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Short- and Mid-Term Impacts of COVID-19 Outbreak on the Nutritional Quality and Environmental Impact of Diet

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Background: Changes in dietary behaviors that occurred at the beginning of the COVID-19 outbreak and in particular during the first national lockdowns have been extensively studied across countries. Beyond the understanding of contextual changes in diets due to a temporary lockdown, it is of interest to study longer-term consequences of the COVID-19 outbreak as sustained changes in diets may have both an impact on population health and the environment.

Objectives: This study aimed to examine both short- (after 1 month) and mid-term (after 1 year) impacts of the COVID-19 outbreak on the nutritional quality and environmental impact of diets, and as a secondary objective on food choice motives.

Methods: We collected dietary data [food frequency questionnaire (FFQ)] and the importance of nine food choice motives through online questionnaires before, during, and after 1 year of the first lockdown for 524 French participants. Adherence to the French dietary recommendations was estimated using the simplified PNNS-GS2, which scores from −17 to 11.5. Environmental impact of diets was assessed by calculating greenhouse gas emissions in CO2eq/2,000 kcal.

Results: We showed a short-term decrease in nutritional quality (−0.26 points on sPNNS-GS2, \(p = 0.017\)) and environmental impact (−0.17 kg CO2eq/2,000 kcal, \(p = 0.004\)) but this decrease was only temporary, and nutritional quality (−0.01 points on sPNNS-GS2, \(p = 0.974\)) and environmental impact (−0.04 kg CO2eq/2,000 kcal, \(p = 0.472\)) were not different from their initial values 1 year later. Some of the food choice motives followed the trend of a short-term increase and a mid-term stability (health, natural content, ethical concern, and weight control). On the contrary, we showed both short- and mid-term decreases in convenience, familiarity, and price motives.

Conclusion: Changes in diets and motives observed during the first lockdown were mostly temporary. However, we highlighted a sustained decrease in the importance of perceived constraints due to food shopping and food preparation which may suggest a trend toward a more positive perception of food-related activities.

Keywords: COVID-19, diet, food choice motives, nutritional quality, environmental impact, longitudinal study
INTRODUCTION

The COVID-19 pandemic and the restrictions that have been imposed by the governments to avoid transmission of the virus (e.g., nationwide lockdowns) led to changes in dietary habits (1). However, most studies that have been published so far examined short-term impacts of the first lockdown on eating behaviors across countries (2–4) and longer-term impacts of the COVID-19 outbreak on dietary habits remain to be explored. Yet, as suboptimal intakes of several foods and nutrients are the major risk factors for non-communicable diseases (5), changes in dietary behaviors sustained over a long period of time may affect the health status of the population.

Only few studies recorded detailed food consumption and compared the nutritional quality of the overall diet before and during the COVID-19 outbreak and they led to mixed results: an increase in the nutritional quality in Quebec (6), a decrease in Spain (7) and Burkina Faso, Ethiopia and Nigeria (8), no change in France but with a large interindividual variability in dietary changes (9). These results suggest that eating habits may have changed in both favorable and unfavorable directions in association with context and individual characteristics. In a previous study investigating the nutritional quality of diet and food choice motives during the first lockdown in France, we also highlighted heterogeneity in changes (10). We showed a decrease in the nutritional quality of diet for individuals who comforted themselves with food during the lockdown (48%) but an increase in the nutritional quality for individuals who tried to better control their weight during the lockdown (29%). In addition, in this same previous study, we observed an increase in ethical concern (21% of the participants) and natural content (19%) as food choice motives during the lockdown, which suggests a growing awareness of the importance of the environmental impact of food choices (10). These results echoed the raise in environmental awareness during the COVID-19 outbreak that has been documented and described by numerous scientists (11–15). However, to our knowledge, the impact of the COVID-19 outbreak on the environmental impact of diets has never been studied.

In cross-sectional studies, higher motives related to health, natural content, and ethical concern have been associated with higher nutritional quality of diet (16–18) and with higher consumption of organic food products (19) whereas higher motives related to price, familiarity, and convenience have been associated with lower nutritional quality of diet (16, 18) and lower consumption of organic food products (19). Nonetheless, less is known about how changes in food choice motives at an individual level may influence food consumption, which would provide valuable insights to identify food choice motives to be tackled through public health interventions to increase the nutritional quality or decrease the environmental impact of diets. As major life disruptions may lead the individuals to engage in a new process of food choice decision-making and thus to reconsider their food choice motives (20, 21), the COVID-19 outbreak gave the unique opportunity to investigate how changes in food choice motives may influence the nutritional quality and the environmental impact of diet at an individual level. In a previous study, we found that short-term changes in mood motives and weight control motives impacted the nutritional quality of diet, negatively and positively, respectively (10). Surprisingly, short-term changes in health motives did not translate into an increased nutritional quality (10). Because dietary habits might be hard to change even though food choice motives have been reconsidered (22), we hypothesized that longer-term changes in food choice motives may be more impactful. For instance, changes in health or ethical concern motives may have an impact on the nutritional quality and environmental impact of the diet after 1 year, whereas these changes may have no impact after 1 month.

