$, $t = 5.147$, LL = 0.196, UL = 0.410, $P \leq 0.01$), and perceived social pressure (FS→ SN, $\beta = 0.414$, $t = 8.782$, LL = 0.317, UL = 0.498, $P \leq 0.01$), that sustained H4, H5, and H6, respectively. Similarly, the results revealed that health consciousness was positively associated with ATT (HC→ATT, $\beta = 0.393$, $t = 8.469$, LL = 0.299, UL = 0.490, $P \leq 0.01$), PBC (HC→PBC, $\beta = 0.273$, $t = 4.993$, LL = 0.168, UL = 0.380, $P \leq 0.01$), and perceived social pressure (HC→ SN, $\beta = 0.363$, $t = 7.674$, LL = 0.281, UL = 0.445, $P \leq 0.01$) as expected from H7, H8, and H9.

The Cohen (Cohen, 1970) criteria of (0.02) for small, (0.15) for medium, and (0.35) for large-size effects was adapted to measure the effect sizes (f^2). All of the variables, except one, exceeded the minimum threshold criterion of (0.02), thus reflecting its effect on the dependent variable (small-to-medium size). However, the PBC (PBC, $f^2 = 0.003$) exhibited no considerable effect on the consumption behavioral intention. **Table 5** illustrates the overall (f^2) results.

Besides, we also evaluated the coefficient of determination (R^2) along with the predictive relevance (Q^2) of independent variables on dependent variables. The computed value of R^2 for the dependent variable (CBI) was (0.616), which indicates that the overall independent variables (ATT, SN, and PBC) in the present study explain (61.6%) variance in the dependent variable (CBI). Similarly, for background factors, the R^2 accounted for dependent variables (ATT, SN, and PBC) were (0.546), (0.490), and (0.271), respectively. This result indicates that food safety and health consciousness explain 54.6, 49, and 27.1% of variances in the dependent variables of ATT, SN, and PBC, respectively.

In addition, adopting the procedures recommended by Shmueli et al. (2019). The PLS predict was also performed. In order to assess the predictive validity, the cross-validation with holdout sampling technique was applied. The overall assessment results are depicted in **Table 6**. Initially, the Q^2 (the comparison of PLS path model and the simple mean prediction) values were measured. The respective Q^2 values of (0.666), (0.541), (0.485), and (0.256) for CBI, ATT, SN, and PBC suggest the appropriate predictive performance of the proposed model. Secondly, to generate predictions, the linear regression model (LM) was followed as suggested by Shmueli et al. (2019). The results suggest that comparing the LM and PLS results, the LM outcomes have lower prediction error in terms of root mean square error (RMSE) and mean absolute error (MAE), indicating the substantial predictive power of the model.

Mediation Effect of TPB Components Among Background Factors and Behavioral Intention

Our theoretical model proposed that TPB components will mediate the structural relationships between background factors (food safety and health consciousness) and the consumption behavioral intentions of Pakistani students to retain the consumption of Pakistani cuisines during their sojourning in China, particularly during the period of COVID-19 (H10a,b,c and H11a,b,c). To examine the mediation effect, and as suggested by Hair et al. (2019), the resampling technique of bootstrapping to generate 5,000 resamples was followed. To report the outcomes generated from each mediation path in the model, we then employed the function of the specific indirect-effect in Smart-PLS (Hair et al., 2019). The P-values, along with the 95% confidence intervals (bias-corrected), are also reported in **Table 7** to ensure the significant importance of the proposed indirect results. The results from the PLS-SEM function of the specific indirect effect revealed that the indirect effect of

TABLE 5 | Assessment of structural paths (Hypothesis testing).

Structural paths	β-Value	t-value	f^2	LL	UL	Results
ATT → CBI	0.515	11.053**	0.314	0.417	0.609	Supported
PBC → CBI	0.040	0.978	0.003	−0.037	0.125	Not supported
SN → CBI	0.309	6.648**	0.123	0.219	0.412	Supported
FS → ATT	0.427	9.421**	0.242	0.337	0.514	Supported
FS → SN	0.414	8.782**	0.203	0.317	0.498	Supported
FS → PBC	0.306	5.147**	0.078	0.196	0.410	Supported
HC → ATT	0.393	8.469**	0.206	0.299	0.490	Supported
HC → SN	0.363	7.674**	0.156	0.281	0.445	Supported
HC → PBC	0.273	4.993**	0.062	0.168	0.380	Supported

***Significance at $p \leq 0.01$.*

In the current study, the intentions were to retain Pakistani food consumption during COVID-19. Pakistani students have positive intentions toward consuming their own food when living in China.

ATT, attitude; SN, subjective norm; PBC, perceived behavioral control; CBI, consumption behavioral intentions; FS, food safety; HC, health consciousness. LL, lower limit; UL, upper limit at 99 percent confidence interval.

food safety on the consumption behavioral intention through the mediation of ATT ($\beta = 0.22$, LL = 0.159, UL = 0.272, $P \leq 0.00$) and SN ($\beta = 0.128$, LL = 0.081, UL = 0.172, $P \leq 0.00$) was significant. Similarly, the indirect effect of health consciousness on the consumption behavioral intention through the mediation of ATT ($\beta = 0.203$, LL = 0.138, UL = 0.279, $P \leq 0.00$) and SN ($\beta = 0.112$, LL = 0.069, UL = 0.163, $P \leq 0.00$) turned out to be significant. However, the specific indirect effect of food safety and health consciousness on the consumption behavioral intention *via* PBC ($\beta = 0.012$, LL = −0.013, UL = 0.040, $P \leq 0.336$) and ($\beta = 0.011$, LL = −0.009, UL = 0.043, $P \leq 0.412$) turned out to be insignificant. Therefore, based on the results, we concluded that the effect of food safety and health consciousness on CBI was mediated by ATT and SN, whereas the PBC does not mediate this relationship.

DISCUSSION AND CONCLUSION

The emergence of COVID-19 has placed a revolutionary strain on the global food system, which has caused changes in the way food is prepared, sold, obtained, and consumed (Leone et al., 2020). With these uncertainties, the sustainable food consumption is perceived as a major issue, particularly in a migrated context (Alam et al., 2020). The frequent food safety incidents and scandals in the Chinese food market, including the emergence of COVID-19, have increased greater concerns of the sojourners with regard to food safety and health consciousness (Qi et al., 2020). In contrast, none of the research has investigated the consumption patterns of the sojourners during the COVID-19 pandemic, particularly in Mainland China. The current research contributes to an appreciation of the reasons for the reluctance of young Pakistani students living in China to consume unfamiliar local food products available in the Chinese food market while preferring to retain the consumption of Pakistani cuisines during the period of the COVID-19 outbreak. In particular, the current research follows one of the highly significant socio–psychological theoretical frameworks, TPB, along with the background factors of food safety and health consciousness.

The findings of the current research highlighted that the TPB is a valuable framework for understanding the desired investigated behavior and has a strong explanatory power. More precisely, the relationships among ATT, SN, and consumption behavioral intentions were found to be significant, which supported H1 and H2; however, the relationship between PBC and consumption behavioral intention (H3) did not receive any support.

Firstly, through investigating the direct relation between TPB components, we found that a positive attitude of young Pakistani students toward Pakistani cuisines predict intention, and indirectly the actual behavior. Consequently, avoiding unfamiliar local food and retaining the consumption of Pakistani cuisines while living in China, supporting H1. The results also confirmed that the consumption behavioral intentions are strongly supported by attitude. This result further suggests that Pakistani students have a more promising evaluation of consuming Pakistani cuisines with a greater likelihood of being involved in actual consumption behavior. Our results are consistent with the previously published literature of Ali et al. (2017) and Sadia et al. (2021); these researchers found a positive relationship between attitude and behavioral intentions of Muslim students to consume halal when living abroad.

Secondly, SN also affects the consumption behavioral intentions of Pakistani students living in China, strongly supporting H2. The SN plays the role of the second most significant determinant of intention. The positive impact of SN reflects that the discussions on the current food scandals and safety concerns in the Chinese food market with referents, such as close friends and family members, positively affect their willingness to avoid unfamiliar food products while living in China. Expectations about food consumption shared with important referent and their effect on the food choices of the consumers are reported in the

TABLE 6 | PLS predict assessment.

PLS prediction summary	
CBI	0.666
ATT	0.541
SN	0.485
PBC	0.256

PLS prediction summary

	PLS			**LM**			**PLS-LM**		
	RMSE	**MAE**	**Q^2 Predict**	**RMSE**	**MAE**	**Q^2 Predict**	**RMSE**	**MAE**	**Q^2 Predict**
ATT2	1.287	0.908	0.342	1.37	0.962	0.317	−0.083	−0.054	0.025
ATT1	1.385	0.962	0.301	1.255	0.875	0.374	0.13	0.087	−0.073
ATT3	1.222	0.907	0.455	1.232	0.915	0.446	−0.01	−0.008	0.009
ATT4	1.447	1.137	0.404	1.448	1.113	0.404	−0.001	0.024	0
CBI4	1.134	0.871	0.489	1.215	0.865	0.484	−0.081	0.006	0.005
CBI6	1.125	0.837	0.427	1.156	0.83	0.529	−0.031	0.007	−0.102
CBI5	1.172	0.929	0.522	1.016	0.728	0.539	0.156	0.201	−0.017
CBI2	1.19	0.897	0.501	1.079	0.777	0.538	0.111	0.12	−0.037
CBI3	1.078	0.804	0.482	1.037	0.752	0.626	0.041	0.052	−0.144
CBI1	1.25	0.946	0.455	1.067	0.781	0.485	0.183	0.165	−0.03
PBC6	1.748	1.497	0.027	1.389	1.023	0.228	0.359	0.474	−0.201
PBC7	1.715	1.449	0.019	1.406	1.037	0.183	0.309	0.412	−0.164
PBC2	1.422	1.063	0.163	1.615	1.217	0.067	−0.193	−0.154	0.096
PBC5	1.747	1.455	0.072	1.794	1.518	0.056	−0.047	−0.063	0.016
PBC1	1.392	1.04	0.225	1.777	1.476	0.04	−0.385	−0.436	0.185
PBC4	1.822	1.568	0.026	1.754	1.494	0.019	0.068	0.074	0.007
PBC3	1.638	1.252	0.039	1.713	1.432	0.02	−0.075	−0.18	0.019
SN5	1.602	1.288	0.215	1.282	0.923	0.293	0.32	0.365	−0.078
SN3	1.454	1.163	0.393	1.553	1.265	0.347	−0.099	−0.102	0.046
SN1	1.289	0.938	0.285	1.466	1.154	0.383	−0.177	−0.216	−0.098
SN4	1.788	1.47	0.056	1.766	1.467	0.08	0.022	0.003	−0.024
SN2	1.561	1.292	0.34	1.604	1.305	0.213	−0.043	−0.013	0.127

ATT, attitude; SN, subjective norm; PBC, perceived behavioral control; CBI, consumption behavioral intentions; FS, food safety; HC, health consciousness; LM, linear regression model; RMSE, root mean square error; MAE, mean absolute error.

recent work of Canova et al. (2020) in the field of organic food industry.

Our results did not provide support for H3, suggesting that PBC is not associated with the consumption behavioral intentions of Pakistani students to consume Pakistani cuisines during their stay in China. This might be due to the perceived lack of availability and relatively high cost of Pakistani food ingredients in the local Chinese food market, which becomes the potential barrier for these sojourners maintaining their eating habits. Moreover, the epidemic prevention and control policies and lockdown to combat the spread of the virus is also an obstacle for the behavioral control. Our results are confirmatory to the findings of Verbeke and López (2005), who found PBC as a potential obstacle for Hispanic consumers preserving their eating habits while living in Belgium. In contrast, some scholars contended that the perceived lack of availability or a relatively high cost of food ingredients would not affect the desired consumption behavior if the importance or personal relevance attached to that food dominates With regard to the background factors, H4 received support since food safety was positively related to attitude, thus mirroring the existent literature (Nevin and Ece, 2012; Wu et al., 2016; Lee et al., 2017). These researchers found a positive effect of food safety on attitude to handle on-campus food practices of university students. Moreover, food safety explained a higher quota of the ATT variance. The results also highlighted that food safety has positive associations with SN and PBC, resultantly supporting H5 and H6. Besides, food safety explained a relatively lower quota of PBC variance, as compared to ATT and SN. Similarly, H7, H8, and H9 received support based on the results. This suggests that health consciousness had a significant positive effect on the attitude of the sojourners, which reflects the extant literature available on organic food (Singh and Verma, 2017; Hansen et al., 2018; Qi et al., 2020). Similar to food safety,

TABLE 7 | Mediation effect.

Structural paths	β-Value	t-Value	*P*-values	LL	UL	Status
FS → ATT → CBI	0.220	7.303	0.000**	0.159	0.272	Supported
FS → PBC → CBI	0.012	0.963	0.336	−0.013	0.040	Not supported
FS → SN → CBI	0.128	5.441	0.000**	0.081	0.172	Supported
HC → ATT → CBI	0.203	5.678	0.000**	0.138	0.279	Supported
HC → PBC → CBI	0.011	0.822	0.412	−0.009	0.043	Not supported
HC → SN → CBI	0.112	4.400	0.000**	0.069	0.163	Supported

***Significance at $p \leq 0.01$.*

ATT, attitude; SN, subjective norm; PBC, perceived behavioral control; CBI, consumption behavioral intentions; FS, food safety; HC, health consciousness; LL, lower limit; UL, upper limit at 99% confidence interval.

health consciousness also had positive associations with SN and PBC.

Based on these results, we argue that food safety and health consciousness play a vital role in the development of an overall positive evaluation of Pakistani students toward retaining their ethnic food consumption during their sojourning in China. The positive effect of food safety and health consciousness on attitude reveals that the more the sojourners are health conscious and trustworthy with regard to the safety aspects of their ethnic food, the more they will have a positive attitude toward it. Similarly, the positive influence of food safety and health consciousness on SN articulated the higher safety concerns regarding unfamiliar local food. To this extent, the Pakistani students living in China believe themselves to be more vulnerable to possible food-borne diseases; the more they will be health conscious and follow the opinions of important others. Subsequently, the positive effect of food safety and health consciousness on PBC suggests that the health and safety concerns associated with consuming unfamiliar local Chinese food facilitate Pakistani students to devote more efforts to retain their ethnic food consumption.

Our results also concluded that with increasing health and safety concerns in the local food market, eating "home food" remains the main focus of Pakistani students living in China. Eating "home food" involves self-cooking at home/student dormitories since Pakistani restaurants and take-away are too expensive and less authentic for being considered as healthy routine options. The observed behavior of the Pakistani students are in line with the results of Kamran (2021), where the respondents reported that the taste and spices of Chinese local food are different from their ethnic cuisines. Besides, self-cooking within the accommodations of the students and sharing a Pakistani meal with fellow Pakistani students strengthen the bond between them, thus helping them to maintain their cultural norms and consumption habits. Cooking and eating Pakistani food together becomes a part of the SN, which helps them in coping strategies to navigate the possible uncertainties and vulnerabilities associated with eating unfamiliar local food in a new environment. With regard to PBC, the positive association of food safety and health consciousness with behavioral control means that the acquisition of Pakistani food ingredients in the local Chinese food market does not remain a problem for Pakistani students. They have learned how and where to buy food ingredients. Even if the supply of the required ingredients in some locations is limited, these sojourners can learn to improvise the original recipes with available new ingredients through the inter-cultural adaption process. For example, the inter-cultural adaption process of the Chinese international students in Europe to replace the original Chinese Lamian noodles with spaghettis, fried with some pickled vegetables and pork meat is the best example available in the literature (Yen et al., 2018). However, the actual behavioral control of Pakistani students to consume their desired food is subject to the pandemic situation and the supply of food ingredients in the local Chinese food market.

Finally, we checked whether TPB classical components lead to mediation between background factors (food safety and health consciousness) and consumption behavioral intentions. The results revealed that food safety and health consciousness were indirectly associated only with behavioral intentions through their substantial effects on ATT (H10a, H11a) and SN (H10b, H11b). The results did not provide support for the indirect association between food safety, health consciousness, and behavioral intention *via* PBC (H10c and H11c). Thus, the overall mediation hypothesis (H10a,b,c and H11a,b,c) were partially supported by the results. The reason for this result might be due to the inverse effects of COVID-19 on movement restrictions, closure of production facilities, and food trade restrictions that caused the perceived lack of availability and the relatively high cost of Pakistani food ingredients in the Chinese food market.

The proposed model, which incorporated food safety and health consciousness as background variables in the classical TPB framework, produced vigorous results to explain the consumption behavioral intention of Pakistani students living in China. However, the background factors were added to assess the role of food safety and health concerns of Pakistani international students, regarding their food preferences during the period of COVID-19. We are aware that this is an operationalization within the classical framework of TPB, which has never been validated nor has been applied to investigate the consumption patterns of the academic sojourners in the previous framework. Nevertheless, within the context of the current study, the introduction of food safety and health consciousness within the framework of TPB was deemed important to assess the presumed determination of intentions to avoid unfamiliar food products during the COVID-19 pandemic. Hence, the background factors

have been proved to be acting as additional predictors within the TPB model to investigate the desired behavior.

PRACTICAL IMPLICATIONS

With regard to the practical implications, the findings of the current research are useful for different stakeholders, including food producers, marketers, policymakers, and even businesses attracted by the ethnic food sector. Firstly, the current study revealed that in response to the health and safety concerns in the wake of COVID-19 pandemic, Pakistani students living in China desire to strive for a safe and healthy life, allocate time, and efforts to prepare their food. Therefore, the Chinese food producers and suppliers need to accommodate it as a market demand. They need to improve the demand-based imports and supply of Pakistani food ingredients and establish effective supply chains to ensure their availability to the consumers.

Secondly, due to the epidemic control and prevention policies implemented by the Chinese government, the PBC of Pakistani international students living in China was adversely affected to retain their ethnic food, thereby, hampering the availability and affordability of Pakistani food ingredients to prepare and consume their ethnic food. The public policies regarding uninterrupted global trade, removing restrictions, and maintaining food and feed supplies need to be revived to enable these sojourners to regain their consumption behavior impeded by COVID-19 control measures.

Thirdly, based on the health and safety concerns identified by this research, improvements could be made to the food provided on the university campus and in the area populated by Pakistan international students. Access to the Chinese Muslim food known as Qing Zhen (clean) might help Pakistani students to overcome their concerns about the reliability of local food as well as to offset their anxiety to avoid any kind of food-borne diseases.