This study aimed to examine short- (after 1 month) and mid-term (after 1 year) impacts of the COVID-19 outbreak on both the nutritional quality and the environmental impact of diets. This study adds to a previous investigation of changes in nutritional quality during the first lockdown in France (10) by also analyzing the evolution of greenhouse gas emissions of diets. As secondary objectives, we aimed to examine short- and mid-term impacts of the COVID-19 outbreak on organic and local food consumption and on food choice motives. As exploratory objectives, we examined the association between short- and mid-term changes in food choice motives and short- and mid-term changes in the nutritional quality and environmental impact of diets.

MATERIALS AND METHODS

Study Design

This was a longitudinal, preregistered (https://osf.io/gwfdh/) online survey using Qualtrics platform (www.qualtrics.com) following up a survey on nutritional quality and food choice motives before and during the first lockdown in France conducted in spring 2020; results have been published elsewhere (10). In the 2020 survey, we retrospectively recorded at the same time dietary data and food choice motives for 938 individuals during the month before the first lockdown (from 17 February to 16 March 2020) and during the first month of lockdown (from 17 March to 16 April 2020). A number of 938 individuals who took part in the 2020 survey were emailed exactly 1 year later, that is on 2 May, 2021. They were asked to answer the same set of questionnaires as in 2020 regarding the 1-month period from the 1 to 30 April 2021: a food frequency questionnaire (FFQ), a food choice motives questionnaire, and a questionnaire on organic and local food consumption. We thus recorded longitudinal data on three 1-month periods per individual: before the first lockdown, during the first lockdown, and 1 year after the first lockdown.

Data Collection

Data were collected from 2 to 15 May to 2021. The participants were all registered in the Chemosens Platform’s PanelSens database declared to the relevant authority (Commission Nationale Informatique et Libertés; CNIL; n°1148039). Eligible participants took part in the 2020 survey and had not moved since then. All participants were contacted by email and provided consent for their participation after being informed that the purpose of the study was to investigate food choices 1 year
after the first lockdown. They received a 10 € Amazon voucher in return for their participation. As in the 2020 survey, three attention check questions (e.g., “How many times have you visited the planet Mars?”) were included in various parts of the questionnaire. The study was approved by the relevant ethical evaluation committee for research (reference: Comité d’Évaluation Éthique de l’Inserm n°20-683bis, delivered on 30 March 2021). All the questionnaires (in French) are available on the OSF page of the project (https://osf.io/gwfdb/).

Food Frequency Questionnaire

Participants reported their diet for the previous month using a validated FFQ that includes 109 foods, 12 non-alcoholic drinks, and 4 alcoholic drinks with frequency assessed by a 6-item scale from “never” to “several times a day” (23). Food groups included in the FFQ were as follows: bread and cereals (4 items), raw vegetables (4 items), cooked vegetables (13 items), starchy foods (10 items), meat and eggs (15 items), fish (9 items), mixed dishes (12 items), dairy products (10 items), fruit (11 items), biscuits and cakes (14 items), and sauces (7 items). Usual portion sizes were estimated with the photographs for different food types on a 5-level scale, derived from the SU.VI.MAX portion book (24) or using average portion size. The consumption frequency of each item was transformed into daily frequency, and daily intake was calculated by multiplying the daily frequency by the estimated portion size. Individual nutrient intakes were calculated by multiplying the daily intake of each food item by its nutritional values from the SU.VI.MAX nutrient composition database (25).

Adherence to the French dietary recommendations before, during, and 1 year after the first lockdown was evaluated using the simplified PNNS-GS2 (sPNNS-GS2), an index previously designed by Chaltiel et al. (26) to reflect adherence to the main 2017 French dietary recommendations. The sPNNS-GS2 builds on the distinction between malus components (less healthy food groups which consumption should be limited, carrying a negative score, i.e., red meat, processed meat, sugary foods, sweet-tasting beverages, alcoholic beverages, and salt) and bonus components (healthier food groups carrying a positive score, i.e., fruits and vegetables, nuts, legumes, whole-grain food, milk and dairy products, fish, and seafood). The sPNNS-GS2 was computed for each participant with slight modifications to the calculation (range: 17–11.5). The sPNNS-GS2 originally included bonus points for added fat below 16% of energy intake (26). The FFQ did not make it possible to calculate the percentage of energy intake accounted for added fat, especially added oils, and this component was not included in the score calculation, as in Marty et al. (10). We also calculated short-term Δ nutritional quality and mid-term Δ nutritional quality, as the difference in sPNNS-GS2 between during and before the first lockdown and between 1 year later and before the first lockdown, respectively. Δ nutritional quality > 0 indicated an increase in nutritional quality over time.

Greenhouse gas emissions (GHGE) in kg CO2eq/kg of the individual diets were calculated before, during, and 1 year after the first lockdown as an indicator of the environmental impact of the diet (27). GHGE were derived from the French food environmental impact database Agribalyse 3.0 drawn up by the French Agency for Ecological Transition that includes GHGE values for 2,480 common food items based on Life Cycle Analyses of food products (28). The items of the FFQ were associated with all the corresponding food items from Agribalyse 3.0. GHGE of each item of the FFQ were calculated as the average GHGE of individual foods from Agribalyse 3.0 associated with each item. GHGE of participants’ daily diets were calculated by multiplying the daily intake of each food item by its associated GHGE per kg. We also calculated short-term Δ GHGE and mid-term Δ GHGE, as the difference in GHGE of diets between during and before the first lockdown and between 1 year later and before the first lockdown, respectively. Δ GHGE > 0 indicated an increase in GHGE over time.

Organic and Local Food Consumption Questionnaire

Participants answered questions about their consumption frequency of organic and local food products for 12 food categories on a 3-point scale: 2 = most of the time, 1 = occasionally, and 0 = never. The 12 categories were as follows: fruit, vegetables, dairy products, meat and fish, eggs, grains, bread, oil, ready-to-eat meals, biscuits, tea and coffee, and wine and beers. This questionnaire was adapted from a previously published version that assessed organic food consumption only and included six additional food or non-food product categories (29); we excluded the six additional categories because they were not part of the FFQ. Organic consumption scores and local consumption scores were calculated before, during, and 1 year after the first lockdown as the mean of participants’ responses across the 12 food categories.

Food Choice Motives Questionnaire

Food choice motives were assessed using a French version of the Food Choice Questionnaire developed in English by Steptoe et al. (30) and adapted by Cottet et al. (31). The French version included 24 items and nine subscales: health (3 items), convenience (3 items), sensory appeal (3 items), natural content (3 items), ethical concern (2 items), weight control (3 items), mood (3 items), familiarity (2 items), and price (2 items). For each subscale, scores before, during, and 1 year after the first lockdown were computed by averaging ratings for individual items. The scores ranged from 1 to 4: 1 = not at all important; 2 = a little important; 3 = moderately important; 4 = very important. Short-term Δ motives and mid-term Δ motives were calculated as the difference of the score for each of the nine subscales between during and before the first lockdown and between 1 year later and before the first lockdown, respectively. Δ motives > 0 indicated an increased importance of the motives over time.

Sociodemographic Questionnaire

Participants were asked for their gender, employment status, highest educational qualification, dietary restriction (none, vegetarian, vegan, gluten-free, sugar-free, lactose-free, allergies), dieting status (yes or no), and weight and height at the time of completion of the initial 2020 online survey. Self-reported body mass index (BMI) was calculated in kg/m².
In 2021, they were asked about their perceived change in eating habits (yes a lot, yes moderately, yes a bit, and no) and in time spent cooking (7-point scale from increased a lot to decreased a lot) during the pandemic. COVID-19-related questions (being or having been ill) were also included for descriptive purpose.

Statistical Analyses
We followed an analytic plan that was preregistered prior to 2021 data collection (https://osf.io/gwfdb/). Any deviations from the preregistered analytic plan are described in Supplementary Table S1. Only participants who completed the 2020 and 2021 surveys were included in the analyses. Participants who failed at least one attention check were excluded. We analyzed data from participants who reported plausible energy intake before, during, and 1 year after the first lockdown, that is, ≤500 and ≥3,500 kcal/day for women, and ≥800 and ≤4,000 kcal/day for men (32, 33). We compared participants that were included and excluded from the present analyses based on sociodemographic measures and dietary outcomes (2020 data).

Cronbach’s α were calculated for the organic and local food consumption questionnaire (before, during, and after 1 year, respectively): organic score (0.91; 0.90; 0.89) and local score (0.87; 0.88; 0.85). Cronbach’s α were also calculated for each food choice motive (before, during, and after 1 year, respectively): health (0.70; 0.71; 0.74), convenience (0.89; 0.85; 0.88), sensory appeal (0.65; 0.66; 0.64), natural content (0.87; 0.86; 0.85), ethical concern (0.64; 0.63; 0.69), weight control (0.81; 0.84; 0.83), mood (0.64; 0.64; 0.66), familiarity (0.63; 0.62; 0.76), and price (0.58; 0.63; 0.66).

For primary analyses examining the effect of the COVID-19 outbreak on the nutritional quality and environmental impact of diet, linear mixed models were used to test the effect of time (categorical: before, during, and after 1 year of the first lockdown) on sPNNS-GS2 and GHGE, with random effect of participant to account for correlation between repeated measures. For secondary analyses examining the effect of the COVID-19 outbreak on organic and local food consumption, linear mixed models were used to test the effect of time on organic and local consumption scores, with random effect of participant to account for correlation between repeated measures. For secondary analyses examining the effect of the COVID-19 outbreak on food choice motives, linear mixed models were used to test the effect of time on the nine subscales of the Food Choice Questionnaire, with random effect of participant to account for correlation between repeated measures. All linear mixed models were replicated controlling for age, gender, educational level, and declared initial BMI.

All statistical analyses were performed using SAS version 9.4 (SAS Institute, Inc. 2013 SAS® 9.4. Cary, NC). The level of significance was set at $p < 0.05$ for preregistered primary, secondary, and exploratory analyses.