Finally, the findings of the current study are generally applicable for other food sectors, particularly during the period of COVID-19. With the emergence of COVID-19, majority of the consumers today prefer to consume healthy food products. Therefore, food producers and marketers of other food sectors need to emphasize on the quality and safety of their products. Moreover, this study also contributes to formalize restaurants and food cafes to ensure food safety and quality standards.

The current research also contributes to the extant literature on the food consumption of the sojourners in different ways. Firstly, it has contributed to the scarce research on the food consumption of Pakistani international students in terms of health and safety concerns during the COVID-19 pandemic. Secondly, the antecedents of the decision of the sojourners to consume their ethnic food in the wake of COVID-19 in a migrated context, adopting a notorious socio-psychological theory, that is, the TPB, were thoroughly investigated. Thirdly, it presented the associations between food safety, health consciousness, and consumption behavioral intention through the mediation of classical TPB components, which are rarely investigated.

Despite its strength, there are few caveats related to the current research. Firstly, due to the use of convenience sampling, generalizability of the present study to entire Pakistani academic sojourners is questionable. Secondly, due to the epidemic control and prevention policies in China, our study is limited to the consumption behavioral intentions phase. The actual behavior of the target population will be assessed in the second phase of the study once the epidemic control and prevention policies are relaxed. Finally, the examination of some additional factors, such as dietary acculturation, consumption values, and consumer trust can also be accompanied by relationships considered in the current research.

To fully understand the role of food safety and health consciousness and their antecedents in the food consumption process, particularly in an unfamiliar food market, future researchers can utilize the current extension in the TPB model to predict food consumption behavior in other food sectors as well.

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 research ethics committee at China University of Geosciences (Wuhan), China. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

MK and SC conceived and designed the study. MK, NK, and AT collected the data. MK and HQ developed the theoretical framework. MK and LJ performed the data analysis. SC and HQ verified the analytical methods. MK wrote the first draft. SC, MI, and RA substantially revised the manuscript. All authors discussed the results and contributed to the final manuscript.

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BRIEF RESEARCH REPORT
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The Food Bank and Food Pantries Help Food Insecure Participants Maintain Fruit and Vegetable Intake During COVID-19

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Charitable food services, including food banks and pantries, support individual and households' food access, potentially maintaining food security and diet quality during emergencies. During the COVID-19 pandemic, the use of food banks and pantries has increased in the US. Here we examine perceptions of food banks and food pantries and their relationship to food security and fruit and vegetable (FV) intake during the first 6 months of the COVID-19 pandemic, using a statewide representative survey ($n = 600$) of residents of Vermont. The utilization of food pantries was more common among food insecure households and households with children. Among food insecure respondents, those who did not use a food pantry were significantly more likely to report consuming less FV during the pandemic. Further, we find respondents who are food insecure and using a food pantry report consuming more FV since the onset of the COVID-19 pandemic. We found that respondents who were both food insecure and reported not using a food pantry were significantly more likely to report both a reduction in fruit consumption ($b = -0.58$; $p = 0.001$) and a reduction in vegetable consumption ($b = -0.415$; $p = 0.012$). These results indicate that these services may support food access and one important dimension of diet quality (FV intake) for at-risk populations during emergencies.

Keywords: food security, coronavirus, food pantry, emergency food assistance, nutrition security

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INTRODUCTION

The COVID-19 pandemic, associated shutdowns, and social distancing measures designed to slow its spread have profoundly impacted the US food system and food access. According to the Pew Research Center, job disruptions have been widespread; lower-income adults have been hardest hit, with half of their households reporting a job or wage loss due to the pandemic (1). These disruptions have been disproportionately acute among women, low-income communities, and people of color (1), which have catalyzed important changes in the food supply chain and food security. Recent research suggests that the food insecurity rates have reached levels unprecedented in recent history (2–4).

With the shift from worksites, schools, and restaurant dining, to greater at-home preparation and consumption, food procurement shifted and, in many cases, overwhelmed grocery stores (5). Simultaneously, food insecure populations turned to charitable feeding systems (e.g., food banks, pantries) (6). Demands for charitable food services are reported to have increased from 50 to 140% in the first months of the COVID-19 pandemic (7, 8). In the year prior to the pandemic, 18% of Vermonters reported experiencing food insecurity (2). Food insecurity rose by 32% in the first months following the outbreak (2). By June 2020, nationwide, more than 82% of food banks reported higher numbers of patrons than they did the year prior (9). A longitudinal population-level survey conducted in Vermont in March and May 2020 found that demand for charitable food services increased by 68%, from 7.1 to 12.0% (10). In October 2020, Feeding America reported they were on track to distribute 50% more food when comparing October 2019 and October 2020 (11).

Health inequalities in the US follow a socioeconomic continuum where low-income, low-resource households disproportionally experience higher levels of food-related health risks (12). Further, inequalities, lack of transportation, and geographic disparities magnify structural and environmental factors contributing to food insecurity and poor dietary health (13, 14). Compared to wealthier households, low-income households cook more meals at home (15) yet consume fewer fruits and vegetables (FV) (16) and are more likely not to meet the servings of FV recommended by the Dietary Guidelines for Americans (17). Nanney et al. (18) examined 269 food shelves using the HEI-2010 (Healthy Eating Index) and concluded that the majority of available food (89%) "needs improvement" for nutritional adequacy. Further, they found significant seasonal fluctuations with the month and quarter scores in July, August, and September significantly higher than in December.

Charitable food services vary in FV distribution from region to region. Vermont is known for its resilient local food system (19) and has several agencies, organizations, and programs to help address hunger issues in the state. According to the Hunger in America 2014 (13) report for Vermont Foodbank, of the 23 meal-based relief agencies analyzed, 42.1% aided clients in accessing local food resources. Further, many sites have introduced client choice (20) to provide food pantry patrons choice; many additional organizations have been transitioning to a client-choice model. This approach allows clients to take products they want and will use. By incorporating behavioral economic techniques, recent initiatives have shown success in nudging clients to select more fruits, vegetables, and nutrient-dense foods (21). COVID-19 has presented new challenges for these programs as they work to meet growing food needs while protecting staff, volunteers, and clients' health.

This study aims to understand charitable food programs' role during the first 6 months of the COVID-19 pandemic. Emerging international research suggests that COVID-19 mitigation has negatively impacted diet quality during the pandemic (22). We explore how FV intake changed among a representative sample of Vermonters and examine the emergency food system's role in maintaining access to FVs during a humanitarian crisis.

METHODS

Survey Development and Recruitment

The research team, in collaboration with other researchers in the National Food Access and COVID research Team (NFACT) (22), developed and piloted a survey in March 2020 (23). After two rounds of data collection in March 2020 and June 2020, additional refinements to the pilot survey included food access, food security, food purchasing, food assistance program participation, dietary intake, perceptions of COVID-19, and individual social distancing behaviors, as well as household and individual sociodemographics (24). Data collection for this study was conducted in August and September 2020 (25). We obtained Institutional Review Board approval from the University of Vermont (IRB protocol 00000873). The survey was explicitly designed to measure critical outcomes (e.g., food access, food security, food purchasing, and dietary intake) both before the COVID-19 outbreak (dated as of March 11, 2020, the day the World Health Organization declared a global pandemic) (26) and since the pandemic began. The survey utilizes validated measures when possible (**Supplementary Table 1**). The survey was piloted in Vermont, with 25 eligible (18 or older) residents in late March, and validation methods (e.g., Cronbach alpha, factor analysis) were used to test the internal validity of questions with key constructs (alpha > 0.70) (2).

Sampling Approaches

We deployed our online survey to a panel of respondents recruited by Qualtrics (Provo, UT). We developed a sampling strategy for achieving a general population sample reflecting characteristics of the state including income, race, and ethnicity in Vermont. This sample was achieved by matching sample recruitment quotas to the income, race (specifically White, Black or African American, American Indian and Alaska Native, Asian, Native Hawaiian or Other Pacific Islander, and Two or more races), and ethnicity (Hispanic, non-Hispanic) population profile of Vermont in the American Community Survey (ACS) (**Supplementary Table 2**) (27). A total of 600 people ages 18 and over responded to the survey, representing a margin of error (95% confidence level) for the adult population of Vermont $\pm 4\%$ (27).

Variables of Interest

We explore three self-reported dependent variables in this analysis (**Supplementary Table 1**). First, we measured food security status using the US Department of Agriculture's 6-item short-form food security module (28). We asked respondents to reflect on the year before the COVID-19 pandemic to collect pre-pandemic food security status. Further, the traditional 12-month period was modified to $\sim$6 months to measure food security status since the start of the COVID-19 pandemic. Following standard scoring protocol, we summarized responses for each item, and classified respondents who answered one or two items affirmatively as living in food insecure households. Second, we measured current FV intake using the National Cancer Institute's two-item screener, modified to apply to the last month and with some example foods removed to shorten it (29).

Finally, we examined the perceived change in FV consumption since the onset of the COVID-19 pandemic. Independent variables included multiple questions related to current food bank and food pantry use, specific charitable food system participant experiences, and transportation other than their own vehicle; we also captured several household and individual-level demographics (**Table 1**).

Statistical Analysis

To examine differences in household food insecurity during the first 6 months of the COVID-19 pandemic, we created three categories of respondents: (1) *households with food security*, including households that were food secure before and since the onset of the COVID-19 pandemic and households who were food insecure at some point in the year before the COVID-19 pandemic began but were no longer food insecure during the first 6 months of the pandemic; (2) *households with persistent food insecurity*, food insecure both at some point in the year before the COVID-19 pandemic began and experiencing food insecurity at some point during the first 6 months of the pandemic; (3) *households with new food insecurity*, categorized as food secure at all times in the year before the COVID-19 pandemic began, but food insecure at some point since the start of the pandemic. We report statistical significance as anything $p < 0.05$.

To determine statistically significant differences between groups, we utilized SPSS Version 27 (30) and Stata Version 16 (31) to run descriptive statistics, chi-square tests, and multivariable logit models. Specifically, we used chi-square tests to analyze food pantry use related to each item of the food security module. In our multivariable regression models, we use a set of demographic controls including gender, children in the household, respondents over 55, respondents identifying as Black, Indigenous, or People of Color (BIPOC) and/or Hispanic, food security status (28), households with any job loss or negative change since the start of the pandemic, households making <$50,000 in 2019, and households using transportation for food access other than their own vehicle (e.g., public transportation, ride from a friend) since March 2020. It is important to note that although this survey is representative of Vermont state characteristics on race and ethnicity, the sample size is not sufficient to analyze racial and ethnic groups in a disaggregated format in models. Therefore, we have disaggregated race and ethnicity in all food security statistics in the results but use aggregated race and ethnicity for modeling. We used a multivariable logit model with these demographic controls to predict food pantry use (yes/no) since the start of the COVID-19 pandemic. Then, we use a multinomial logit model with demographic controls to predict a change in FV consumption since COVID-19 (decreased, stayed the same, or increased). Finally, we use a multivariable regression model to predict the current intake of FV, measured on a continuous scale, with demographic controls. All variables and their descriptions are included in **Supplementary Table 1**. Coefficients are reported as odds ratios for the logistic regression model only. We used all available data to estimate effect sizes and interactions and assumed any missing data were missing at random.

TABLE 1 | Survey respondents' individual and household demographic characteristics.

Characteristic	Respondents ($N = 600$)
Age - no. (%)	
18–34	153 (25.5)
35–54	182 (30.3)
55+	263 (43.8)
Children in household - no. (%)	
Yes	178 (30.2)
No	415 (70.0)
Gender - no. (%)	
Female	404 (67.3)
Male	190 (31.7)
Transgender/Non-binary/Self-described	6 (1.0)
BIPOC - Race - no. (%)	
White	559 (93.2)
Two or more races	22 (3.7)
American Indian or Alaska Native	5 (0.8)
Asian	4 (0.7)
Black or African American	9 (1.5)
BIPOC - Ethnicity - no. (%)	
Not Hispanic or Latino	583 (97.2)
Hispanic or Latino	17 (2.8)
2019 Household Income - no. (%)	39 (6.5)
<$10,000 per year	
$10.000–24,999	81 (13.5)
$25,000–49,999	141 (23.5)
$50,000–74,999	110 (18.3)
$75,000–99,999	77 (12.8)
$100,000 or more	145 (24.1)
Job change during the COVID-19 pandemic - no. (%)	
Lost job	149 (24.8)
Reduced hours or income	208 (34.7)
Furloughed	122 (20.3)
Any change	270 (46.23)
No changes	314 (53.8)
Food security status during the COVID-19 pandemic - no. (%)	
Food secure	414 (69.0)
Persistently food insecure	116 (19.3)
Newly food insecure	49 (8.2)
Transportation use other than vehicle during the COVID-19 pandemic - no. (%)	
Yes	30 (5.0)
No	568 (95.0)
Daily fruit consumption during the COVID-19 pandemic- no. (%)	
None	66 (11.0)
1/2 cup or less	127 (21.2)
1/2 to 1 cup	158 (26.3)
1–2 cups	156 (26.0)
2–3 cups	66 (11.0)
3–4 cups	15 (2.5)
4 or more cups	12 (2.0)

(Continued)

TABLE 1 | Continued

Characteristic	Respondents (*N* = 600)
Daily vegetable consumption during the COVID-19 pandemic- no. (%)	
None	32 (5.3)
1/2 cup or less	82 (13.7)
1/2 to 1 cup	134 (22.3)
1–2 cups	186 (31.0)
2–3 cups	106 (17.7)
3–4 cups	44 (7.3)
4 or more cups	16 (2.7)
Food pantry use during the COVID-19 pandemic - no. (%)	
Yes	86 (14.5)
No	508 (85.5)

RESULTS

Demographic Characteristics of Respondents

Our sample reflected the demographic composition of the Vermont population for income, race, and ethnicity distribution. The majority of our respondents identified as female (67.3%), non-Hispanic White, without children in the household, and had a household income below $75,000 (**Table 1**). Almost half of the respondents (46.2%) experienced a change in employment at some point between March and September 2020. Changes included loss of employment (24.8%), reduced hours or income (34.7%), and furlough (20.3%). Only 5.0% of respondents utilized transportation other than a personal vehicle between March and September 2020 (**Table 1**).

Food Insecurity Prevalence

Nearly one in three (29.0%) respondent households were food insecure at some point between March and September 2020. Among those experiencing food insecurity since the start of the pandemic ($n = 165$), 72.1% also experienced food insecurity at some point in the year before the pandemic; in comparison, 27.9% were newly food insecure (**Table 1**).

Fruit and Vegetable Consumption

The 2020–2025 Dietary Guidelines for Americans (DGA), released on December 28, 2020, recommend that people needing 2,000 calories per day should include at least 2 cups of fruit and 2.5 cups of vegetables in their daily diets. During the COVID-19 pandemic, 15.5% of respondents met the recommendation for fruit intake, and ∼27.7% of respondents met the recommendations for vegetables (**Table 1**).

Changes in Fruit and Vegetable Consumption During the First 6 Months of COVID-19

Multinomial logit models predicted factors contributing to more, less, or the same FV consumption during the first 6 months of COVID-19 ($p \leq 0.001$, **Table 2**). Respondents who were food insecure and did not use a food pantry since the beginning of the COVID-19 pandemic reported consuming significantly less FV ($b = 2.29$; $p < 0.001$). Further, among respondents who utilized food pantries since the start of the COVID-19 pandemic, both food insecure and food secure participants also reported consuming significantly less FV ($b = 1.72$; $p < 0.001$ and $b = 1.174$; $p = 0.034$). Conversely, we found BIPOC/Hispanic respondents were more likely to have increased their FV intake ($b = 0.96$; $p = 0.026$) during the first 6 months of the pandemic as compared to non-Hispanic White respondents. Finally, we found that food insecure respondents who reported utilizing a food pantry reported consuming significantly more FV since the start of the COVID-19 pandemic ($b = 1.138$; $p = 0.17$)

Fruit and Vegetable Consumption During the First 6 Months of COVID-19

Using multivariable regression models, we found that respondents in households with children ($b = 0.29$; $p = 0.039$), those who use a form of transportation other than their own vehicle ($b = 0.63$; $p = 0.020$), and those over 55 years old ($b = 0.27$; $p = 0.049$) reported having higher fruit intake during the first 6 months of the pandemic than respondents from households without children, those who used their own vehicle, and those aged 18–55 years (**Table 3**). We found that respondents from low-income households ($b = -0.39$; $p = 0.002$) and respondents in food insecure households ($b = -0.57$; $p = 0.001$) were more likely to report consuming less fruit than higher income and food secure households. We found that respondents over 55 years old ($b = 0.34$; $p = 0.013$) reported having higher vegetable intake in the first 6 months of the pandemic compared to younger respondents and those from low-income households ($b = -0.63$; $p = 0.000$). Finally, we found that respondents who were both food insecure and reported not using a food pantry were significantly more likely to report both a reduction in fruit consumption ($b = -0.58$; $p = 0.001$) and a reduction in vegetable consumption (b = 0.415; $p = 0.012$).

Pantry Utilization Buffers Aspects of Food Access Among Low-Income Households

Food pantry users were significantly more likely to be food insecure ($p < 0.001$) than non-pantry users. While low-income households (earning <$50,000 annually) were more likely to use food pantries, we also found that, for low-income households, using food pantries was associated with greater affirmative responses for each food security item [Chi-squared $p < 0.001$ for all differences (**Supplementary Figure 1**; **Supplementary Table 3**)]. Expressly, as compared to respondents not using a food pantry, 21% fewer respondents from low-income households who utilized a food pantry since March 2020 agreed that the food they had did not last and they did not have money to get more (20.0%; 41.2%) and that they could afford to eat a balanced meal (20.2%; 40.7%). Among those earning $50,000 annually or less, 60% fewer respondents whose households utilized food pantries agreed that adults in their household had cut the size of their meals or skipped meals

TABLE 2 | Multinomial logit model predicting change in fruit and vegetable consumption during the first 6 months of the COVID-19 pandemic.