RESULTS
Participants
A number of 938 participants who took part to the 2020 survey were contacted by email and 594 consented to participate. We excluded 18 participants who did not complete the study, 17 who failed an attention check, 34 who reported implausible energy intake, and one who reported an incorrect identification number resulting in a sample size of 524 participants with correct responses before, during, and 1 year after the first lockdown. Table 1 presents participants’ characteristics. The participants in the 2021 study were slightly older than the participants in the 2020 study who did not complete the 2021 survey (Supplementary Table S2) but did not differ regarding gender, employment status, highest educational qualification, initial BMI, and dietary outcomes before the first lockdown (energy intake, sPNNS-GS2, and GHGE). In 2021, 72% of the participants declared that their eating habits have changed since the beginning of the pandemic and 96% reported an increase in time spent cooking. Moreover, 86 participants (17%) declared that they have been affected by COVID-19 since the beginning of the pandemic.

| TABLE 1 | Participants’ characteristics in 2020, $n = 524$. |
|----------|--------------------------------------------------|
| Age, years, mean (SD) | 39.5 (12.0) |
| Gender, female, $n$ (%) | 417 (79.6) |
| Employment status, $n$ (%) |  |
| Full or part-time | 406 (77.4) |
| Student | 34 (6.5) |
| Retired | 33 (6.3) |
| Looking for a job | 37 (7.1) |
| Looking after home | 5 (1.0) |
| Other | 9 (1.7) |
| Highest educational qualification, $n$ (%) |  |
| < High-school + 2 years diploma | 129 (24.6) |
| High-school + 2 years diploma | 107 (20.4) |
| High-school + 3 or + 4 years diploma | 131 (25.0) |
| ≥ High-school + 5 years diploma | 157 (30.0) |
| Dietary restrictions, none, $n$ (%) | 468 (89.3) |
| Dieting status, yes, $n$ (%) | 74 (14.1) |
| Reported BMI, kg/m$^2$, mean (SD) | 24.4 (4.9) |
| Implausible weight or height*, $n$ (%) | 6 (1.1) |

*Excluding weight < 30 or > 250 kg, height < 1.45 or > 3 m.
TABLE 2 | Nutritional quality, environmental impact, organic and local food consumption, and food choice motives over time.

|                                | Before first lockdown | During first lockdown | 1 year after first lockdown | Raw (n = 524) | Adjusted† (n = 518) |
|--------------------------------|----------------------|----------------------|-----------------------------|---------------|---------------------|
| Total energy (kcal/d)          | 1,667 (581) a        | 1,888 (632) b        | 1,871 (635) b               | 45.63 <0.001  | 45.57 <0.001       |
| sPNNS-GS2 (kg CO$_2$eq/d)      | 1.14 (2.49) a        | 0.88 (2.69) b        | 1.15 (2.58) a               | 3.81 0.022    | 3.73 0.024         |
| GHGE (kg CO$_2$eq/2,000 kcal)  | 4.72 (2.05) a        | 5.20 (2.23) b        | 5.22 (2.12) b               | 22.41 <0.001  | 23.37 <0.001       |
| Organic score                  | 0.63 (0.49) a        | 0.62 (0.48) a        | 0.68 (0.47) b               | 12.99 <0.001  | 13.68 <0.001       |
| Local score                    | 0.60 (0.42) a        | 0.61 (0.45) ab       | 0.64 (0.41) b               | 4.40 0.013    | 4.42 0.012         |

Food choice motives

- **Health**
  - Before: 2.75 (0.68) a
  - During: 2.86 (0.70) b
  - 1 year: 2.70 (0.69) a
  - Change: 21.45 <0.001

- **Convenience**
  - Before: 2.49 (0.83) a
  - During: 2.07 (0.78) b
  - 1 year: 2.40 (0.79) c
  - Change: 76.48 <0.001

- **Sensory appeal**
  - Before: 3.31 (0.53) a
  - During: 3.33 (0.56) a
  - 1 year: 3.31 (0.52) a
  - Change: 0.82 0.443

- **Natural content**
  - Before: 2.89 (0.78) a
  - During: 2.94 (0.78) b
  - 1 year: 2.87 (0.75) a
  - Change: 4.59 0.010

- **Ethical concern**
  - Before: 2.82 (0.80) a
  - During: 2.88 (0.81) b
  - 1 year: 2.73 (0.83) c
  - Change: 15.78 <0.001

- **Weight control**
  - Before: 2.30 (0.71) a
  - During: 2.42 (0.78) b
  - 1 year: 2.29 (0.75) a
  - Change: 13.19 <0.001

- **Mood**
  - Before: 2.19 (0.70) a
  - During: 2.44 (0.76) b
  - 1 year: 2.32 (0.71) c
  - Change: 39.11 <0.001

- **Familiarity**
  - Before: 2.55 (0.73) a
  - During: 2.45 (0.78) b
  - 1 year: 2.30 (0.77) c
  - Change: 30.64 <0.001

- **Price**
  - Before: 2.83 (0.61) a
  - During: 2.78 (0.70) ab
  - 1 year: 2.74 (0.66) b
  - Change: 6.02 0.003

All values are mean (SD). Values with the same letter are not statistically different at $\alpha = 0.05$, pairwise comparisons for raw and adjusted models led to the same results.

*Linear mixed models testing the effect of time on dependent variables.
†Control variables: age, gender, initial BMI (six missing values), and highest educational qualification.

In bold: significant changes over time at $\alpha = 0.05$.

Evolution of Nutritional Quality, Environmental Impact, Organic and Local Food Consumption, and Food Choice Motives

A significant effect of time was found on nutritional quality and GHGE of diet and on organic and local food consumption (Table 2). Total energy intake and GHGE per day increased on the short-term then remained constant. We observed a short-term decrease but no mid-term changes in nutritional quality and GHGE per 2,000 kcal whereas the increase in organic and local food consumption was mid-term only. A significant effect of time was also found on all food choice motives, except for sensory appeal motives that remained stable over time (Table 2). Regarding the evolution of food choice motives over time, we observed a short-term increase in health, natural content, ethical concern, and weight control motives but no mid-term increase and even an overall decrease compared to before the first lockdown for ethical concern motives. On the contrary, the decrease in convenience, familiarity, and price motives was both short-term and mid-term as was the increase in mood motives. The results were the same in both raw and adjusted models.

Associations Between Short- and Mid-Term Changes in Food Choice Motives and Short- and Mid-Term Changes in Nutritional Quality or Environmental Impact of Diet

As exploratory analyses, we examined the associations between short- and mid-term changes in food choice motives and short- and mid-term changes in nutritional quality and environmental impact (GHGE/2,000 kcal) of diet (Table 3). Short- and mid-term increases in weight control motives were associated with short- and mid-term changes in nutritional quality and environmental impact respectively, and also with short- and mid-term increases in GHGE/2,000 kcal. On the contrary, short-term increase in price motives was associated with short-term decrease in nutritional quality, and with short-term decrease in GHGE/2,000 kcal. Mid-term increase in natural content motives was associated with mid-term increase in nutritional quality only. Short-term increase in mood motives was associated with short-term increase in GHGE/2,000 kcal. On the contrary, mid-term increase in ethical concern motives was associated with mid-term decrease in GHGE/2,000 kcal.
Influence of motives on nutritional quality and GHGE/2,000 kcal, short-term (during–before lockdown) and mid-term (one year later–before lockdown). 

| Dependant variable | Δ nutritional quality | Δ GHGE/2,000 kcal |
|--------------------|-----------------------|-------------------|
|                    | Raw model (n = 524) | Adjusted model (n = 518) | Raw model (n = 524) | Adjusted model (n = 518) |
| Δ Health            | β (95%IC)             | β (95%IC)          | β (95%IC)             | β (95%IC) |
|                     | 0.05 (−0.59; 0.70)   | 0.05 (−0.60; 0.70) | 0.03 (−0.37; 0.42)   | −0.03 (−0.35; 0.30) |
| Δ Convenience       | 0.19 (−0.08; 0.46)   | 0.20 (−0.08; 0.48) | 0.04 (−0.20; 0.22)   | −0.01 (−0.15; 0.13) |
| Δ Sensory appeal    | −0.27 (−1.09; 0.54)  | −0.33 (−1.16; 0.49) | −0.38 (−0.78; 0.03)  | −0.11 (−0.53; 0.30) |
| Δ Natural content   | 0.34 (−0.38; 1.07)   | 0.37 (−0.36; 1.11) | 0.44 (0.05; 0.83)    | −0.01 (−0.38; 0.35) |
| Δ Ethical concern   | 0.10 (−0.62; 0.41)   | −0.09 (−0.61; 0.43) | 0.03 (−0.32; 0.37)   | 0.12 (−0.15; 0.38) |
| Δ Weight control    | 0.99 (0.61; 1.36)    | 0.96 (0.60; 1.36)   | 0.42 (0.08; 0.76)    | 0.01 (−0.03; 0.02) |
| Δ Mood              | −0.44 (−0.62; 0.03)  | −0.47 (−0.93; 0.01)| −0.10 (−0.51; 0.11)  | 0.25 (0.01; 0.48) |
| Δ Familiarity       | −0.07 (−0.46; 0.33)  | −0.09 (−0.49; 0.30) | 0.04 (−0.25; 0.33)   | 0.12 (−0.09; 0.29) |
| Δ Price             | −0.59 (−0.95; −0.22) | −0.58 (−0.95; −0.21)| −0.11 (−0.48; 0.25)  | −0.20 (−0.30; −0.02)|

In bold: parameters significantly different from zero at α = 0.05.

Multiple linear regressions testing the effect of the nine motives simultaneously on dependent variables.

Control variables: age, gender, initial BMI (six missing values), and highest educational qualification.

1Short- and mid-term changes in motives as predictors of short- and mid-term changes in dependent variables, respectively.

DISCUSSION

This longitudinal study explored individual changes in diet impact, and organic and local food consumption, during the first lockdown and over the first year of the COVID-19 outbreak. We confirmed the temporary decrease in nutritional quality and found temporary changes in motivational profiles associated with specific food behaviors (24–33, 34–36).