Variable	Coefficient	Standard error	*P*=	95% Confidence interval	
Less fruit and vegetable consumption since COVID					
Gender (female)	0.26	0.27	0.329	−0.27	0.80
Children in household	0.51	0.28	0.067	−0.04	1.05
Age (over 55 y/o)	−0.13	0.29	0.664	−0.70	0.44
Race/Ethnicity (BIPOC/Hispanic)	0.44	0.43	0.447	−0.52	1.17
Change in employment status	0.21	0.24	0.396	−0.27	0.68
Low-income households (<50 K)	0.22	0.27	0.412	−0.30	0.74
No food pantry, food insecure	2.29	0.31	0.000	1.68	−2.90
Food pantry, food insecure	1.72	0.37	0.000	0.99	2.45
Food pantry, food secure	1.17	0.56	0.034	0.09	2.26
Transportation use other than vehicle	−0.23	0.49	0.637	−1.20	0.73
More fruit and vegetable consumption since COVID					
Gender (female)	−0.03	0.31	0.928	−0.63	0.58
Children in household	0.44	0.34	0.201	−0.23	1.11
Age (over 55 y/o)	−0.14	0.35	0.695	−0.83	0.56
Race/Ethnicity (BIPOC/Hispanic)	0.96	0.43	0.026	0.12	1.79
Change in employment status	0.55	0.30	0.063	−0.03	1.13
Low-income households (<50 K)	−0.46	0.33	0.172	−1.11	0.20
No food pantry, food insecure	0.70	0.45	0.122	−0.19	1.58
Food pantry, food insecure	1.14	0.25	0.017	0.20	2.080
Food pantry, food secure	0.68	0.71	0.337	−0.71	2.08
Transportation use other than vehicle	0.12	0.62	0.852	−1.10	1.33

The base outcome on the dependent variable is no change in fruit and vegetable consumption, so results show the coefficients predicting less or more consumption compared to no change. For food security status, the base outcome is no food pantry, food secure, so results for the other food security statuses are in comparison to this base outcome.

because there was not enough money for food as compared to respondents whose households did not utilize food pantries (15.6%; 21.1%). Among the same subset of respondents, four percent fewer respondents whose households utilized a food bank or food pantry reported that they had to eat less (17.0%; 20.8%) or cut the size of their meals or skip meals (17.1%; 21.3%) because there was not enough money for food.

Food Pantry Utilization

About one in seven respondents (14.5%) reported that their household utilized a food bank or food pantry between March and September 2020 (**Table 4**). Those with increased odds of utilizing these food distribution services were food insecure (OR = 6.55, 95% CI = 3.52, 12.20) and low-income households (OR = 3.85, 95% CI = 2.01, 7.38), and respondents using transportation other than their own vehicle (OR = 4.68, 95% CI = 1.87, 11.70) (**Table 4**).

Food Pantry Participant Experiences

We found that the vast majority of respondents (85%) who utilized food pantries during the first 6 months of the pandemic ($n = 86$) agreed or strongly agreed that food pantries have been helpful (**Supplementary Figure 2**). Approximately one-third of pantry users indicated concerns, including that pantries run out of food often (35%), have long lines and wait times (34%), and have inconvenient or irregular hours (30%). Other concerns among food pantry users included pantries not having the food their family likes (22%) or good quality food (22%) and not knowing how to prepare food the pantry provides (12%).

DISCUSSION

To our knowledge, this is the first study to examine the relationship between the charitable food system (food banks, pantries/shelves) and FV consumption during the COVID-19 pandemic. Overall, we find that 14.5% of our respondents utilized a food pantry which mirrors increased demand nationally as evidenced by media outlets' reports (7–9). Among food insecure respondents, we found those who did not use a food pantry were significantly more likely to report consuming less FV during the pandemic. Additionally, we found that respondents who are food insecure and using a food pantry report consuming more FV since the onset of the pandemic. Furthermore, we found that respondents who were both food insecure and reported not using a food pantry were significantly more likely to report both a reduction in fruit consumption and a reduction in vegetable consumption. These results suggest that utilization of food banks and food pantries has a relationship with perceptions of FV access and reported intake.

Although low-income households were more likely to prepare home cooked meals before the COVID-19 pandemic (15), disparities exist in FV intake across socioeconomic status. Home cooked meals are generally associated with higher FV intake (32). While most households do not eat enough FV—low-income

TABLE 3 | Multivariable regression models predicting fruit and vegetable consumption during the first 6 months of COVID-19.

Variable	Coefficient	Standard error	*P*=	95% Confidence interval	
Fruit consumption since the start of the COVID-19 pandemic					
Gender (female)	0.08	0.12	0.507	−0.15	0.32
Children in household	0.29	0.14	0.039	0.01	0.56
Age (over 55 y/o)	0.27	0.13	0.049	0.00	0.53
Race/Ethnicity (BIPOC/Hispanic)	0.26	0.21	0.206	−0.15	0.67
Change in employment status	0.06	0.12	0.580	−0.16	0.29
Low-income households (<50 K)	−0.39	0.13	0.002	−0.64	−0.14
No food pantry, food insecure	−0.58	0.17	0.001	−0.90	−0.25
Food pantry, food insecure	−0.32	0.20	0.117	−0.71	0.08
Food pantry, food secure	−0.40	0.31	0.204	−1.00	0.21
Transportation use other than vehicle	0.63	0.27	0.020	0.10	1.16
Vegetable consumption since the start of the COVID-19 pandemic					
Gender (female)	0.15	0.12	0.226	−0.09	0.39
Children in household	0.07	0.14	0.608	−0.20	0.35
Age (over 55 y/o)	0.33	0.13	0.013	0.07	0.60
Race/Ethnicity (BIPOC/Hispanic)	0.26	0.21	0.217	−0.15	0.66
Change in employment status	0.19	0.12	0.105	−0.04	0.41
Low-income households (<50 K)	−0.635	0.13	0.000	−0.88	−0.39
No food pantry, food insecure	−0.42	0.16	0.012	−0.74	−0.09
Food pantry, food insecure	−0.28	0.20	0.161	−0.67	0.11
Food pantry, food secure	−0.09	0.31	0.775	−0.69	0.51
Transportation use other than vehicle	0.21	0.27	0.428	−0.31	0.74

Models were run independently with separate dependent variables (i.e., fruit consumption and vegetable consumption).

TABLE 4 | Multivariate analysis predicting odds of food pantry use since the start of the COVID-19 pandemic.

Variable - pantry use since COVID	Odds ratio	Std. error	*P*=	95% Confidence interval	
Gender (female)	0.99	0.32	0.965	0.53	1.85
Children in household	1.34	0.44	0.364	0.71	2.55
Age (Over 55 y/o)	1.38	0.49	0.364	0.69	2.76
Race/Ethnicity (BIPOC)	1.60	0.76	0.324	0.63	4.04
Change in employment status	1.33	0.39	0.324	0.76	2.36
Low-income households (<$50 K)	3.85	1.28	0.000	2.01	7.38
Food insecure households	6.55	2.08	0.000	3.52	12.20
Transportation use other than vehicle	4.68	2.19	0.001	1.87	11.70

households and those with food insecurity are especially at risk of low FV intake and limited dietary variety. Higher FV intake is associated with a reduced risk of cardiovascular disease, cancer, co-morbidities, and all-cause mortality (33). Our results suggest that the food bank/food pantry system may play a role in blunting the adverse effects of a humanitarian crisis like the COVID-19 pandemic by increasing food access for low-income households and thereby mitigating reductions in their overall FV intake.

Although we found an association between food security status and pantry use, Robaina and Martin (32) demonstrated that our low-income pantry users answered specific statements within the USDA Food Security Module at a significantly lower affirmative rate compared to low-income non-users. We recognize that the USDA defines food security based on Anderson's 1990 Report (34), where food security is acquired "without resorting to emergency food supplies" (34). Our findings demonstrate that the food bank/food pantry system may have helped maintain several components of food access and FV intake among food insecure users of this system. Our results suggest that although food bank use does not impact the overall food security rate, food security indicators such as "food did not last" and they "could not afford a balanced meal" are associated with positive outcomes among those using food pantries. Further evidence that use of food banks/food pantries may improve food access includes our findings that 85% of users found food pantries helpful.

As expected, both food insecure and low-income populations are at greater odds of using a food bank/food pantry as compared

to food secure and higher income households. We also found the population using any form of transportation other than their own vehicle to be more likely to use a food bank/food pantry, probably due at least in part to the greater reliance on public transportation among low-income persons in the US (35, 36). Further, studies suggest associations between unemployment and significantly lower levels of car ownership especially among BIPOC and female head of household families (37). With state and local social distancing requirements informing distribution, many food pantries have shifted from a super-market-type layout to a drive-up operation where volunteers assembled pre-packaged food boxes and placed them in the patron's vehicle (9). Patrons who rely on public transportation may experience barriers to this new food distribution model. Future studies should include inquiries into the patrons experience with pre-packaged food box distribution.

Although FV intake did not differ between non-Hispanic White and respondents from racial and ethnic minority populations at the time of our survey, BIPOC/Hispanic respondents were more likely to report a significant increase in FV intake during the first 6 months of the COVID-19 pandemic. This is notable and important since increasing FV intake is a national public health goal, and FV intake tends to be lower among some racial and ethnic groups (38). The FV intake among BIPOC respondents mirrors findings in France by Marty et al. (39), who found an increase in FV consumption during the lockdown. However, their subjects also increased their consumption of sugary foods, sodium, and alcoholic beverage, which our study did not capture (40).

We acknowledge that charitable food services are part of a broader system of food access and food security. The charitable food system is designed as an emergency stop-gap and is valuable in crises like the one presented by the COVID-19 pandemic, but does not replace the central role of federal nutrition assistance programs, which are purposely designed to supplement the diverse needs of the most vulnerable Americans. Researchers (41) indicate that the chronic reliance on charitable food services can worsen food security for many households and limit access to culturally and medically appropriate foods. An additional important role of the charitable food system is to help link people to other programs in times of need. It remains to be investigated the extent to which this occurred during the COVID-19 pandemic.

Limitations

We note a few limitations. First, although our approach's strength was the use of quota sampling to achieve alignment between the sample and the population of Vermont with respect to race, ethnicity, and income, respondents may have differed in other ways. Prior work has demonstrated differences between participants in online survey research and the general population, including greater participation among women, which we saw in our sample (42, 43). Online surveys may lead to response bias and the over-representation of females. Second, self-reported dietary data are subject to recall and response bias (44). Although the two-item FV intake instrument that we used has adequate reliability, it has low validity for measuring precise intake levels (29). We used this instrument to compare individuals concerning FV intake rather than estimate actual intake in line with recommendations (29). Further, our study was conducted in August and September when the availability of local FV is at an annual peak. Research is needed that utilizes a more robust and inclusive measure of dietary intake and dietary quality. Finally, these cross-sectional data do not allow rigorous evaluation of a causal link between food pantry use and food security or FV intake. Future research should address these limitations and consider the longer-term associations between food pantry use, food security, and dietary intake in crisis contexts.

Conclusion

This study documented use and experiences with the charitable food system, including associations with food security and FV intake outcomes, among a statewide sample in Vermont, US, in the first 6 months of the COVID-19 pandemic. We found that food bank/food pantry use significantly increased in Vermont since the start of the COVID-19 pandemic. The results document improved FV intake among low-income households that utilized food pantries as compared with low-income households that did not. Taken together, the results suggest that the charitable food system is an important way in which people can supplement their food budget and maintain food access during a humanitarian crisis. However, it is essential to note that Vermont's resilient food system and support programs may have impacted these results and the seasonal abundance when this survey was conducted. Additional research should be conducted more fully to understand these relationships over time and in greater depth. Increased analysis of the food provided through food pantries serving diverse populations may be important to assess the overall accessibility of healthy, culturally, and medically acceptable foods for at-risk populations. The heightened usage of the charitable food system during the COVID-19 pandemic highlights not only the importance of food pantries but reinforces the need for funding, maintenance, and preparedness of these emergency programs.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Institutional Review Board approval was obtained from the University of Vermont under protocol 00000873. Consent was obtained from all participants prior to data collection. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

FB, KR, EB, and MN wrote the original manuscript, provided data curation, code, codebooks, resources, read, edited,

and approved the final manuscript. FB and KR provided conceptualization. FB and MN provided methods and data curation. MN, FB, and EB acquired funding. 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.2021.673158/full#supplementary-material

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Changes in Vegetable Consumption in Times of COVID-19—First Findings From an International Civil Science Project

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The crisis related to the COVID-19 pandemic influenced food security and nutrition through both direct and indirect pathways. This ranged from short-term to long-term impacts, not only on health but also on food systems and thus on nutrition. This study aimed to identify how the observed constraints affected the food intake of populations across the globe. Here, special attention was paid to the consumption of vegetables and legumes and the diversity within these food groups. An online survey on Food and COVID-19 was conducted using a semi-structured questionnaire translated into several languages. Binary logistic regression models and Poisson regression models were calculated to evaluate changes in consumption patterns and to test potential determinants for the changes. For more detailed information on reasons for changes open ended questions were analysed qualitatively. Time spend at home, working from home, and mental stress were important drivers for changes in dietary intake according to the 1,042 respondents included in this analysis. The participants observed a change in food quantity (38%) and vegetable intake (27%). No changes were observed for the number of vegetable groups consumed, while significant reductions in diversity were detected within all vegetable groups. Moreover, associations between the number of consumed vegetable types during the COVID-19 pandemic and income regions as well as gender were found. The regression analysis showed that the level of decrease in vegetable diversity in the different vegetable groups were often depending on educational and occupational status, gender and household environment. Changes in food prices were related to changes in vegetable intake *per se*, overall vegetable diversity, and diversity within the provitamin A rich vegetable group. Food systems are not static and are transitioning quickly as could be observed during the Covid-19 pandemic. There is a need for a nutrition strategy to strengthen the resilience of vulnerable households to consume a diverse diet in adequate amount even in times of a pandemic.

Keywords: COVID-19, vegetable diversity, income region, food intake, vegetable group, dietary diversity

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INTRODUCTION

COVID-19 (coronavirus disease 2019) refers to an infectious respiratory disease transmitted by SARS-CoV-II, which was first reported in Wuhan, China, in December 2019. Since then it was reported around the globe and was declared a global pandemic by the World Health Organisation (WHO) on 11th March 2020 (1, 2). By February 2021, globally more than 113 million cases and more than 2.5 million deaths were recorded. Globally, most cases were officially reported in the Americas and Europe (3).

Since COVID-19 has been declared a global pandemic, countries all over the world took measures such as contact and travel restrictions, store closures, curfews during day or at night or other general confinements to limit the further spread of the virus. These restrictions were in turn affecting the economic situation of many people and thus the purchasing power of these households (4).

The crisis related to the COVID-19 pandemic influenced food security and nutrition through both direct and indirect pathways. Direct pathways may be trade and transport restrictions which negatively impacted on food availability whereas indirect pathways include effects like no school feeding due to school closures or loss of income and thus reduced food purchasing power. This ranged from short-term to long-term impacts, not only on health but also on food systems and thus on nutrition. In this context, the High level of Panel Experts of the Committee on World Food Security (CFS) have emphasised that the initial situation of individual countries and regions and their resilience to such crises will play a decisive role in determining the severity of the disruption as the pandemic evolves (5).

The pandemic challenged the economic and physical access to sufficient and nutritious food, especially for already vulnerable groups and countries (6). Because of trade restrictions and panic buying food items run out of stock or were not affordable for low income households after food prices raised following the trade restrictions (7–9). In countries where workers for food production needed to be hired from other countries food production and processing were affected, too, reducing the availability of perishable foods and subsequently rising prices (9, 10). The impact on the food chain, in the form of restaurant closures and supermarket regulations to avoid food shortages, became apparent soon after first countries started with border closures to reduce the risk of transmitting the virus due to high mobility (9). The services provided by canteens at the workplace, in schools and universities were also minimised or completely cut off which put especially children worldwide at risk to become food insecure (11, 12). Families with school children who relied on meals provided at school struggled to feed their children properly. Although preventive measures were being taken, social media constantly shows out-of-control situations in food stores, which can lead to food shortages and the faster spread of the virus (13). Adjustments were also being implemented to protect and serve citizens and to support the food sector, including delivery services, e.g., school meals were brought to the children's homes (UK) (14), fast food companies to provide school meals (Spain) (15), food baskets were offered from balconies (Naples, Italy) (16) or placed at fences (Berlin, Germany) (17), or food aid was distributed by the Governments (Uganda and USA) (18, 19). In Brazil this concept was shown to work well in large cities, but its accessibility did not reach all socioeconomic groups and geographic locations (13).

Before the Covid-19 pandemic began, a group of scientist looked at how current dietary practises impact planetary health (20). The same group called for substantial transformations in food production and consumption to benefit human and environmental health. This would require among others a shift toward healthy dietary patterns, i.e., limited intake of animal source foods, and an increase in the consumption of legumes, vegetables, fruits, nuts, and seeds (20). The World Health Organisation nutrition advice for adults during the Covid-19 outbreak emphasises the need to regular consume fruits, vegetables, and legumes (21, 22). However, the nutrient values of vegetables can vary thousandfold among different varieties of the same food (23). Many studies on Covid-19 and dietary changes looked at overall changes in food purchasing patterns, consumption and lifestyle only and paid little attention to dietary diversity or even diversity within a food group (6, 8, 9, 12, 24). The "Food systems in times of COVID19" (COVID-Food systems) project aimed to identify how the observed constraints affect the food systems and dietary behaviour of populations across the globe. The objective of this study was to investigate changes in food intake following up on the trade restrictions and recommendations along the debate on planetary health. Following up on the WHO recommendations to consume adequate amount of vegetables and legumes to maintain health, special attention was paid to the change in the consumption of vegetables and legumes and its diversity.

This paper thus presents the analysis of the dietary changes (food quantity, overall vegetable consumption, and vegetable diversity) in relation to the restrictions and lockdown scenarios in diverse populations. Furthermore, individual and environmental characteristics as a possible cause of these changes were investigated to describe the groups most vulnerable to greatest reduction in diversity in vegetable consumption.

METHOD

In close collaboration with members of the international research community from 12 different countries who were interested to join the COVID-Food systems project we developed an online semi-structured questionnaire. The transdisciplinary developed questionnaire asked for socio-demographic information, living environment of the participants, aspects of the participants food systems, food intake, and aid programs as well as the participants perceptions toward changes following the restrictions established in the respective countries. After a consensual validation process including two rounds of pre-testing the questionnaire consisted finally of 65 questions of which 15 were closed, 15 were open-ended, while 35 were designed as mixed questions. The closed-ended questions offered a list of predetermined responses. The open ended questions asked for observations made by the participants providing space for a text without limitation of characters. The mixed questions were offering space to

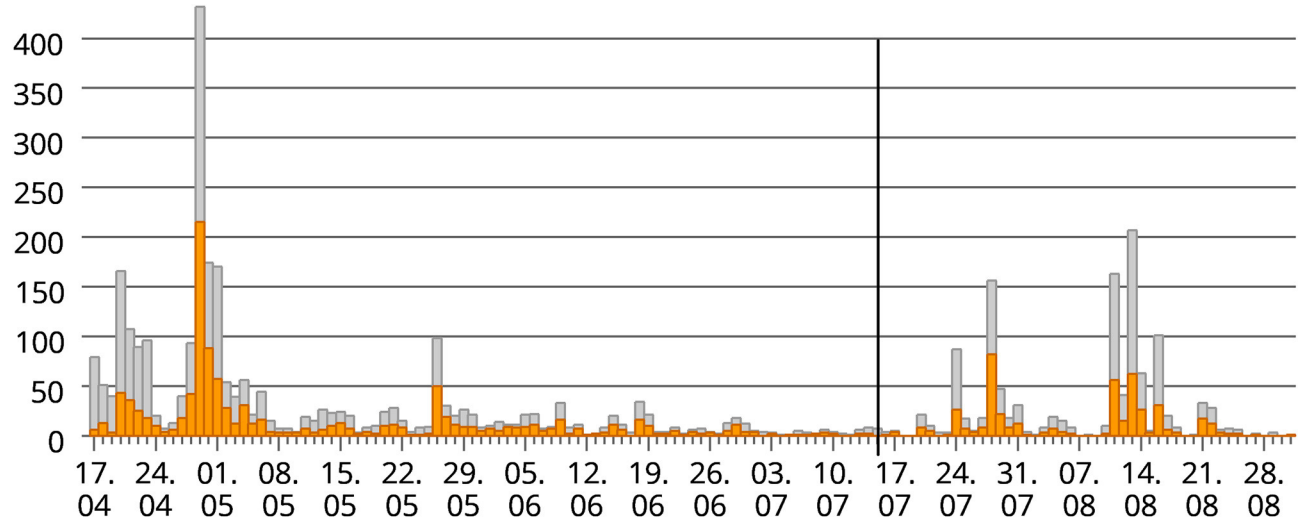

FIGURE 1 | Response pattern of the data collection over time (17.4.-31.8.2020) (x-axis, date of data collection; y-axis, number of responses; orange, completed questionnaires; grey, total responses but incomplete or klicks; black vertical line, end of data collection for this study).

comment and add information about the responses made to the question which had offered a predetermined response scale, e.g., "yes/no/don't know or other, please specify." Changes in food consumption were assessed retrospectively using the same questions to assess the situations prior to and since the pandemic started. The question on price change was measured using a Likert scale (strong increase, little increase, no change, little decrease, and strong decrease).

Various translations of the questionnaire, originally designed in English were developed during the ongoing data collection, namely into Chinese, German, Polish, Russian, Spanish, and Vietnamese among others. The translations were back-translated to English for validation of the translation. The survey took place over a period of 4.5 months starting on 17.04.2020 with the English version.

There were no exclusion criteria for participants. The questionnaire was accessible to anyone with a device with internet access; resulting in a convenience sampling. The SoSci Survey platform was used to create and conduct the online survey tool (25). Data protection was done in accordance with the German data protection laws and regulations, the survey server and operator were placed in Munich, Germany. The survey platform is free for non-commercial research like this study. The authors do not have any conflict of interest.

The link to the survey was uploaded on the project website on "Sustainable Food systems—going beyond Food Security" and on the institutional website of the Centre for International Development and Environmental Research of the University of Giessen (26, 27). The survey was promoted by all questionnaire developers from 12 different countries with different impact *via* social media, email lists, personal contacts and their networks, and the email distribution list of the University of Giessen. The participation was voluntary at any stage and the participants had to actively confirm their willingness to participate. Therefore, no institutional approval was needed according to the review board of the Justus-Liebig University Gießen, Germany.

In total, the link to the survey was used 7,566 times. The klicks included any use of the link whether it was done on purpose or by accident or by a search engine. Thus, no conclusions can be made on how many people were interested in the study but rejected their participation after reading the introduction. Out of the total klicks, 1,528 were counted as completed questionnaires (participants responded to the final question). Participants who did not confirm their willingness to participate were excluded in the data analysis.

As we assume that the data has a risk to be blurred we used an exploratory approach for the analysis. Consequently, we did not follow a specific hypothesis and abstained to do a sample size calculation prior to the data collection.

Selection of Data Included Into This Study

There were several peaks in responses following the various promotion campaigns. The completed responses came from individuals living in 62 different countries. Mid July 2020 a special data collection campaign was started in Poland which resulted in a series of new responses from Polish citizens (**Figure 1**). To avoid confusion with the first lockdown/restriction wave it was decided to exclude for this study the data which was collected after the 15.7.2020.

Preparations for Data Analysis

The responses given in the option "other" in the responses to questions related to *household members, education, occupation, housing environment,* and *restrictions*, were integrated into the existing response categories or new response categories were created if necessary. In order to show regional differences, countries were grouped according to their income status following the classification of the World Bank based on the gross national income (GNI) per capita; the upper cut offs were set at

US$1,035 for low income countries, US$4,045 for lower middle income countries, and US$12,535 for upper middle income countries (28).

Food Quantity

Respondents were asked to evaluate the amount of food they were eating at the time they filled the questionnaire in comparison to the before-pandemic time. Three answers were available: (a) just as much than before the pandemic, (b) less than before the pandemic, and (c) more than before the pandemic.

Binary logistic regression models were used to calculate Odds Ratios (OR) for the change. To obtain more precise information on the amount of food, food items, and reasons for changes the open-ended parts of the question were evaluated qualitatively based on summaries of the provided responses. All comments given in any other language than English were translated to English. Quoted comments were corrected for spelling mistakes. Country of residence, age, and gender were indicated in parentheses for each direct quote given in quotation marks. In the case of indirect quotes only the country of residence was reported in parentheses.

Vegetable Consumption and Vegetable Diversity

The impact of COVID-19 pandemic on the consumption of vegetables was evaluated based on the respective questions (a) "Prior to Covid-19 pandemic: Did you consume any of the vegetables listed below over a period of 4 weeks (1 month) prior to Covid-19?" and (b) "Since the pandemic started: Did you consume any of the vegetables listed below in the last 4 weeks?". It was distinguished between the periods of time the change occurred looking at 4, 8, and 12 weeks retrospectively starting at the time of the interview. A list of 96 types of vegetables was stratified into 5 groups: *dark green leafy vegetables* (e.g., amaranthus leaves, Feldsalat, bok choy), *vitamin-A rich vegetables* (e.g., carrots, pumpkin, sweet red pepper), *starchy vegetables* (e.g., cassava, white potatoes, corn/maize), *legumes* (adzuki beans, chickpeas, sweet peas), *other vegetables* (e.g., tomatoes, asparagus, cabbage). The groups were defined based on guidelines for the vegetable groups used to estimate the minimum dietary diversity for women (29). Data without time reference were not considered. Vegetable diversity was defined counting the (a) number of groups covered in the diet and (b) number of different types consumed within each vegetable group prior to and since the pandemic. The numbers counted for the time since COVID-19 were subtracted from the number prior to the pandemic, thus, positive values indicate a reduction and negative values an increase in diversity over time.

Food Prices

To analyse if perceived changes in food prices had an influence on the amount of food, vegetable consumption and vegetable diversity consumed, a price index was calculated. A perceived price change was assessed based on the 10 food groups of the minimum dietary diversity score for women (staple foods, legumes, nuts and seeds, milk and milk products, meat and fish, eggs, dark green leafy vegetables, vitamin-A rich vegetables and fruits, other vegetables, other fruits) (29). The changes in prices for all food groups were summed up with 2 points for a "strong increase," 1 point for a "little increase," 0 points for "no change," −1 points for a "little decrease," and −2 points for a "strong decrease" per food group.

Statistical Analysis

Binary logistic regression models were used to analyse which factors have an influence on changes in food intake. A Poisson regression was calculated for food intake and in particular vegetable diversity to determine the time effect. Estimated marginal means are presented to visualise effects. Binary logistic regression and Poisson regression models were also calculated and adjusted for age, gender, and income regions in order to test the effects of lockdown and restriction scenarios. The models were created with the procedure Genlinmixed in SPSS and robust standard errors were used. Control variables were listed below the tables presenting our findings. The *p*-values of the multiple pairwise comparisons in the regressions were calculated according to sequential Bonferroni. IBM SPSS Statistics 27 was used for all statistical analysis.

RESULTS

During the survey period 17.4.-15.7.2020, 1,083 participants completed the questionnaire, of whom 1,042 gave their consent that the data from the questionnaire may be used for research purposes. More than 3/4 of the participants were females (77%), while 22% were male and 0.7% responded as non-binary. Two thirds of the participants (62%) were between 20 and 39 years old. The group younger than 15 and all groups from the age of 70 and above accounted for <1% each (**Figure 2**).

More general characteristics are presented in **Table 1**. Most of the respondents were university graduates (71%), followed by high school graduates or people with an A-levels certificate (15%). Being an employee, a civil servant and University student or training was the most mentioned occupation (29, 28, and 28%, respectively).

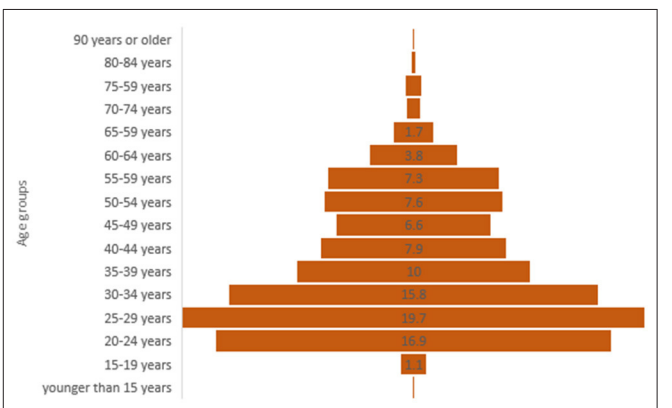

FIGURE 2 | Distribution of age groups within the study population indicated in percent ($n = 1{,}041$).

TABLE 1 | General characteristics of the participants.

	Percentage
Gender (n = 1,042)	
Female	76.7
Male	22.3
Non-binary	0.7
Preferred not to say	0.3
Educational level (n = 1,041)	
No degree or below the level of high school	5.6
Finished high school	14.8
Completed apprenticeship or vocational baccalaureate diploma	8.9
University degree	70.7
Occupation (n = 1,035)	
Student in school	2.0
University student or training	27.7
Unemployed	3.7
Employee	28.8
Self-employed	7.2
Civil servant	27.7
Retirement/Pension	2.8
Geographical region (n = 1,037)	
Asia and the Pacific	14.8
Latin America and the Caribbean	4.5
North America	3.8
Africa	4.2
Europe	72.7
Income region (n = 1,037)	
Low income countries	1.5
Lower middle income countries	11.9
Upper middle income countries	9.1
High income countries	77.5
Living environment (n = 1,039)	
Rural area	21.4
Peri urban area	14.0
Small town (<1 h walking distance from farmland)	16.8
Small town (1–4 h walking distance from farmland)	10.9
Big town (1–4 h walking distance from farmland)	3.5
Big town (province capital)	11.8
City	10.1
Mega city	2.8
Capital city	8.8
Household types: "I live … (n = 1,026)	
Alone	15.6
With my partner	29.6
2 generation family	18.3
3 generation family	5.7
1 generation shared flat	14.3
2 generation shared flat	7.6
Single parents with children of different age	1.9
Other	1.4
Different family types with children of unknown age	5.6
Lockdown scenarios (multiple responses) (n = 1,042)	
Contact restrictions	72.6
Travel restrictions	74.8
Only food retailers/supermarkets, drugstores and pharmacies are open	53.1
Curfew during day	4.8
Curfew at night	6.8
You are not allowed to leave your house but only to buy food	11.7
Other restrictions	10.7
Not that I know	3.5
Change in food quantity since the pandemic started (n = 1,037)	
Eat less food (any)	15.1
Amount of food (any) did not change	62.0
Eat more food (any)	22.9

*Estimated mean age = 37 years; estimated based on age group prevalences (**Figure 2**).*

The majority (91%) reported no change in the occupational status due to COVID-19, 4% claimed that their working hours had decreased, their job had been temporarily suspended or they had experienced economic losses due to COVID-19 which might affect the level of food expenditure. Still, loss of their jobs due to the pandemic was reported by 5% of the respondents. Any support from the government, associations, religious communities, or individuals was received by 8%.

Overall, 62 countries were covered in this study, but the countries were unevenly represented. Nearly all geographical regions were covered, however the majority of the respondents resided in Europe (73%) at the time of their participation. The majority of participants lived in Germany (67%), followed by Vietnam (8%), China (4%), USA (4%), Colombia (1.4%), Poland (1.3%), and Kenya (1.3%); the remaining 14% of the respondents live in 53 different countries (**Supplementary Table 1**). Stratified by income region, 77.5% lived in high income countries, 9.1% in upper middle income countries, 11.9% in lower middle income countries, and only 1.5% in low income countries. In the course of the survey, 63% reported experiencing a lockdown and 16% were not affected anymore while 21% stated that they had not been affected at all by a lockdown. **Table 1** shows that contact and travel restrictions (73 and 75%) as well as restricted store openings (53%) were predominant. Curfews during day, curfews at night and full lockdowns only affected 4.8, 6.8, and 11.7% of the respondents, respectively. Only 3.5% of the participants reported that they did not know about any existing restrictions in their living area.

Changes in Food Quantity

The majority of the respondents (62%) did not observe any change in the amount of food they consumed. The proportion of people who observed an increase over time was higher than those who observed a decrease (23 vs. 15%) (**Table 1**). The greatest change in food quantity occurred in the group of people who indicated that they had entered into a lockdown. The change occurred in both directions: decrease and increase in the

TABLE 2 | Perceived change in food quantity in relation to lockdown scenarios indicated in percent in reference to prior to the pandemic.

	Eat less food	Amount of food did not change	Eat more food	Change in vegetable intake*
Low income countries $N = 16$	25.0	68.8	6.3	28.6
Lower middle income countries $N = 123$	19.5	63.4	17.1	21.1
Upper middle income countries $N = 94$	18.1	64.9	17.0	23.3
High income countries $N = 804$	14.0	61.1	24.9	28.6
No lockdown ($N = 215$)	12.6	67.4	20.0	22.7
No lockdown anymore ($N = 163$)	8.6	68.5	22.8	26.5
Lockdown ($N = 655$)	17.4	58.7	23.9	28.9

Perceived change, either decrease or increase.

amount of food consumed. Compared to the group that was no longer affected by a lockdown, the ones that did not experience a lockdown indicated more often to eat less than before the pandemic (96 and 13%, respectively). The share of respondents eating more than before the pandemic ranged between 20 and 24% regardless of whether they (had) experienced any lockdown or not (**Table 2**).

To obtain more information about the possible reasons for a change we asked the respondents to give a more detailed explanation for reported change in food intake. Most frequently mentioned reasons for an increase in the consumed amount of food were isolation, boredom, more home-cooked meals, more free time, spending more time at home, working from home, having meals together with the family, and mental stress. All of these reasons might be direct or indirect result of the restrictions implemented by the governments.

The binary logistic regression on the decrease in the amount of food eaten confirmed a significant influence of the lockdown scenarios. The proportion of people who ate less in the group that experienced a lockdown was higher than in the group that was no longer in lockdown, with an average difference of 14.2% (−0.142, 95% CI [−0.257, −0.027], $p = 0.010$). No significant effects could be identified for the specific types of restrictions and in regard to increase in the amount of food and the various restrictions and lockdown scenarios (**Table 3**).

Overall, the change in food quantity in relation to income regions was lowest in the low income countries and highest in the high income countries. The group of people who said they ate more than before the pandemic was represented most frequently in the high income countries (25%) and least frequently in the low income countries (6%). In contrast, the prevalence of participants reporting to eat less was lowest in high income countries (14%) and highest in low income countries (25%) (**Table 2**).

With an increase by one age-group (**Figure 2**), the chance to increase the amount of consumed food decreased by 9.6%, adjusted (ad) for gender, income region, occupation, education, household type and living environment (adOR = 0.904, 95% CI [0.831, 0.983], $p = 0.018$).

Changes in Overall Vegetable Consumption

Out of the 1,042 participants included in this study, 995 reported in detail on their vegetable consumption. Out of these, 27% indicated a change in their vegetable consumption which was not associated with age (**Figure 3C**). The proportion of participants who indicated a change decreased with the length of the time period (4, 8, and 12 weeks retrospectively starting at the time of the interview), ranging from 25% in the last 4 weeks to 8% in the last 12 weeks. Even though the overall effect of "living environment" was not significantly influencing vegetable consumption (**Figure 3**), the pairwise comparisons between mega cities and peri urban areas as well as mega cities and small towns (farmland within 1 h walking distance) showed significant differences with 21% more respondents from the peri urban area and 20% more respondents from the small town reporting a change in their vegetable intake compared to respondents from mega cities (0.207, 95% CI [0.007, 0.407], $p = 0.033$ and 0.200, 95% CI [0.001, 0.399], $p = 0.047$, respectively).

The change in vegetable consumption occurred in both directions: increase and decrease which resulted in an overall "no change" for all respondents. Reasons for decrease were "reduced access and availability" as reported from Bangladesh, Ecuador, Guatemala, Ireland, Kenya, New Zealand, Poland, Vietnam, Spain, Tanzania, and USA, "increased prices" reported from Ecuador, Fiji, Kenya, and Germany or because respondent went "less shopping" (Germany and USA) or "those who provided the meals, do not make balanced dishes and you have to eat what they are offering" as mentioned by a respondent from Columbia (35–39 year old woman). "Children do not eat as diversely" or "my parents buy less vegetables than I would" were mentioned by women from Germany (35–39 years old and 20–24 years old, respectively) indicating new household settings due to students staying at home. But also, time constraints and stress were pointed out by a man as factor influencing vegetable consumption: "Less vegetables, [because] less time to cook (work and childcare), more emotional stress" (Germany, 45–49 years, male).