In line with the status quo regarding nutritional quality and environmental impact, no qualitative evolution of the diet was observed after the first lockdown (24–33). In the initial life disruption caused by the lockdown, there was an impact on the quality of dietary patterns associated with specific food behaviors (24–33, 34–36) which reflects no qualitative evolution of the diet. In this period, we found a mid-term trend toward more healthy and local food consumption consistent with the evolution of preference. However, we also found a trend toward more traditional habits. This decrease in nutritional quality was observed after the first lockdown and over the first year of pandemic. This decrease in nutritional quality was observed in all samples of individuals and identified motivational profiles associated with specific food behaviors (24–33, 34–36).
However, cross-sectional associations do not predict what would happen in the case of a change in individual motivations over time. Here, we demonstrated that mid-term increase in motives related to natural content and weight control was related to an increased nutritional quality of diet and that mid-term increase in motives related to ethical concern was related to a decreased environmental impact of diet whereas a mid-term increase in weight control motive was related to an increased environmental impact of diet. However, contrary to what was observed in cross-sectional studies (16, 18), increased health and ethical concern motives were not associated with increased nutritional quality of diet. Our observations were limited to natural changes in food choice motives caused by the unusual situation of the COVID-19 outbreak and its consequences (e.g., successive lockdowns). Other life disruptions that result in longer-term contextual changes at individual levels may more likely result in sustained changes in food choice motives and consequently in food behaviors (21).

Collectively, the present results on food choice motives bring into question the conditions under which changes in motives may remain stable over time and translate into actual behavioral change. According to the COM-B model of behavior proposed by Michie et al. (45), motivation defined as all brain processes that energize and direct behavior plays a central role in predicting actual behavior. This model also depicts a retroactive loop from the behavior to the motivation; the repetition of a behavior in line with a motivation in turns reinforces this motivation. In our sample, a short-term increase in health motives was not associated with short-term changes in nutritional quality, that is, a behavior change that would have been expected in line with the change in motivation. One year later, health motives were back to their initial level. On the contrary, we observed both a short-term decrease in convenience motives and a short-term increase in time spent cooking during the first lockdown (10). One year later, convenience motives were still lower than before the first lockdown and participants declared having spent more time cooking during the past year. We may hypothesize that a change in motivation will be remaining only if it translates in a new behavior in line with the new motivation that successfully incorporates into a daily routine.

In this study, we recorded total dietary intake through a validated FFQ allowing to calculate indicators based on whole-diet composition. This is a major strength of this study as numerous studies that investigate the impact of the COVID-19 outbreak on food behaviors have only asked questions about the consumption of specific food groups, for example, healthy and unhealthy key food groups (4), sugared-sweetened beverages and sweet or salty snacks (2), and fresh food, non-perishable food, readymade meals, and sweet snacks (3). However, we note that FFQs are subjected to recall bias that may have affected dietary data. Another strength of this study is that the same questionnaires were completed three times by the same participants which makes this study the first to our knowledge that have investigated lasting effects of the COVID-19 outbreak on food behaviors. In addition, we took care of contacting the participants exactly 1 year after the first lockdown to record dietary intake at the same period of the year which limited seasonal effect on food consumption. Our sample was not representative of the French population and included more women and individuals with higher educational level, which constitutes a limitation of our study and limit the generalisability of the results. In addition, only 63% of the participants from the initial survey accepted to complete the follow-up survey which may have biased the sample toward individuals with the strongest interest in food. Finally, eight models were run to explore the associations between short- and mid-term changes in food choice motives and short- and mid-term changes in nutritional quality and environmental impact. In each model, we tested nine predictors, hence a total of 72 statistical tests which increased the likelihood of finding an association by chance alone.

**CONCLUSION**

The slight decrease in nutritional quality and environmental impact of diet observed during the first lockdown was only temporary, and we observed no difference between before and 1 year after the beginning of the COVID-19 outbreak. In the same vein, after an increase during the first lockdown, motives related to health, natural content, and ethical concern went back to their initial level after 1 year of pandemic. On the contrary, motives related to convenience, familiarity, and price remained at a lower level of importance, which indicates a sustained decrease in perceived constraints due to food shopping and food preparation. It would be of interest to investigate how these changes would translate into new food habits in the long run, notably consumption of less convenient yet healthy and environment-friendly food items (e.g., pulses).

**DATA AVAILABILITY STATEMENT**

The original contributions presented in the study are publicly available. This data can be found here: https://osf.io/gwfdb/.

**ETHICS STATEMENT**

The studies involving human participants were reviewed and approved by Comité d’Évaluation Ethique de l’Inserm, n°20-683bis. The patients/participants provided their written informed consent to participate in this study.
AUTHOR CONTRIBUTIONS
LM: conceptualization, investigation, formal analysis, and writing—original draft. BL-G: methodology, software, writing, reviewing, and editing. SN: conceptualization, investigation, writing, reviewing, and editing. 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.2022.838351/full#supplementary-material