Changes in Vegetable Diversity

The mean number of vegetable groups covered in the diets was 4.5 out of 5 for the two time points: prior to and since the pandemic started. No significant association was found between age and diversity within the observed vegetable groups excluding "other vegetables." The latter was associated with a small increase over "time" by age (**Supplementary Table 2**). In the case of overall vegetable diversity, the consumption of vegetable categories showed a shift of the median only for low income countries. The medians for the number of different vegetable types consumed per each food group were more stable over time in the high income countries than in the other regions. The open responses indicated a trend from fresh vegetables to frozen, canned vegetables or storable vegetables. At the same time study participants reported that they have "more time to cook" (Poland and

TABLE 3 | Odds ratios for perceived changes in food and vegetable intake.

	Food quantity[§]		Vegetable intake[§]	Vegetable categories*[#]	Vegetable diversity[#]				
	Decrease	Increase			Dark green leafy	Provitamin A rich	Starchy	Legumes	Other
Basic model, not adjusted									
OR					**0.832**	**0.866**	**0.878**	**0.848**	**0.938**
p					**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
95% CI					**0.805/0.860**	**0.841/0.893**	**0.836/0.923**	**0.817/0.879**	**0.909/0.967**
No lockdown-no lockdown anymore									
OR	0.547	1.038	1.019	1.387	**1.191**	0.981	1.072	1.057	1.109
p	0.102	0.892	0.476	0.216	**0.028**	0.779	0.543	0.552	0.158
95% CI	0.265/1.127	0.605/1.782	0.968/1.072	0.825/2.332	**1.019/1.392**	0.861/1.119	0.857/1.341	0.880/1.269	0.961/1.280
No lockdown-lockdown									
OR	1.315	1.133	1.036	1.349	1.126	1.083	1.161	1.107	1.040
p	0.310	0.587	0.091	0.167	0.061	0.104	0.123	0.172	0.493
95% CI	0.775/2.233	0.722/1.776	0.994/1.080	0.882/2.064	0.994/1.275	0.984/1.192	0.960/1.404	0.957/1.281	0.930/1.163
No contact restrictions-contact restrictions									
OR	1.063	0.977	0.768	1.033	1.030	1.067	1.135	1.068	1.079
p	0.804	0.907	0.171	0.106	0.598	0.173	0.140	0.344	0.156
95% CI	0.654/1.728	0.656/1.453	0.527/1.120	0.993/1.075	0.924/1.147	0.972/1.171	0.959/1.343	0.932/1.224	0.971/1.198
No travel restrictions-travel restrictions									
OR	0.998	0.852	0.859	**0.968**	1.020	0.947	0.912	0.954	0.949
p	0.992	0.399	0.409	**0.037**	0.698	0.191	0.216	0.436	0.277
95% CI	0.625/1.591	0.587/1.237	0.598/1.234	**0.939/0.998**	0.923/1.128	0.872/1.028	0.789/1.055	0.848/1.074	0.863/1.043
No store closures-only food stores, drugstores and pharmacies are open									
OR	1.230	1.351	1.308	0.991	0.993	1.023	0.982	1.059	1.046
p	0.296	0.068	0.083	0.535	0.870	0.524	0.766	0.285	0.273
95% CI	0.833/1.816	0.978/1.866	0.965/1.773	0.964/1.019	0.915/1.079	0.953/1.098	0.871/1.107	0.953/1.177	0.965/1.132
No curfew during day-curfew during day									
OR	1.131	1.356	1.454	0.936	1.021	0.941	0.940	0.872	0.904
p	0.813	0.584	0.408	0.341	0.894	0.679	0.716	0.442	0.539
95% CI	0.408/3.135	0.455/4.038	0.598/3.536	0.815/1.074	0.755/1.379	0.706/1.256	0.671/1.315	0.614/1.238	0.654/1.249
No curfew at night-curfew at night									
OR	1.802	1.002	1.700	1.034	0.925	1.129	1.128	**1.707**	0.982
p	0.162	0.997	0.182	0.543	0.560	0.325	0.367	**0.000**	0.899
95% CI	0.788/4.122	0.371/2.704	0.780/3.704	0.929/1.152	0.710/1.204	0.886/1.438	0.868/1.468	**1.301/2.240**	0.739/1.305
You are allowed to leave the house-you are not allowed to leave the house but only to buy food									
OR	1.014	0.943	0.819	1.023	1.043	0.949	1.027	0.921	1.061
p	0.966	0.824	0.470	0.458	0.644	0.479	0.800	0.425	0.478
95% CI	0.541/1.900	0.559/1.590	0.475/1.410	0.963/1.086	0.871/1.249	0.820/1.098	0.834/1.264	0.751/1.128	0.901/1.248

[§]*Binary logistic regressions calculated for the change.*

[#]*Poisson regressions calculated for the time period since the onset of COVID-19, significance level: $p < 0.05$, 95% CI = 95% confidence intervals, adjusted for age, gender, and income regions.*

**Vegetable categories (max. 5 = dark green leafy vegetables, provitamin A rich vegetables, starchy vegetables, legumes, and other vegetables), dark green leafy vegetables (max. 18), provitamin A rich vegetables (max. 8), starchy vegetables (max. 9), legumes (max. 17), and other vegetables (max. 33).*

OR, odds ratio; CI, confidence interval. Bold means: values were estimated to be statistically significant, $p < 0.005$ and the respectives values were bolded to facilitate reading.

Germany) and that they "eat more carrots and reduce the total amount of vegetables" (China, 30–34 years, male) or increased their vegetable consumption "for better health and immunity" (Colombia, Ecuador, Ethiopia, Germany, Honduras, Vietnam). More vegetables were consumed also because "no fish or butchery are open" (India, 50–54 years, male) or "mainly due to the fact that stores run out of pasta" (Germany, 50–54 years, female).

The diversity of the "dark green leafy vegetable" consumption reduced since the beginning of the pandemic with an average decrease of 0.71 vegetable types (0.706, 95% CI [0.579, 0.832], max = 18 types, $p < 0.001$). The overall variety within the food group "provitamin A rich vegetables" ranged from 0 to 8. The diversity within the vegetable groups decreased on average by 0.39 vegetable types (0.389, 95% CI [0.308, 0.470], $p < 0.001$). With an average value of 1.2 before and 1.1 since COVID-19,

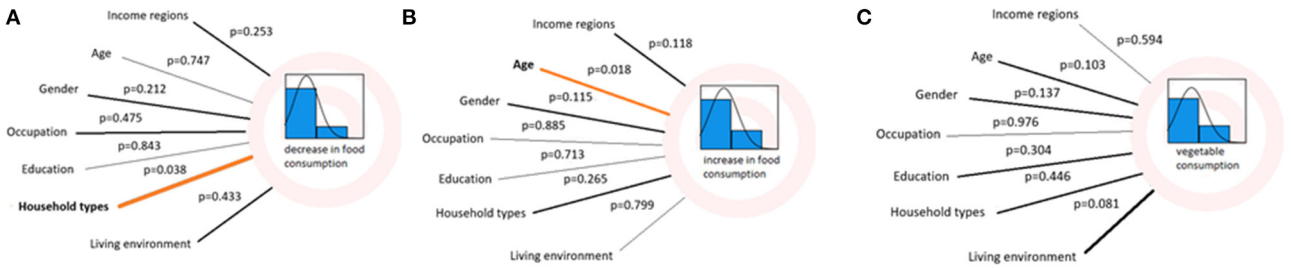

FIGURE 3 | Results of binary logistic regression models for correlations between personal factors and housing situations and **(A)** decrease in food quantity, **(B)** increase in food quantity, **(C)** change in vegetable consumption (orange line indicates a correlation with $p < 0.05$).

"starchy vegetables" was the group of vegetables with the lowest variety (min-max: 0–9). Nevertheless, a decrease in diversity within the group was observed with an average decrease of 0.15 vegetable types (0.147, 95% CI [0.091, 0.203], $p < 0.001$). Between 0 and 17 legume types were counted in this study. The mean value was 3.4 before the pandemic and 2.9 since its beginning. Also, for "legumes," a significant time effect was shown with an average decrease of 0.51 legume types since the onset of the pandemic (0.513, 95% CI [0.398, 0.628], $p < 0.001$). "Other vegetables" was the group with the highest variability. In total 33 different types of "other vegetables" were mentioned. The mean value was 8.7 before and 8.1 since COVID-19. Like for the other vegetable groups, the diversity decreased significantly since the beginning of the pandemic with an average decrease of 0.54 vegetable types (0.542, 95% CI [0.286, 0.798], $p < 0.001$). The actual number of different vegetable types consumed per vegetable group and the mean values prior to and since the pandemic started are presented in **Supplementary Table 3**.

The OR of the basic model estimated that individuals had a lower chance of eating a greater number of different "dark green leafy vegetables" (16.8%), "provitamin A rich vegetables" (13.4%), "starchy vegetables" (12.2%), "legumes" (15.2%), and "other vegetables" (6.2%) since the onset of the pandemic (calculated based on OR) (**Table 3**).

The Poisson regressions presented in **Table 3** show that travel restrictions had a significant effect on vegetable diversity, thus, a 3.2% lower chance for consuming a higher number of vegetable types, when age, gender and income regions were hold constant (adOR = 0.968, 95% CI [0.939, 0.998], $p = 0.004$). Respondents that were no longer affected by a lockdown had about a 1.2 times higher chance of consuming a higher diversity of dark green leafy vegetables than those that had not been affected (adOR = 1.191, 95% CI [1.019, 1.392], $p = 0.028$). Respondents that experienced a curfew at night having about a 1.7 times higher chance for a more diversified legume intake compared to those that were not affected (adOR = 1.707, 95% CI [1.301, 2.240], $p < 0.001$). In contrast, affected by a curfew at night led to an increase in diversity of the legumes by 0.8 in times of COVID-19 (−0.813, 95% CI [−1.431, −0.194], $p = 0.010$). For all other restrictions and vegetable groups no significant correlations were found.

Reduction in vegetable diversity was associated in this study with "income region," gender, education level, occupation, household type, and the living environment of the respondent. Hence, respondents living in lower middle income countries, being a woman, having a university degree, being unemployed, living in a 3-generational family and living in a small town were in general associated with the greatest reduction in diversity in each five vegetable groups. The most pronounced reductions were found for dark green leafy vegetables, legumes, and other vegetables, the lowest reductions in the vegetable groups "starchy vegetables" and "provitamin A rich vegetables" (**Table 4**). The Poisson model for dark green leafy vegetables showed, for example, a significant reduction in the diversity since the onset of the COVID-19 pandemic for all income regions with the greatest decrease occurring in the lower middle income countries [1.1 vegetable types less (1.076, 95% CI [0.542, 1.611] $p < 0.001$)]. Also, for both woman and man there was a significant reduction in the diversity of consumption of dark green vegetables with women consuming on average 1 vegetable type (1.001, 95% CI [0.540, 1.462], $p < 0.001$) and men 0.9 vegetable type (0.927, 95% CI [0.543, 1.311], $p < 0.001$) less than before COVID-19. The 3-generation families were the ones with the greatest reduction of diversity of dark green leafy vegetables since the outbreak of COVID-19 [1.3 vegetable types less (1.281, 95% CI [0.581, 1.980), $p < 0.001$)]. As for the living environments, inhabitants of cities had the greatest decrease in their diversity of dark green leafy vegetables (1.563, 95% CI [0.879, 2.247], $p < 0.001$).

Price Models

Poisson models that examined the effect of perceived price changes on the diversity of vegetable consumption showed no significant association for dark green leafy, starchy vegetables, legumes, and other vegetables. For provitamin A rich vegetables as well as for the diversity of the vegetable groups, a significant correlation was found with a negative coefficient of −0.011 and −0.006, respectively. The odds ratio showed that with a one unit increase in the price index, the chance of consuming a greater number of different provitamin A rich vegetables decreases by 1.1% when adjusted for age, gender, and income region (adOR = 0.989, 95% CI [0.980, 0.999], $p = 0.029$). In the case of overall vegetable diversity persons reporting a stronger increase in prices or increased prices in more food groups were more likely to cover less vegetable groups in their diet; one unit increase in the price index reduced the chance of consuming a larger

TABLE 4 | Results of Poisson regressions for changes since the onset of the pandemic in the diversity of vegetable categories, dark green leafy vegetables, and provitamin A rich vegetables.

	Vegetable categories			Dark green leafy vegetables			Provitamin A rich vegetables		
	Mean difference	***p***	**95% CI**	**Mean difference**	***p***	**95% CI**	**Mean difference**	***p***	**95% CI**
Income regions									
Low income	0.003	0.993	−0.644/0.650	**1.043**	**0.021**	**0.162/1.925**	0.027	0.822	−0.211/0.266
Lower middle income	0.180	0.140	−0.059/0.418	**1.076**	**0.000**	**0.542/1.611**	**0.369**	**0.013**	**0.079/0.658**
Upper middle income	0.060	0.697	−0.244/0.365	**0.678**	**0.006**	**0.199/1.157**	0.278	0.159	−0.109/0.666
High income	0.004	0.975	−0.230/0.237	**0.728**	**0.003**	**0.254/1.203**	0.103	0.438	−0.158/0.365
Gender									
Female	0.050	0.712	−0.215/0.315	**1.001**	**0.000**	**0.540/1.462**	0.227	0.058	−0.008/0.461
Male	0.078	0.536	−0.168/0.323	**0.927**	**0.000**	**0.543/1.311**	0.171	0.083	−0.022/0.365
Education									
No degree/degree below level of high school	0.173	0.412	−0.241/0.588	**1.284**	**0.000**	**0.574/1.994**	0.132	0.512	−0.263/0.527
High school/A-level degree	−0.004	0.975	−0.254/0.246	**0.891**	**0.000**	**0.462/1.320**	0.077	0.487	−0.141/0.295
Apprenticeship/vocational baccalaureate diploma	0.041	0.774	−0.238/0.320	**0.670**	**0.004**	**0.210/1.129**	**0.275**	**0.044**	**0.007/0.543**
Vocational university diploma	0.046	0.671	−0.167/0.260	**0.984**	**0.000**	**0.614/1.355**	**0.317**	**0.001**	**0.137/0.497**
Occupation									
Student in school	−0.047	0.885	−0.677/0.584	0.426	0.502	−0.830/1.683	−0.320	0.290	−0.914/0.273
University student/Trainee	0.189	0.101	−0.037/0.414	**0.929**	**0.000**	**0.541/1.318**	**0.310**	**0.012**	**0.069/0.551**
Unemployed	0.109	0.593	−0.292/0.510	**1.173**	**0.003**	**0.410/1.935**	**0.445**	**0.029**	**0.046/0.844**
Employee	0.105	0.378	−0.128/0.337	**1.109**	**0.000**	**0.730/1.487**	**0.308**	**0.002**	**0.112/0.504**
Self-employed	−0.069	0.625	−0.346/0.208	**0.998**	**0.000**	**0.498/1.498**	0.087	0.598	−0.237/0.411
Civil servant	0.087	0.497	−0.163/0.336	**0.949**	**0.000**	**0.587/1.312**	**0.305**	**0.005**	**0.093/0.516**
Retirement/Pension	0.080	0.683	−0.304/0.463	**1.124**	**0.002**	**0.428/1.820**	0.269	0.170	−0.116/0.655
Household types									
Living alone	0.056	0.664	−0.196/0.307	**0.760**	**0.000**	**0.389/1.132**	0.171	0.117	−0.043/0.386
With partner	−0.014	0.913	−0.269/0.241	**0.810**	**0.000**	**0.415/1.204**	0.125	0.253	−0.089/0.338
2 generation family (underage children)	−0.023	0.861	−0.281/0.235	**0.834**	**0.000**	**0.421/1.248**	0.141	0.235	−0.092/0.373
3 generation family	0.240	0.175	−0.107/0.587	**1.281**	**0.000**	**0.581/1.980**	**0.594**	**0.010**	**0.145/1.042**
1 generation shared flat	0.022	0.884	−0.270/0.313	**0.900**	**0.000**	**0.453/1.348**	0.047	0.704	−0.197/0.292
2 generation shared flat	0.247	0.284	−0.205/0.699	**1.238**	**0.003**	**0.420/2.057**	0.269	0.255	−0.194/0.732
Other types	−0.075	0.601	−0.356/0.206	**0.989**	**0.000**	**0.501/1.477**	0.050	0.699	−0.204/0.305
Living environment									
Rural area	0.041	0.737	−0.196/0.278	**0.801**	**0.000**	**0.437/1.164**	0.164	0.102	−0.033/0.361
Peri urban area	0.162	0.216	−0.095/0.420	**0.905**	**0.000**	**0.471/1.340**	**0.256**	**0.031**	**0.024/0.489**
Small town (<1 h from farmland)	0.163	0.211	−0.092/0.419	**0.947**	**0.000**	**0.498/1.395**	**0.351**	**0.002**	**0.124/0.578**
Small town (1–4 h from farmland)	0.106	0.487	−0.192/0.403	**1.073**	**0.000**	**0.573/1.572**	**0.562**	**0.000**	**0.270/0.853**
Big town (<4 h from farmland)	0.007	0.958	−0.263/0.278	**0.762**	**0.004**	**0.238/1.286**	0.048	0.791	−0.304/0.399
Big town (province capital)	0.134	0.373	−0.161/0.429	**0.858**	**0.000**	**0.423/1.293**	0.159	0.222	−0.096/0.413
City	0.287	0.090	−0.044/0.618	**1.563**	**0.000**	**0.879/2.247**	**0.435**	**0.010**	**0.105/0.765**
Mega city	−0.319	0.197	−0.804/0.166	**0.931**	**0.018**	**0.160/1.702**	−0.422	0.176	−1.034/0.189
Capital city	−0.009	0.949	−0.270/0.253	**0.727**	**0.005**	**0.217/1.236**	0.108	0.462	−0.181/0.397

	Starchy vegetables			Legumes			Other vegetables		
	Mean difference	***p***	**95% CI**	**Mean difference**	***p***	**95% CI**	**Mean difference**	***p***	**95% CI**
Income regions									
Low income	−0.087	0.825	−0.859/0.685	0.680	0.065	−0.043/1.404	0.582	0.341	−0.617/1.781
Lower middle income	**0.500**	**0.001**	**0.208/0.793**	**0.511**	**0.003**	**0.181/0.841**	**1.360**	**0.004**	**0.443/2.277**

(Continued)