REFERENCES
1. Bennett G, Young E, Butler I, Coe S. The impact of lockdown during the COVID-19 outbreak on dietary habits in various population groups: a scoping review. Front Nutr. (2021) 8:1–10. doi: 10.3389/fnut.2021.626432
2. Drieskens S, Berger N, Vandevijvere S, Gisle L, Braekman E, Charafeddine R, et al. Short-term impact of the COVID-19 confinement measures on health behaviours and weight gain among adults in Belgium. Arch Public Heal. (2021) 79:1–10. doi: 10.1186/s13690-021-00542-2
3. Janssen M, Chang BPI, Hristov H, Pravst I, Profeta A, Millard J. Changes in food consumption during the COVID-19 pandemic: analysis of consumer survey data from the first lockdown period in Denmark, Germany, and Slovenia. Front Nutr. (2021) 8:1–20. doi: 10.3389/fnut.2021.635859
4. Robinson E, Boyland E, Chisholm A, Maloney NG, Marty L, et al. Obesity, eating behavior and physical activity during COVID-19 lockdown: a study of UK adults. Appetite. (2021) 156:104853. doi: 10.1016/j.appet.2020.104853
5. Ashwin A, Sur PJ, Fay KA, Cornaby L, Ferrara G, Salama JS, et al. Health effects of dietary risks in 195 countries, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet. (2019) 393:1958–972. doi: 10.1016/S0140-6736(19)30041-8
6. Lamarche B, Brassard D, Lapointe A, Laramée C, Kearney M, Côté M, et al. Changes in diet quality and food security among adults during the COVID-19-related early lockdown: results from NutriQuébec. Am J Clin Nutr. (2021) 113:984–92. doi: 10.1093/ajcn/nqa363
7. del Pozo de la Calle S, Alonso Ledesma I, Nuñez O, Castelló Pastor A, Lope Castelló Pastor A, Lope Carvajal V, Fernández de Larrea Baz N, et al. Composition and nutritional quality of the diet in Spanish households during the first wave of the COVID-19 pandemic. Nutrients. (2021) 13:1–14. doi: 10.3390/nu13051445
8. Madzorera I, Ismail A, Hemler EC, Korte ML, Olufemi AA, Wang D, et al. Impact of COVID-19 on nutrition, food security, and dietary diversity and quality in Burkina Faso, Ethiopia and Nigeria. Am J Trop Med Hyg. (2021) 105:295–309. doi: 10.1093/ajtmh/pza029_035
9. Deschasaux-Tanguy M, Druesne-Pecollo N, Esseddik Y, de Edeleny F, Allès B, Andreeva V A, et al. Diet and physical activity during the COVID-19 outbreak on dietary habits in various population groups: a coping review. Matern Child Nutr. (2021) 17:1–10. doi: 10.1111/mcn.13140
10. Severo EA, De Guimarães JCF, Dellarmelin ML. Impact of the COVID-19 pandemic on environmental awareness, sustainable consumption and social responsibility: evidence from generations in Brazil and Portugal. J Clean Prod. (2021) 286:1–14. doi: 10.1016/j.jclepro.2020.124947
11. Jribi S, Ben Ismail H, Dogguy D, Debbabi H. COVID-19 virus outbreak lockdown: what impacts on household food wastage? Environ Dev Sustain. (2020) 22:3939–55. doi: 10.1007/s10668-020-00740-y
12. Sarkis J, Cohen MJ, Dewick P, Schröder P. A brave new world: lessons from the COVID-19 pandemic for transitioning to sustainable supply and production. Resour Conserv Recycl. (2020) 159:104894. doi: 10.1016/j.resconrec.2020.104894
13. Cohen MJ. Does the COVID-19 outbreak mark the onset of a sustainable consumption transition? Sustain Sci Pract Policy. (2020) 161:3–12. doi: 10.1080/15487733.2020.1740472
14. Alles B, Péneau S, Kesse-Guyot E, Baudry J, Hercberg S, Méjean C. Food choice motives including sustainability during purchasing are associated with a healthy dietary pattern in French adults. Nutr J. (2017) 16:1–12. doi: 10.1186/s12937-017-0279-9
15. Pelletier JE, Laska MN, Neumark-Sztainer D, Story M. Positive attitudes toward organic, local, and sustainable foods are associated with higher dietary quality among young adults. J Acad Nutr Diet. (2013) 113:127–32. doi: 10.1016/j.jand.2012.08.021
16. Kontinnen H, Sarlio-Lähteenkorva S, Silventoinen K, Männistö S, Hakkuakala A. Socio-economic disparities in the consumption of vegetables, fruit and energy-dense foods: the role of motive priorities. Public Health Nutr. (2013) 16:873–82. doi: 10.1017/S136898001203540
17. Baudry J, Péneau S, Allès B, Touvier M, Hercberg S, Galan P, et al. Food choice motives when purchasing in organic and conventional consumer clusters: focus on sustainable concerns (the nutrinet-santé cohort study). Nutrients. (2017) 9:1–17. doi: 10.3390/nu9020088
18. Verplanken B, Wood W. Interventions to break and create consumer habits. Am Mark Assoc. (2006) 25:90–103. doi: 10.1509/ijpm.25.1.90
19. Nash N, Whittle C, Whitmarsh L. Rapid Review of “Moments of Change” & Food-Related Behaviours. (2020). Available online at: https://www.food.gov.uk/sites/default/files/media/document/fsa-rapid-literature-review-final.pdf (Accessed February 24, 2022).
20. Wood W, Runger D. Psychology of habits. Annu Rev Psychol. (2016) 67:289–314. doi: 10.1146/annurev-psych-122414-033417
21. Kadawathagedara M, Ahiawala N, Dufourg MN, Forhan A, Charles MA, Lloret S, et al. Diet during pregnancy: influence of social characteristics and migration in the ELFE cohort. Matern Child Nutr. (2021) 17:1–13. doi: 10.1111/mcn.13140
22. Hercberg S, Deheeger M, Preziosi P. SU.VI.MAX. Portions Alimentaires : Manuel Photos Pour l’Estimation des Quantités. Economica: Paris (2002).
25. Herceberg S. *Table de Composition des Aliments SU.VI.MAX*. Paris: Economica (2006).

26. Chaltiel D, Adjibade M, Deschamps V, Touvier M, Herceberg S, Julia C, et al. Programme national nutrition santé - Guidelines score 2 (pns-ps2): Development and validation of a diet quality score reflecting the 2017 French dietary guidelines. *Br J Nutr.* (2019) 122:331–42. doi: 10.1017/S0007114519001181

27. FAO, WHO. *Sustainable Healthy Diets - Guiding Principles*. Rome (2019).

28. ADEME. *Agribalyse v3.0*. (2020) Available online at: https://ecolab.ademe.fr/agribalyse (accessed July 25, 2021).

29. Baudry J, Méjean C, Péneau S, Galan P, Herceberg S, Lairon D, et al. Health and dietary traits of organic food consumers: results from the NutriNet-Santé study. *Br J Nutr.* (2015) 114:2064–73. doi: 10.1017/S000711451500376X

30. Steptoe A, Pollard TM, Wardle J. Development of a measure of the motives underlying the selection of food: the “food choice questionnaire.” *Appetite.* (1995) 25:267–84. doi: 10.1006/app.1995.0061

31. Cottet P, Ferrandi J-M, Lichtlé M-C, Plchon V. La compréhension des moteurs des comportements alimentaires : une approche par le food choice questionnaire. 12ème Journée du Marketing Agroalimentaire (2018). Available online at: https://hal.univmontp2.fr/hal-01900329/document

32. Banna JC, McCrory MA, Fialkowski MK, Boushey C. Examining plausibility of self-reported energy intake data: considerations for method selection. *Front Nutr.* (2017) 4:1–6. doi: 10.3389/fnut.2017.00045

33. Willett W. *Nutritional Epidemiology*, 3rd ed. New York, NY: Oxford University Press (2013).

34. Statista. *Share of People That Are More Inclined to Buy Consumption Goods If They Are Produced Locally in France from 2008 to 2020. Consumer Goods FMCG*. (2020). Available online at: https://www.statista.com/statistics/1129420/consumers-attracted-by-local-products-in-france/ (accessed October 15, 2021).

35. FiBL, IFOAM. *The World of Organic Agriculture*. Rheinbreitbach. (2020).

36. Philippe K, Chabanet C, Issanchou S, Monnery-Patris S. Child eating behaviors, parental feeding practices and food shopping motivations during the COVID-19 lockdown in France: (How) did they change? *Appetite.* (2021) 161:105132. doi: 10.1016/j.appet.2021.105132

37. Santé Publique France. *Confinement : Quelles Conséquences sur les Habitudes Alimentaires?* (2020). Available online at: https://www.santepubliquefrance.fr/presse/2020/confinement-quelles-consequences-sur-les-habitudes-alimentaires (accessed October 15, 2021).

38. Philippe K, Issanchou S, Monnery-Patris S. Contrasts and ambiguities in French parents’ experiences regarding changes in eating and cooking behaviours during the COVID-19 lockdown. *Food Qual Prefer.* (2021) 96:104386. doi: 10.1016/j.foodqual.2021.104386

39. Rozin P, Fischler C, Imada S, Sarubin A, Wrzesniewski A. Attitudes to food and the role of food in life in the U.S.A., Japan, Flemish Belgium and France: possible implications for the diet – health debate. *Appetite.* (1999) 33:163–80. doi: 10.1006/app.1999.0244

40. Powell LH, Shima C, Kazlauskaitė R, Appelhans BM. Lifestyle in France and the United States: an American perspective. *J Am Diet Assoc.* (2010) 110:845–7. doi: 10.1016/j.jada.2010.03.029

41. Pettinger C, Holdsworth M, Gerber M. Psycho-social influences on food choice in Southern France and Central England. *Appetite.* (2004) 42:307–16. doi: 10.1016/j.appet.2004.01.004

42. Brown E, Dury S, Holdsworth M. Motivations of consumers that use local, organic fruit and vegetable box schemes in Central England and Southern France. *Appetite.* (2009) 53:183–8. doi: 10.1016/j.appet.2009.06.006

43. Piennak Z, Verbeke W, Vanhonacker F, Guerrero L, Hersleth M. Association between traditional food consumption and motives for food choice in six European countries. *Appetite.* (2009) 53:101–108. doi: 10.1016/j.appet.2009.05.019

44. Kesse-Guyot E, Péneau S, Méjean C, Szabo de Edelenyi F, Galan P, Herceberg S, et al. Profiles of organic food consumers in a large sample of french adults: results from the nutrinet-sante cohort study. *PLoS ONE.* (2013) 8:e76998. doi: 10.1371/journal.pone.0076998

45. Michie S, Van Stralen MM, West R. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. *Implement Sci.* (2011) 6:1–11. doi: 10.1186/1748-5908-6-42

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