TABLE 4 | Continued

	Starchy vegetables			Legumes			Other vegetables		
	Mean difference	***p***	**95% CI**	**Mean difference**	***p***	**95% CI**	**Mean difference**	***p***	**95% CI**
Upper middle income	0.106	0.435	−0.160/0.371	0.399	0.077	−0.044/0.842	0.387	0.314	−0.366/1.140
High income	**0.182**	**0.007**	**0.049/0.316**	**0.478**	**0.032**	**0.040/0.916**	0.767	0.126	−0.216/1.750
Gender									
Female	0.188	0.168	−0.079/0.455	**0.558**	**0.004**	**0.179/0.938**	**0.883**	**0.036**	**0.059/1.708**
Male	0.151	0.242	−0.102/0.405	**0.554**	**0.001**	**0.231/0.878**	**0.700**	**0.031**	**0.064/1.335**
Education									
No degree/degree below level of high school	0.219	0.261	−0.163/0.600	**0.560**	**0.044**	**0.015/1.106**	1.038	0.080	−0.125/2.202
High school/A-level degree	0.002	0.991	−0.283/0.286	**0.524**	**0.003**	**0.183/0.865**	0.554	0.155	−0.210/1.317
Apprenticeship/vocational baccalaureate diploma	0.265	0.093	−0.044/0.573	**0.414**	**0.019**	**0.069/0.759**	0.708	0.075	−0.072/1.487
Vocational university diploma	0.187	0.121	−0.049/0.424	**0.754**	**0.000**	**0.402/1.106**	**0.856**	**0.011**	**0.198/1.515**
Occupation									
Student in school	0.212	0.352	−0.234/0.657	0.452	0.460	−0.755/1.659	−0.611	0.470	−2.269/1.048
University student/Trainee	0.180	0.110	−0.041/0.401	**0.459**	**0.004**	**0.145/0.773**	0.388	0.244	−0.265/1.040
Unemployed	0.354	0.168	−0.150/0.859	**1.126**	**0.003**	**0.396/1.856**	**1.562**	**0.025**	**0.200/2.924**
Employee	0.105	0.424	−0.152/0.361	**0.481**	**0.000**	**0.211/0.752**	**0.945**	**0.005**	**0.280/1.610**
Self-employed	0.039	0.868	−0.417/0.495	0.328	0.096	−0.058/0.714	**1.032**	**0.046**	**0.017/2.047**
Civil servant	0.082	0.552	−0.189/0.354	**0.437**	**0.001**	**0.175/0.699**	0.551	0.088	−0.083/1.186
Retirement/Pension	0.206	0.252	−0.147/0.558	**0.612**	**0.011**	**0.139/1.084**	**1.918**	**0.025**	**0.240/3.595**
Household types									
Living alone	0.175	0.154	−0.065/0.415	**0.488**	**0.005**	**0.149/0.827**	0.679	0.051	−0.003/1.361
With partner	0.112	0.430	−0.167/0.391	**0.575**	**0.002**	**0.213/0.936**	0.623	0.106	−0.132/1.378
2 generation family (underage children)	0.082	0.524	−0.170/0.333	**0.501**	**0.009**	**0.127/0.875**	0.464	0.218	−0.275/1.203
3 generation family	**0.508**	**0.024**	**0.067/0.949**	**0.604**	**0.004**	**0.195/1.013**	**1.589**	**0.017**	**0.284/2.895**
1 generation shared flat	0.041	0.842	−0.362/0.444	**0.482**	**0.023**	**0.065/0.898**	0.471	0.234	−0.305/1.248
2 generation shared flat	0.110	0.608	−0.311/0.531	**0.957**	**0.006**	**0.277/1.638**	1.328	0.067	−0.091/2.748
Other types	0.166	0.318	−0.160/0.491	0.326	0.091	−0.052/0.703	0.468	0.216	−0.273/1.210
Living environment									
Rural area	0.055	0.682	−0.207/0.317	**0.541**	**0.001**	**0.230/0.853**	0.620	0.084	−0.083/1.323
Peri urban area	0.167	0.258	−0.122/0.455	**0.689**	**0.001**	**0.273/1.105**	**0.866**	**0.025**	**0.109/1.622**
Small town (<1 h from farmland)	0.133	0.351	−0.146/0.412	**0.708**	**0.000**	**0.312/1.105**	**0.993**	**0.018**	**0.172/1.814**
Small town (1–4 h from farmland)	0.254	0.170	−0.109/0.616	**1.049**	**0.000**	**0.564/1.535**	**0.933**	**0.022**	**0.136/1.730**
Big town (<4 h from farmland)	0.214	0.253	−0.153/0.581	0.284	0.179	−0.130/0.698	0.621	0.211	−0.353/1.595
Big town (province capital)	0.056	0.697	−0.228/0.341	**0.485**	**0.016**	**0.092/0.877**	0.558	0.182	−0.262/1.377
City	0.210	0.192	−0.106/0.526	**0.834**	**0.002**	**0.310/1.358**	**1.294**	**0.010**	**0.316/2.271**
Mega city	0.224	0.263	−0.169/0.617	0.302	0.454	−0.488/1.092	0.488	0.595	−1.312/2.288
Capital city	0.216	0.239	−0.143/0.575	0.227	0.152	−0.084/0.537	0.621	0.130	−0.183/1.425

Vegetable categories (max. 5), including dark green leafy vegetables, provitamin A rich vegetables, starchy vegetables, legumes and other vegetables, dark green leafy vegetables (max. 18), provitamin A rich vegetables (max. 8), Poisson regression, mean difference = mean before COVID-19—mean since COVID-19, thus, positive values indicate a reduction and negative values an increase in diversity over time; significance level: $p < 0.05$, 95% CI = 95% confidence intervals, adjusted for all other tested predictors and age.
Starchy vegetables (max. 9), legumes (max. 17), and other vegetables (max. 33).
Poisson regression, mean difference = mean before COVID-19—mean since COVID-19, thus, positive values indicate a reduction and negative values an increase in diversity over time; significance level: $p < 0.05$, 95% CI = 95% confidence intervals, adjusted for all other tested predictors and age.

number of vegetable groups by 0.6% (adOR = 0.994, 95% CI [0.989, 0.999], $p = 0.024$). Binary logistic regression models did not show significant correlations between price changes and increase or decrease of food consumption in general but only for change in vegetable consumption with a small but positive coefficient of 0.039. This indicates that the stronger the increase in perceived prices or the more food groups were affected by a rise in prices the more likely was a change in vegetable consumption. With a one unit increase in the price index, the chance of changing one's vegetable consumption

TABLE 5 | Results of binary logistic and Poisson regressions for the independent variable "perceived price changes"*.

	Coefficient	*p*	OR	95% CI lower bound	95% CI upper bound
Decrease in food quantity§	0.022	0.280	1.022	0.982	1.064
Increase in food quantity§	0.015	0.656	1.015	0.950	1.084
Vegetable consumption§	**0.039**	**0.003**	**1.040**	**1.014**	**1.067**
Vegetable categories#	**−0.006**	**0.024**	**0.994**	**0.989**	**0.999**
Dark green leafy vegetables#	−0.007	0.202	0.993	0.981	1.004
Provitamin A rich vegetables#	**−0.011**	**0.029**	**0.989**	**0.980**	**0.999**
Starchy vegetables#	−0.014	0.062	0.986	0.972	1.001
Legumes#	−0.012	0.067	0.988	0.975	1.001
Other vegetables#	−0.008	0.195	0.993	0.981	1.004

Vegetable categories = dark green leafy vegetables, provitamin A rich vegetables, starchy vegetables, legumes, and other vegetables.

**The changes in prices for all food groups were summed up with 2 points for a "strong increase," 1 point for a "little increase," 0 points for "no change," −1 points for a "little decrease," and −2 points for a "strong decrease" per food group.*

§*Binary logistic regression (food quantity, vegetables consumption).*

#*Poisson regression (vegetable categories), OR, odds ratio, significance level: $p < 0.05$, 95% CI = 95% confidence intervals, adjusted for age, gender, and income regions.*

increased by 4% (adOR = 1.040, 95% CI [1.014, 1.067], $p = 0.003$; **Table 5**).

DISCUSSION

In this study, one out of five persons ate more than prior to the Pandemic whereas fewer people reported to eat less. At the same time, the findings of this study showed that the restrictions and lockdown events negatively impacted on the level of diversity in vegetable consumption. The reduced consumption of different vegetable types was only partly due to lockdown scenarios but mainly due to individual factors which became probably more pronounced by the side effects of the pandemic.

Changes in Food Quantity

Decreased appetite or feeling of hunger, lower caloric needs due to less physical effort, losing, or stabilising weight, mental stress, reduction of out of home consumption, and price increases were described as the reasons of a reduction of quantity of food consumed since the pandemic started. Besides general reasons for controlling one's eating habits such as the caloric intake, most of the given reasons were related to the implemented restrictions. Overall, the reasons given for the reduction in food quantity were more diverse than the ones for the increase since the onset of the pandemic.

After the pandemic has been declared, 22.9% of the respondents reported to have consumed more food and 15.1% less food. This rate was lower than in a Polish study which showed that the proportion of people eating more than before COVID-19 was 43.5%—almost twice as high as in this study (30). An online survey among 1,964 Bavarian university students in March/April 2020 also reported higher levels for an increase in food intake, i.e., 31.2% reporting an increase and 16.8% a decrease during the lockdown (31). Whereas, a Dutch study conducted in April 2020 with 1,030 participants reported much lower rates for both directions of change; 8.2% ate less and 8.9% more food during lockdown (32) which was even lower than in our study. A survey conducted among 879 adults with a mean age of 36 years in Saudi Arabia in late April 2020 showed that the majority (57.5%) changed the number of meals during the day during the curfew in comparison to the meals before COVID-19 which indicates a change in the amount of food intake, too (33). However, all these studies observed only a period of 1–2 weeks during the very beginning of the pandemic in March/ April 2020 whereas in our study we observed a period of more than 4 months. On average, it was more likely to eat more than less food following the declaration of the pandemic which lasted even if there was no lockdown or restriction anymore as could be seen in this study. This shows that changes in dietary behaviour were not just a short-term effect at the beginning of the pandemic but lasted much longer. Still, these data may have flawed along the line of the respective restrictions put in place.

Food intake changes were not associated with differences between lockdown scenarios or specific restrictions. This might be related to one's mental state, personal coping strategies, and individual reaction to governmental regulations (34). The reaction on the restrictions on a personal level might be more important in this context than the specific restrictions themselves.

A significant effect of age on food intake was found in our study with respect to increase in food quantity. The younger the participants were, the more likely they reported an increase in the amount of food they had eaten since the COVID-19 pandemic. Results of the Bavarian study mentioned above also indicated that younger people more likely changed the amount of food they consumed (31). This may be explained with that younger persons are less resilient toward crisis like this pandemic and thus more prone to stress (35). The increased food intake is considered to be a compensation strategy for stress or to comfort themselves (36). Furthermore, older individuals might be less affected by emotional eating and thus have a more stable dietary behaviour (35, 37). However, unlike our results there was no effect for age in the Polish population under quarantine (30).

Similar to Sidor and Rzymski (30) we could not detect any significant effects for gender, educational level, occupation, or place of living on overall food intake changes. Emotional eating and depression is linked to each other and may be moderated by gender, thus, women showing stronger effects than men (36, 38). In our study being a woman was not associated with overall food intake changes but with a higher chance to eat less diverse. However, a study in the Netherlands showed that women were more likely to eat more during a lockdown compared to men and that participants within the group of lower educational level were more likely to have reduced their food intake since the beginning of the lockdown (32) which could not be confirmed in this study.

A multi-country study conducted from mid-April to end of May using the same method as in this study showed a strong relation between country of residence and the mean food intake since the onset of the pandemic (39). Because of the imbalanced sample we did not test the effect of different countries. However,

no significant influence of income regions on the change of food quantity was found in our sample. Evaluating the influence of perceived changes in food prices our findings showed no significant correlation, neither with decrease nor with increase in overall food quantity consumed.

The hypothesis that mental stress and anxious feelings could be one reason for a change in food quantity was supported by the study of Di Renzo et al. which showed that anxious feelings were likely to occur during the pandemic due to isolation (36). Furthermore, their respondents declared eating more to comfort themselves. The occurrence of over-eating since the lockdown was more noticeable in individuals who were older, had a higher BMI, were not on a diet before COVID-19 and who felt anxious since the COVID19 outbreak (36, 40). Emotional eating was more likely to occur to persons with a higher BMI, with more symptoms of a depression, and higher levels of anxiety (41). The same study supports the hypothesis that loss of life quality due to the lockdown and psychological distress may cause an increase in perceived emotional eating (41) which was not looked at in this study.

Changes in Overall Vegetable Consumption

Any change in overall vegetable consumption was reported by 27% of the participants in this study. Almost the same number of persons stated to have increased their vegetable intake to those who reported a reduction since the beginning of the COVID-19 pandemic. Moreover, a self-reported shift from fresh and perishable vegetables toward canned, frozen, and storable vegetables emerged. Reasons given for the decline in vegetable intake included reduced availability and access, rise in prices, reduced shopping frequency, seasonality, and changes in work situations. In the case of the increase in vegetable consumption, reasons mentioned by the respondents included more home-cooked meals, for better health and immunity, more time to cook, seasonality, switching to a vegetarian diet and for a higher variation of meals. Vegetable intake is associated with habit, motivation, knowledge, and goals (42). This indicates that individual decisions may play a greater role than social groups in changing vegetable consumption during the pandemic.

Whereas, agrobiodiversity loss has already caused production losses and food insecurity, the current Covid-19 pandemic and related food crisis has in addition contributed to an increase in food insecurity (43, 44) and the consumption of mainly perishable foods such as fresh fruits and vegetables, meat and dairy declined (45). An overall change or a change in either one or the other direction in vegetable consumption was also seen in other studies. A large consumer study in Denmark, Germany and Slovenia observed in the very beginning of the lockdown about the same prevalence of change in vegetable consumption with more respondents reporting a decrease (15.2–22.6%) than increase (7.3–12.0%) (46). In the same study a shift from fresh foods toward foods with longer shelf life was observed, too (46). Young people from Southern Europe and South America had significantly increased the consumption of vegetables and legumes (39). In the multi-country study the proportion of adolescents who consumed the recommended weekly amount of legumes (2–4 servings) even increased and 7.8% more young people ate vegetables every day (35% before COVID-19 to 43% during confinement) (39). A survey from Spain also showed an increase in the consumption of legumes during confinement. In this case, the number of subjects who stated that they ate at least 3 portions of pulses a week increased by 6.1% from 25.4 to 31.5% (47). In contrast, a decrease in the frequency of legumes consumption has been observed for Ethiopia since the beginning of the COVID-19 pandemic and 22% of the respondents reported, vegetables were no longer consumed due to rumours that certain foods could lead to COVID-19 infection (48). Other studies also showed a decline in the consumption of vegetables and fresh fruits (8, 30). In Iran the greatest change over time was observed for white roots and dark green leafy vegetables whereas provitamin A rich vegetables were the most consumed vegetables in these households both before and since the COVID-19 outbreak (8). Whereas, in Bavaria, Germany, no relevant difference in the consumption of fruits and vegetables among members of Bavarian universities was observed (31).

The evaluation of all potential factors influencing the change in vegetable consumption showed no significant correlations in our models. In contrast, Ruiz-Roso et al. (39) observed significantly higher intakes of fruits and vegetables by girls than by boys during confinement. They also reported that adolescents from households with at least seven members were the least likely to meet weekly vegetable intake recommendations in comparison to all household groups with fewer members (39). The same study compared different countries and showed that in Southern Europe and South America, Colombia had the lowest rates of vegetable consumption, while Brazil was the country with the highest legume consumption. Spain, on the other hand, was the only one of the countries studied that did not show an increase in legume intake since the beginning of the pandemic (39). It seems that age plays a role as a significant increase in vegetable intake was only detected for adolescents over 14 years of age (39) whereas individuals over 45 years of age were to be the ones with the lowest frequency of daily fruit and vegetable intake (63%) and daily intake of legumes (15.3%) in Poland (30).

Being a woman was indicated to be a risk factor toward feeling challenged to eat healthy foods, while older respondents were more likely to face no such obstacles (32). These findings suggest that commonly accepted determinants for poor dietary choices were reinforced during the pandemic.

Changes in Vegetable Diversity

To date, no comparable studies are available that address the changes of vegetable diversity due to the COVID-19 pandemic. A study in the United States using data from a digital behaviour change weight loss program observed a decrease in the consumption of salads while the consumption of starchy vegetables increased, which indicates a shift in vegetable selection but not whether less vegetable types were consumed (49). In general, higher diversity of vegetables can lead to the intake of a larger range of vitamins, minerals, and phytochemicals, which in turn can have a positive effect on health and nutritional status (50, 51). For most restrictions types and lockdown scenarios we could not identify any effect on the diversity of vegetable consumption. Only curfew at night was positively associated

with an increase in legume diversity. The fact that lockdown scenarios and restrictions did mostly show no effects on overall vegetable consumption might be a result of globalised trade. Barriers and bans installed by some countries or regions may have led to unavailability of specific vegetables in countries not affected by a lockdown themselves (52). For example, the lockdown in Spain and Italy could have led to a limitation of vegetables in the European market due to their important role as vegetable producers and exporters (13). This effect may have occurred in other regions of the world as well yet, might have been compensated by the countries own production not being exported anymore. Contact and travel restrictions implemented by certain countries have led to issues in the harvesting and transport sectors because of border closures and lack of field workers that normally come from abroad (53). Countries depending on vegetable imports may have faced issues in providing their population with a high diversity of vegetables even though they did not implement restrictions themselves (52). In this context, lockdowns implemented in certain countries may have had an impact on global trade and availability of vegetable diversity (54) but this could not been shown within this study.

To identify potential vulnerable groups, we tested changes in vegetable diversity over time for different social groups and for different living environments. Our results suggest that the region where people reported from, the "income regions," played a crucial role for diversity of all vegetable groups and the overall diversity consumed in both time periods. The same effect was observed for gender except for the starchy vegetables and legumes. Household types had a significant effect on the overall diversity prior to COVID-19 and on the category other vegetables for both time periods. The fact that in several cases pre-COVID-19 effects disappeared since the COVID-19 outbreak indicates that the food environment has converged between the different groups. This may reflect that overall supply and availability were important factors but also that individuals had in most cases fewer opportunities for out of home eating than before. Moreover, the change may be caused by more than one predictor, as especially in the global context it is likely that potential reasons differ in certain regions. However, this would need to be confirmed in further studies.

Change of Food Prices and Vegetable Consumption

Our findings showed that perceived changes in food prices are significantly correlated with the change in vegetable consumption. The stronger the increase in perceived prices or the more food groups were affected by a rise in prices, the more likely was a change in vegetable consumption. An increase in prices can lead to issues in affordability, especially in combination with loss of income (55). Due to consumer decisions this may affect the supply of vegetable more than the supply of staple foods.

In the case of perceived price changes for a basic food basket, our study showed that there was a significant association with the number of vegetable groups consumed and the number of different provitamin A rich vegetable types. Within all other vegetable groups, no effect of price changes on the variety was observed which maybe also due to only about 5% of respondents experiencing a loss of their job. Due to increased prices, especially in combination with loss of income, respondents may have had to compromise on their vegetable diversity (55). The difference between the provitamin A rich vegetables and the four other vegetable groups might be the result of a different extent of price rises for the different vegetable groups or a different impact on the availability due to seasonality and trade restrictions as was mentioned by a German respondent in the open answers. The latter showed also that the less frequent shopping, worsening of food availability in stores, closures of canteens, no motivation or time for cooking, and seasonality in the context of certain countries contributed to the observed change in vegetable consumption patterns. Personal situations including time availability, mental state, and motivation to cook and diversify the diet could have played a major role as shown by the open answers in our study. This may also be an explanation for the lack of differences between restriction scenarios.

SUMMARY AND CONCLUSION

In our international survey on Food and COVID-19 more increase than decrease of general food consumption was detected from April to July 2021 compared to the period prior to the pandemic. The reaction on the COVID-19 restrictions on a personal level were more decisive influencing food consumption than the specific restrictions themselves. The increase in vegetable consumption was reported by as many participants as the decrease and a clear shift from fresh and perishable vegetables toward canned, frozen, and storable vegetables was observed. The restrictions and lockdown events negatively impacted the diversity in vegetable consumption but mainly due to individual factors which became probably more pronounced by the side effects of the pandemic. The most vulnerable to greatest reduction in diversity in vegetable consumption were those living in lower middle income countries, being a woman, having a university degree, being unemployed, living in a 3-generational family and living in a small town. Perceived changes in food prices were significantly correlated with the change in vegetable consumption. The stronger the increase in perceived prices or the more food groups were affected by a rise in prices, the more likely was a change in vegetable consumption.

Food systems are not static and are transitioning quickly as could be observed during the Covid-19 pandemic. Consequently, a nutrition strategy is needed to strengthen the resilience of all households so that they can consume a balanced, diverse, and sustainable diet in sufficient quantities especially as regards highly perishable foods such as vegetables for planetary health (20).

STRENGTHS AND LIMITATIONS

The strength of this study are the sample size and the internationality of the study participants. This enabled us

to provide a first overview about the impact of the Covid-19 pandemic at international level who responded to the same questions although the number of respondents from low income countries was limited. The latter are shown to complete the picture, yet, should be used with care. We also have to acknowledge that the chosen method, online survey, is a barrier for participation from most vulnerable populations, poor people, and/or elders who do not have access to the resources. Also, it was reported to us that the poor internet capacities in some countries hindered people to participate. Therefore, results should be interpreted with caution only, especially for the low income countries. Nevertheless, we think that our results can contribute to the ongoing debate on dietary diversity and serve as initial estimates that should be followed up by conducting representative studies.

The survey covered an important time during the first half year of the pandemic and allowed to observe different scenarios of restrictions. At the same time the long period may have biassed the recall of the participants in terms of dietary patterns prior to the lockdown. Like with food frequency questionnaires underestimation can be expected (56). This study did not randomly select participants, but relied on volunteers who may have participated because they were more health conscious. This may have limited the recall bias. In this study we used an explorative approach and due to the lockdown and mobility restrictions designed it as online survey. We did not have funds available to facilitate the data collection with a company support and/or telephone-based interviews which limited our possibilities to mobilise a larger number of respondents. However, we think the sample size allows to get a first impression how the pandemic has impacted consumers at global level. The results serve thus to generate and not to confirm hypotheses on how Covid-19 impacted dietary intake of populations.

Despite the limitations of the study, this study is the first to look at the diversity of food intake at global level and the findings show that there is an urgent need to pay attention to vegetable diversity in local and global food systems and in research on the same.

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 Review Board of the medical faculty of the Justus Liebig University Gießen, Germany. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

LS conducted the data cleaning and the statistical analysis under the lead of IJ. IJ prepared the manuscript based on the findings from LS with contributions from GK, KJ, IH, and EH. IJ, LS, KJ, IH, and EH developed and translated the questionnaire with the support of an international network. IJ was the principle investigator and responsible for the conceptualisation of the study design. All the authors read and approved the final manuscript.

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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.2021.686786/full#supplementary-material

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Food Access Worries, Food Assistance Use, Purchasing Behavior, and Food Insecurity Among New Yorkers During COVID-19

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The coronavirus disease of 2019 (COVID-19) disrupted health, economy, and food systems across the United States. This cross-sectional study examined the relationship between food access worries, food assistance use, and purchasing behaviors and food insecurity during COVID-19 among residents of New York State. New Yorkers were recruited to complete a web-based survey through Qualtrics. The survey took place in the summer and fall of 2020 and asked respondents about food access worries, food assistance use, food insecurity, and food purchasing behaviors. Chi-square analysis examined the relationships between food concerns, food assistance use, purchasing behaviors, and demographic characteristics by reported food insecurity, and significant results were analyzed in a series of logistic regression models. Results showed that higher food worries, Supplemental Nutrition Assistance Program (SNAP) use, reported food assistance and delivery as food sources, and self-reported Hispanic ethnicity were associated with a higher likelihood of experiencing food insecurity. Future research is needed to assess the ongoing impacts of the pandemic on food access and food insecurity, particularly among underserved groups. Measures that provide additional money for food and improved food access can alleviate barriers to accessing enough healthy food at this time.

Keywords: COVID-19, food security, food access, food assistance, food purchase behavior

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INTRODUCTION

The coronavirus disease of 2019 (COVID-19) had a major impact on health, social life, and the economy across the globe. Over 71 million infections and 1 million deaths have been reported worldwide, with over 22% of cases and 29% of deaths occurring in the United States (1). Social distancing measures were implemented in order to contain the spread of the disease, which led to employment and food system disruptions. These disruptions resulted in business closures that

forced about 22 million Americans into unemployment in April 2020 and increased rates of food insecurity, which includes the ability to consistently acquire nutrient-rich, desirable, and varied foods (2–7).

Increases in the volume of food purchased by consumers placed a strain on an inflexible food supply chain that failed to respond to the pandemic (8). Illness among workers in processing facilities due to shared housing and transportation and close proximity of employees in work environments reduced facility capacity (9, 10). This led to many farmers disposing of foods that required further processing (11). Further, food shortages in stores, concerns about food safety (12–14), and localized stay-at-home orders changed purchasing behaviors of consumers. Consumers increased their use of online ordering for pick-up and delivery from restaurants and grocery stores, increased their time spent cooking at home, and reduced overall purchases from restaurants (15). At the same time, food supply and work disruptions widened existing disparities in food access (6). Black and Hispanic Americans are more likely to work essential jobs, such as those in retailing, transportation, manufacturing, healthcare, construction, and the food system, which pay lower wages and lack flexibility and paid sick leave (16–21). These jobs were more likely lost during the pandemic, which further exacerbated financial issues among groups that were already more likely to suffer from food insecurity prior to the pandemic (22, 23).

Several studies have examined food access issues during COVID-19, mostly within the context of food insecurity. Studies have reported increased food insecurity since COVID-19 and issues with food access among food-insecure populations (4, 5). Those experiencing food insecurity reported higher levels of worry about food access and challenges related to food access, including the ability to find the types of foods desired, getting enough food through food assistance programs and emergency food organizations, and an inability to afford to stock up on food for 2 weeks as recommended (4, 5). Food-insecure individuals were also less likely to have sick and vacations days and more likely to report that they would lose their job if they missed too much work (4). This study extends the current research area by examining the relationship between food purchasing behaviors and food insecurity.

In March 2020, when COVID-19 was declared a pandemic by the WHO (24), New York became the epicenter of the virus in the United States (25). On March 20, 2020, Governor Cuomo issued the Executive Order New York State on Pause, a stay-at-home order and closure of all non-essential businesses in the state to slow the spread of the virus (26). As of December 2020, there were over 28,000 deaths from COVID-19 in NY State. Deaths disproportionately affected racial and ethnic minorities. Hispanic New Yorkers accounted for 34% of the deaths but only 29% of the state population and Black New Yorkers accounted for 28% of the deaths but only 22% of the population (27). The purpose of this study was to assess the relationship between food access concerns, food assistance use, and purchasing behaviors and food insecurity in a sample that oversampled New York State residents who were Black, Hispanic, and low-income or low-education during COVID-19.

MATERIALS AND METHODS

Study Design and Sample

A cross-sectional proportional quota sample of 525 New Yorkers was recruited by Qualtrics from their survey panels to complete a web survey. The survey was adapted from a validated food access survey developed by the National Food Access and COVID-19 Research Team (NFACT) (28–30). It included open- and closed-ended questions about food sources, food security, purchasing behavior, food assistance, risk factors for COVID-19, and social determinants of health. Quotas were set to recruit 50% Black or African American, 50% Hispanic, and 50% low-income or low-education participants to oversample groups with an increased risk for food insecurity and for adverse consequences related to COVID-19 (19, 20, 31, 32). Individual panel members were classified as eligible to participate if they were age 18 or older and resided in New York State, excluding New York City. Potential study participants were asked about their race, ethnicity, income, education, and age to evaluate fit with the quotas. Potential participants that met the inclusion criteria but fell outside of the quotas needed to fill the sample were classified as ineligible, and the survey was ended. A response rate is not available with quota data collection through Qualtrics panels because the number of people invited to participate in the survey is not reported by Qualtrics.

Data Collection

Data from Black or African American and Hispanic participants were collected from July 15 to September 18, 2020, and data from non-Hispanic white participants were collected from December 7–11, 2020. Data on non-Hispanic white participants were collected approximately 3 months after data on Black and Hispanic participants. Case counts were higher during data collection from non-Hispanic white participants; however during both times of data collection, COVID-19 restrictions policies were similar with a regional and clustered approach based on positive rates and hospital capacity and when looking at county level data; during both periods of data collection, there was a significant variation in COVID case counts (33, 34). The median time to complete the survey was 16 min. To ensure quality responses, five quality checks were included within the survey to check for agreement between responses that should have been consistent, for example, an agreement between repeated questions about demographic characteristics. Respondents with a flag for more than two of the quality checks were excluded from the final sample. Surveys completed in faster than half the median time were replaced due to low quality. Finally, survey responses were evaluated to identify poor-quality responses and removed if there was evidence of straight-lining, gibberish, and non-sense answers in accordance with recommended quality review criteria by Qualtrics (35, 36).

Measures

The outcome food insecurity was assessed using the United States Department of Agriculture six-item Food Security Survey Module (37). Participants were asked to answer the six-item module about the time period "Since the COVID-19 outbreak

(March 1, 2020)." The six-item module was scored (range 0–6) consistent with USDA guidelines (37). Participants scoring 0–1 were classified as having high or marginal food security (food secure), and a score of 2–6 was classified as having low or very low food security (food insecure). The six-item Food Security Survey Module has a sensitivity of 92.0% and a specificity of 99.4% for overall food insecurity (38). Food-related worries were assessed by asking participants if they had worried about a set of eight food-related issues since the COVID-19 pandemic began (yes = 1, no or not applicable = 0), including food becoming more expensive, food becoming unsafe or contaminated, losing access to food assistance programs, not being able to afford enough food, not having enough food in stores, not having enough food stocks to stay home, the country not having enough food to feed everyone, and losing so much income that you cannot afford food. A food worry scale was computed (range 0–8), and high food-related worries were classified as worries above the mean (>4.65). Questions about food access were adopted directly from the NFACT survey, which achieved an alpha value of 0.70 (5). Negative impacts on employment during COVID-19 were used as a proxy for economic instability. Participants were asked if they experienced any employment changes since the pandemic began (lost job, reduced hours or income, furloughed, work from home, increased hours, no job changes, not applicable/do not work). Participants indicating job loss, reduced hours or income, or furlough were classified as having a negative job impact due to COVID-19 (negative job impact = 1, no negative job impact = 0).

Food assistance program use was assessed by asking participants to check all food assistance programs that their household had used since the pandemic began, including the Supplemental Nutrition Assistance Program (SNAP); Women, Infant, and Children's Program (WIC); school meal programs (including school lunch, breakfast, or summer meals), a food pantry or food bank; or other assistance programs such as the Commodity Supplemental Food program, Meals on Wheels, or other programs. A variable was created to measure the use of any food assistance program by classifying checking yes for any food assistance program (any/none).

To assess purchasing behavior, participants were asked whether they bought more, the same amount, or less of a set of goods, including fresh produce, frozen produce, snack foods, juice or soda, and frozen dinners. Five variables were created to capture increased purchasing since the pandemic (more = 1, the same or less = 0). The food source was assessed by asking participants where they purchased food since the pandemic began (grocery, convenience, or specialty store; grocery, meal kit, or Meals on Wheels delivery; restaurant take-out or dine-in; food pantry, school food, or meals served in a group setting; market of farmers, community-supported agriculture, or gardening). Five variables were created to capture food sources; if participants selected purchasing from any source within each category (store, delivery, restaurant, food assistance, or local), they were classified as purchasing food from that source.

Finally, demographic characteristics collected on the sample included income in 2019 (<$13,000, $13,000–24,999, $25,000–49,999, $50,000–74,999, $75,000+), gender (male, female, transgender, non-binary), education (high school or less, some college, 2-year degree, 4-year degree, graduate studies), and age (18–24, 25–34, 35–44, 45–54, 55–64, 65+).

Data Analysis

Food security, food worries, food sources, food assistance use, purchasing behaviors, and demographics were described for the total sample. A chi-square analysis was performed to evaluate differences in the outcome food insecurity. To evaluate differences across data collection time points, food insecurity by race and ethnicity adjusting for the county of residence was examined in a logistic regression analysis. Using a model-building approach, factors independently associated with the outcome food insecurity were included in a set of logistic regression models (39). The first model examined individual worries related to food and negative job impacts, the second model added food sources, the third model added food assistance program use, the fourth model added purchasing behavior, and the final model added sample demographic characteristics. The log-likelihood, Akaike's information criterion (AIC), and Bayesian Information Criterion (BIC) were used to evaluate the model fit (39, 40). Analyses were performed in Stata version 16.1 (41).

RESULTS

The sample (n = 525) was 47% Black or African American, 42% Hispanic, and 11% non-Hispanic white and 62% female (**Table 1**). Over 30% of participants reported an income below $25,000 in 2019, a quarter of the sample (27%) reported an income between $25,000 and $50,000, 17% reported an income between $50,000 and $75,000, and the remaining 22% reported an income >$75,000. Approximately half of the sample reported less than a college degree with 28% reporting high school or less and 23% reporting some college but not graduating with a degree. Over 40% of participants were aged 18–34 years, about one-third of the sample was in the middle-age groups of 35–54, and the remaining quarter of respondents were aged 55 years and older.

Nearly half of the study participants (46%) reported experiencing food insecurity and 55% expressed a high level of food-related worries (**Table 1**). Over one-third of the sample (37%) reported a negative job impact during the COVID-19 pandemic. Most participants reported getting food from grocery stores (95%) and restaurants (73%). One-third of the participants (33%) reported using local food sources such as farmers' markets or community-supported agriculture, and 41% reported using delivery services to obtain food. One-quarter of the participants (25%) reported using food assistance programs for food supplies. Half of the study participants reported using any food assistance program (49%). More than one-third reported using SNAP (36%), 7% used WIC, 10% used a school meal program, and 15% used a food bank.

When looking at food purchasing (**Table 1**), 38% reported buying more fresh produce and 34% reported buying more frozen produce since the COVID-19 pandemic. When looking at purchasing less healthful foods, 32% of the participants

TABLE 1 | Demographic characteristics and food worries, food security, food assistance use, and purchasing behaviors of the sample, counts, and frequencies ($n = 525$).

	Count	Percent
Race/ethnicity		
Non-Hispanic White	60	10.8
Black or African American	260	46.9
Hispanic	234	42.2
Income		
<$13,000	100	18.1
$13,000–24,999	84	15.2
$25,000–49,999	150	27.1
$50,000–74.999	96	17.3
$75,000+	124	22.4
Gender		
Male	203	36.6
Female	346	62.5
Transgender	1	0.2
Non-binary	4	0.7
Education		
High school or less	155	28.0
Some college	130	23.5
2-year degree	104	18.8
4-year degree	119	21.5
Graduate studies	46	8.3
Age		
18–24	98	17.7
25–34	137	24.7
35–44	110	19.9
45–54	78	14.1
55–64	73	13.2
65+	58	10.5
High food worries	306	55.2
Food insecure since COVID-19	246	45.8
Negative job impact due to COVID-19	205	37.0
Food source: store	527	95.1
Food source: delivery	226	40.8
Food source: restaurant	406	73.3
Food source: food assistance	137	24.7
Food source: local food sources	180	32.5
Used any food assistance since COVID-19	273	49.3
Used SNAP since COVID-19	200	36.1
Used WIC since COVID-19	37	6.7
Used school meals since COVID-19	54	9.8
Used a food Bank since COVID-19	85	15.3
Used other food assistance since COVID-19	5	0.9
Purchased more fresh produce since COVID-19	209	37.7
Purchased more frozen produce since COVID-19	191	34.5
Purchased more snack foods since COVID-19	176	31.8
Purchased more juice/soda since COVID-19	155	28
Purchased more frozen dinners since COVID-19	150	27.1

reported buying more snack foods, 28% reported buying more sugar-sweetened beverages, and 27% reported buying more frozen dinners.

Bivariate analysis of high food-related worries, food sources, food assistance programs, and purchasing behavior by food security status since the COVID-19 pandemic showed that there were statistically significant differences between food-secure and food-insecure participants for high food-related worries, all food sources except for restaurants, all food assistance programs, and all purchasing behaviors (**Table 2**). Food-related worries were greater among participants reporting food insecurity (69%) than those reporting food security (44%). Negative job impacts were reported by a greater proportion of participants experiencing food insecurity since the pandemic (51%) compared to 25% of food-secure participants. Food-insecure participants reported using delivery (55%), food assistance (37%), and local food sources (40%) more frequently than food-secure participants (30, 14, and 26%, respectively). Participants experiencing food insecurity since the COVID-19 pandemic reported using all food assistance programs and purchasing more of all types of food more frequently than participants not experiencing food insecurity. The greatest difference in food assistance program use between the two groups was observed for the use of SNAP with 23% of food-secure participants and 51% of food-insecure participants reporting using the SNAP program (28-point difference). The greatest difference in food purchasing between the two groups was observed for frozen produce with 28% of food-secure participants and 43% of food-insecure participants reporting buying more frozen produce during the pandemic (15-point difference).

To evaluate the differences across data collection time points, the outcome food insecurity was examined by race and ethnicity adjusting for the county of residence as a proxy for disease burden variation across the two time points. For example, on August 15, 2020, there were zero cases in Delaware county and 50 cases in Erie county. On December 15, 2020, there were five cases in Delaware county and 396 cases in Erie county (34). Race and ethnicity were statistically significantly associated with the outcome food insecurity [odds ratio (OR) 1.88, 95% CI 1.44, 2.47], and the county was not significant in explaining variance in the outcome.

Factors independently associated with the outcome food insecurity were included in the multivariate analysis (**Table 3**). In model one, food-related worries and negative job impact due to COVID-19 were examined with the outcome food insecurity. Participants with high food-related worries were more than two and a half times more likely to report food insecurity since the pandemic (OR 2.60, 95% CI 1.80, 3.75). Participants reporting a negative job impact due to COVID-19 were nearly three times more likely to report food insecurity since the pandemic compared to participants with no impact or an increase in income or hours (OR 2.92, CI 2.01, 4.25).

In model two (**Table 3**), food sources were examined. High food-related worries (OR 3.21, CI 2.14, 4.82), negative job impact due to COVID-19 (OR 2.34, CI 1.57, 3.48), using delivery (OR 2.22, CI 1.49, 3.30), and using food assistance (OR 2.59, CI 1.62, 4.16) increased the likelihood of food insecurity, and getting food from grocery stores (OR 0.38, CI 0.15, 0.97) decreased the likelihood of food insecurity. In post-testing, the use of local

TABLE 2 | Factors independently associated with food security since the pandemic, chi-square analysis ($n = 525$).

	Food secure		Food insecure		
	Count	%	Count	%	*p* diff*
High food worries	128	44.0	170	69.1	$p < 0.001$
Negative job impact due to COVID-19	73	25.1	127	51.6	$p < 0.001$
Food source: store	282	96.9	229	93.1	$p < 0.05$
Food source: delivery	89	30.6	135	54.9	$p < 0.001$
Food source: restaurant	210	72.2	186	75.6	0.366
Food source: food assistance	42	14.4	92	37.4	$p < 0.001$
Food source: local food source	77	26.5	99	40.2	$p < 0.01$
Used SNAP since COVID-19	67	23.0	126	51.2	$p < 0.001$
Used WIC since COVID-19	7	2.4	30	12.2	$p < 0.001$
Used school meals since COVID-19	13	4.5	41	16.7	$p < 0.001$
Used food bank since COVID-19	27	9.3	57	23.2	$p < 0.001$
Used other food assistance since COVID-19	3	1.0	2	0.8	0.793
Used any food assistance since COVID-19	95	32.7	171	69.5	$p < 0.001$
Purchased more fresh produce since COVID-19	94	32.3	111	45.1	$p < 0.01$
Purchased more frozen produce since COVID-19	81	27.8	7	43.5	$p < 0.001$
Purchased more snack foods since COVID-19	76	26.1	94	38.2	$p < 0.01$
Purchased more juice/soda since COVID-19	67	23.0	83	33.7	$p < 0.01$
Purchased more frozen dinners since COVID-19	62	21.3	85	34.6	$p < 0.01$
Race/ethnicity					
Non-Hispanic White	45	15.5	15	6.1	$p < 0.001$
Black or African American	146	50.2	104	42.3	
Hispanic	100	34.4	127	51.6	
Income					
<$13,000	43	14.8	49	19.9	$p < 0.01$
$13,000–24,999	36	12.4	46	18.7	
$25,000–49,999	72	24.7	74	30.1	
$50,000–74.999	59	10.3	36	14.6	
$75,000+	81	27.8	41	16.7	
Gender					
Male	115	39.5	84	34.2	0.199
Female, transgender, non-binary	176	60.5	162	65.9	
Education					
High school or less	76	26.1	71	28.9	$p < 0.05$
Some college	60	20.6	65	26.4	
2-year degree	48	16.5	53	21.5	
4-year degree	78	26.8	40	16.3	
Graduate studies	29	10.0	17	6.9	
Age					
18–24	39	13.4	54	22	$p < 0.001$
25–34	51	17.5	82	33.3	
35–44	62	21.3	45	18.3	
45–54	48	16.5	29	11.8	
55–64	44	15.1	26	10.6	
65+	47	16.2	10	4.1	

**p difference from chi-square analysis.*

foods did not strengthen the model and therefore, was dropped from the subsequent analysis.

In model three (**Table 3**), food assistance programs were added. High food-related worries (OR 2.74, CI 1.81, 4.16), negative job impact (OR 2.41, CI 1.58, 3.66), use of delivery (OR 2.35, CI 1.54, 3.59), and use of food assistance (OR 2.06, CI 1.22, 3.48) persist in explaining the variance in the outcome food insecurity and grocery store use is explained away with the

TABLE 3 | Factors associated with food security since the pandemic, logistic regression ($n = 525$).

	Model 1		Model 2		Model 3		Model 4		Model 5	
	OR*	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
High food worries	**2.60**	**1.80, 3.75**	**3.21**	**2.14, 4.82**	**2.74**	**1.81, 4.16**	**2.58**	**1.69, 3.96**	**2.82**	**1.81, 4.40**
Negative job impact due to COVID-19	**2.92**	**2.01, 4.25**	**2.34**	**1.57, 3.48**	**2.41**	**1.58, 3.66**	**2.34**	**1.53, 3.56**	**2.20**	**1.42, 3.42**
Food source: store			**0.38**	**0.15, 0.97**	0.39	0.15, 1.03	0.39	0.15, 1.04		
Food source: delivery			**2.22**	**1.49, 3.30**	**2.35**	**1.54, 3.59**	**2.21**	**1.43, 3.40**	**2.31**	**1.46, 3.65**
Food source: food assistance			**2.59**	**1.62, 4.16**	**2.06**	**1.22, 3.48**	**1.97**	**1.16, 3.34**	**1.97**	**1.16, 3.34**
Food source: local food source			1.53	0.99, 2.39						
Used SNAP since COVID-19					**3.19**	**2.09, 4.88**	**3.19**	**2.08, 4.90**	**3.21**	**1.98, 5.21**
Used WIC since COVID-19					**3.11**	**1.21, 7.99**	**3.16**	**1.22, 8.14**	2.39	0.89, 6.39
Used school meals since COVID-19					2.00	0.94, 4.27	2.01	0.93, 4.32		
Used food bank since COVID-19					1.33	0.72, 2.46	1.35	0.73, 2.50		
Purchased more fresh produce since COVID-19							1.17	0.76, 1.83		
Purchased more frozen produce since COVID-19							1.31	0.83, 2.07		
Purchased more snack foods since COVID-19							1.09	0.66, 1.78		
Purchased more juice/soda since COVID-19							0.96	0.58, 1.58		
Purchased more frozen dinners since COVID-19							1.01	0.60, 1.70		
Race/ethnicity										
Non-Hispanic White									ref	
Black or African American									1.26	0.57, 2.80
Hispanic									**2.40**	**1.07, 5.40**
Income										
<$13,000									ref	
$13,000–24,999									1.29	0.62, 2.69
$25,000–49,999									1.12	0.58, 2.16
$50,000–74.999									0.65	0.31, 1.37
$75,000+									0.71	0.33, 1.52
Education										
High school or less									ref	
Some college									1.16	0.64, 2.12
2-year degree									1.26	0.65, 2.44
4-year degree									0.77	0.40, 1.49
Graduate studies									1.21	0.49, 2.98
Age										
18–24									ref	
25–34									0.74	0.39, 1.42
35–44									0.52	0.26, 1.02
45–54									**0.45**	**0.21, 0.97**
55–64									0.55	0.25, 1.19
65+									**0.35**	**0.14, 0.91**
Log likelihood	−336.76		−308.34		−287.40		−285.97		−274.38	
AIC	679.53		630.67		594.80		601.94		594.75	
BIC	692.39		660.67		637.66		666.23		693.33	

**Odds ratios and 95% confidence intervals reported from the logistic regression analysis.*
Bolded numbers indicate a statistically significant finding.

addition of food assistance measures. SNAP (OR 3.19, CI 2.09, 4.88) and WIC use (OR 3.11, CI 1.21, 7.99) increased the odds of food insecurity.

In model four (**Table 3**), purchasing behaviors were added to the model. Purchasing behaviors were not statistically significant in explaining the variance in the outcome food security. Food-related worries (OR 2.58, CI 1.69, 3.96), job disruption (OR 2.34, CI 1.53, 3.56), delivery (OR 2.21, CI 1.43, 3.40), food assistance use (OR 1.97, CI 1.16, 3.34), SNAP (OR 3.19, CI 2.08, 4.90), and WIC use (OR 3.16, CI 1.22, 8.14) persist as accounting for the variance in the outcome. In post-testing, the use of school meals and food banks and purchasing behaviors did not strengthen the model. These measures were dropped from the subsequent modeling.

The final model (**Table 3**) added sample demographic characteristics. After accounting for sample characteristics, high food-related worries, job disruption due to COVID-19, food assistance, SNAP use, and Hispanic ethnicity were associated with greater odds of food insecurity since the COVID-19 pandemic and older age was associated with decreased odds of food insecurity. Participants with a high level or food-related worries were 2.82 times more likely (OR 2.82, CI 1.81, 4.40) to report food insecurity since the pandemic. Participants reporting a negative job impact during the pandemic were more than twice as likely to report food insecurity than participants without a job disruption or an increase in hours or income (OR 2.20, CI 1.42, 3.42). Participants reporting getting food through delivery services were more than twice as likely (OR 2.31, CI 1.46, 3.65) to report food insecurity. SNAP users in the sample were more than three times more likely (OR 3.21, CI 1.98, 5.21) to report food insecurity compared to non-SNAP users. Hispanic participants were nearly two and a half times more likely (OR 2.40, CI 1.07, 5.40) to report food insecurity compared to non-Hispanic white participants. Participants aged 65 or older were 65% less likely (OR 0.35, CI 0.14, 0.91) to report food insecurity compared to younger participants (aged 18–24 years). Evaluation of AIC and BIC indicated that with the addition of each set of food-related variables, model fit improved with the exception of model 4 (40, 42).

DISCUSSION

This study examined factors associated with food insecurity among New York State residents that oversampled for Black, Hispanic, and low-income and education. After accounting for other factors, higher food worries, a negative job impact, SNAP use, self-reported Hispanic ethnicity, and reported food assistance and delivery as food sources were associated with a higher likelihood of experiencing food insecurity.

Research on food insecurity during COVID-19 at the national and local levels and among high-risk populations, such as low-income, low education, and Black, Indigenous, and people of color (BIPOC), are emerging throughout the United States. Studies have commonly reported or projected increased rates of food insecurity during COVID-19 (4–7, 43–47). National studies examining food insecurity, challenges, and worry have reported increased rates of food insecurity among low-income households (43, 47), households with low education (6, 43), BIPOC households (6, 43, 44, 47), households with children (6, 44, 47), those experiencing employment disruption (6, 43, 44), and SNAP participants (6). A nationally representative study on low-income adults found that they were less able to comply with recommendations to stock up on 2 weeks of groceries and more likely to need extra money for food and bills (6). Food-insecure households experienced more fear and worry about COVID-19 in general (44) and about food during COVID-19 in particular (45).

Similar findings were reported in studies in specific states or localities. A study of emerging adults in Minnesota found that food-insecure adults reported eating less and expressed food-related concerns, such as worry about the safety of going to stores (46). A longitudinal study in Pittsburgh in two low-income, predominantly African American neighborhoods found that COVID-19 led to increased rates of food insecurity (48). Food bank and SNAP participation remained unchanged in these communities during the pandemic, suggesting that the existing safety nets were failing to reach those with emerging needs. Dubowitz et al. (48) also found that psychological distress, loss of work, and concerns about leaving home to buy food contributed to food insecurity. Lastly, a study in Vermont found higher rates of food insecurity among respondents experiencing job disruption, households with children, and among respondents with low income and education (5). Food-insecure respondents were more likely to experience challenges with food access and to express higher food-related worry (5). Although, national and local studies conducted to date on food access and insecurity during COVID-19 report similar findings, the variation in state response to the pandemic (i.e., stay at home order timing and length and food assistance program waiver requests) and projected impacts of the pandemic on food insecurity by state and locality (7) warrant examinations of food insecurity and food access challenges and worry at the state and local levels.

The results of this study align with much of the work that has been conducted on food access and insecurity during COVID-19. Participants indicating a high level of pandemic food-related worries were more likely to be food-insecure since the pandemic. The high level of pandemic food worries among food-insecure study participants may be related to the high level of economic, health, and social disruption created by the pandemic (12, 14). Food supply fluctuations created by the COVID-19 pandemic may be contributing to worries about there being enough food in the food supply or securing sufficient food supplies for their household (4, 5, 8). Hispanic participants had an increased likelihood of food insecurity compared to non-Hispanic white participants in this sample. This aligns with the greater burden of food insecurity experienced by Hispanic-headed households in non-pandemic times with a prevalence of 15.6% in 2019 compared to 7.9% among non-Hispanic white households (23). It also aligns with a greater burden of COVID-19 impacts falling on minority individuals (17, 19, 49). Job loss or disruption since the pandemic was associated with higher odds of experiencing food insecurity. The pandemic resulted in the loss or disruption of millions of jobs; in the United States, the unemployment rate

increased from 3.5% in February 2020 to a high of 14.8% in April 2020, marking the highest unemployment rate since the Current Population Survey began collecting data (50). Loss of income has been linked to food insecurity both before and since the pandemic (5, 51).

Supplemental Nutrition Assistance Program use was associated with an increased likelihood of food insecurity. The SNAP program was designed to increase access to healthy food for eligible low-income households and consequently improve food security (52, 53). There are documented challenges with measuring food insecurity among SNAP participants due to the self-selection bias—people that are food-insecure are more likely to seek food assistance (53). However, studies of food insecurity among SNAP users accounting for the self-selection effect have found a reduction in food insecurity among new SNAP participants that persists into program usage (53–55). Given the documented food insecurity prevalence among SNAP users, we posit that the increased likelihood of food insecurity may be related to unmet needs during the pandemic among study participants or due to greater anxiety or concern related to uncertainty and the economic and health impacts of the pandemic. If the association between SNAP use is related to unmet needs, this may highlight the importance of greater funding levels for SNAP participants. Additional research on food insecurity among SNAP users during the pandemic with monthly data would shed additional light on the food insecurity burden among SNAP participants.

No studies have reported on the relationship between food purchasing behaviors and food insecurity during COVID-19. The only purchasing behaviors that were significant in this analysis were reported food sources. The rationale behind including specific food types (healthy and less healthy) was to examine if participants purchasing less healthy foods were more likely to experience food insecurity, and it appears that food source (food assistance use and delivery) is more indicative of food insecurity than purchasing any specific food category. In developing new interventions for supporting families and food access, food delivery and food assistance programs may be useful avenues for increasing food distribution or outreach to target populations. Further, amid uncertainty and food chain disruptions, emphasizing healthy food availability through these channels may better support food-insecure families than other outlets.

This study has several limitations to bear in mind when considering the results. The study design was cross-sectional; therefore, analyses are not able to determine causal relationships. To mitigate this limitation, survey questions asked respondents specifically about purchasing behavior, food sources, food worries, and food assistance in relation to COVID-19. The purposive quota sampling frame intentionally oversampled minority and low-income New Yorkers to recruit a sufficient sample size of groups with an increased risk for COVID-19 infection and complications, as well as with an increased risk for food insecurity. With COVID-19 disparities, understanding the experiences of individuals with greater risk was prioritized over representativeness. As a result of purposive quota sampling, generalizations cannot be made about New Yorkers. Data on non-Hispanic white participants were collected ∼3 months after data on Black and Hispanic participants. The economic impacts of the pandemic were ongoing during this time; enhanced unemployment insurance benefits had expired and a second economic relief bill had not yet been passed. Further, with a greater disease burden in December compared to the summer months when data were collected from Black and Hispanic participants, we would expect disparities to be underestimated rather than overestimated. Regional variation in case counts, which remained over time, posed an additional limitation on the analysis. County residence as a proxy for different disease burden between time points adjusted for race and ethnicity was not significant in explaining the variance in the outcome. The survey was administered through a web-based platform; therefore, only individuals with internet access were able to participate in the study. Most Americans (89% overall, 88% of Hispanics, and 87% of Black Americans) have access to the internet; however with economic disruption, there may be increased accessibility challenges (56). Given the widespread impact of the pandemic in New York State, a web survey was selected to facilitate timely completion of data collection and provides an important snapshot of the lived experiences of many New Yorkers during the pandemic.

Future research are needed to assess the ongoing impacts of the pandemic on food access and food insecurity, particularly among underserved groups. Concerns about food during this time may be important factors related to reduced food security and policy efforts to address these concerns may be necessary. Measures that provide additional money for food, support price reductions for food delivery, and support the provision of healthy foods through food assistance programs may alleviate barriers to accessing enough healthy food. Making current expansions in food assistance program benefits permanent may improve food access as the United States recovers from COVID-19 and in the long term, as we know that food assistance take-up rates decline as benefits decline (57). Focusing on food assistance, however, may not be enough. The causes of food insecurity extend beyond low-income to include physical and mental health, family structure, and access to child care, to name a few, so policy efforts that expand access to health care and child care may provide additional support for families to meet their basic needs, including food. In particular, policies that streamline the process to apply for SNAP benefits across states, improve access to mental health services, incentivize or require the adoption of Medicaid expansion, and increase funding for child care may help families access food in the future and during times of crisis.

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 D'Youville College IRB. The patients/participants provided their Written Informed Consent To Participate In This Study.

AUTHOR CONTRIBUTIONS

LC was involved in conceptualization, methodology, and funding acquisition. LC and SR were involved in analysis, writing the original draft preparation, and writing the review and editing. Both authors have read and agreed to the published version of the manuscript.

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