Diet and physical activity during the coronavirus disease 2019 (COVID-19) lockdown (March–May 2020): results from the French NutriNet-Santé cohort study

Mélanie Deschasaux-Tanguy,[1] Nathalie Druesne-Pecollo,[1] Younes Esseddik,[1] Fabien Szabo de Edelenyi,[1] Benjamin Allès,[1] Valentina A Andreeva,[1] Julia Baudry,[1] Hélène Charreire,[2] Valérie Deschamps,[3] Manon Egnell,[1] Leopold K Fezeu,[1] Pilar Galan,[1] Chantal Julia,[4] Emmanuelle Kesse-Guyot,[1] Paule Latino-Martel,[1] Jean-Michel Oppert,[5] Sandrine Péneau,[1] Charlotte Verdot,[3] Serge Hercberg,[1,4] and Mathilde Touvier[1]

[1]Sorbonne Paris Nord University, Institut National de la Santé et de la Recherche Médicale (INSERM), Institut National de Recherche pour l'Agriculture, l'Alimentation et l'Environnement (INRAE), Conservatoire National des Arts et Métiers (CNAM), Nutritional Epidemiology Research Team (EREN), Epidemiology and Statistics Research Center–University of Paris (CRESS), Bobigny, France; [2]Paris-Est University, Lab'Urba, Université Paris-Est Créteil (UPEC), Créteil, France; [3]Nutritional Surveillance and Epidemiology Team (ESEN), French Public Health Agency, Sorbonne Paris Nord University, Epidemiology and Statistics Research Center–University of Paris (CRESS), Bobigny, France; [4]Department of Public Health, Paris Seine-Saint-Denis University Hospital System, Assistance Publique - Hôpitaux de Paris (AP-HP), Bobigny, France; and [5]Department of Nutrition, Institute of Cardiometabolism and Nutrition, Sorbonne University, Pitié-Salpêtrière Hospital, Paris, France

ABSTRACT

Background: Since December 2019, coronavirus disease 2019 (COVID-19) has been spreading steadily, resulting in overwhelmed health-care systems and numerous deaths worldwide. To counter these outcomes, many countries, including France, put in place strict lockdown measures, requiring the temporary closure of all but essential places and causing an unprecedented disruption of daily life.

Objectives: Our objective was to explore potential changes in dietary intake, physical activity, body weight, and food supply during the COVID-19 lockdown and how these differed according to individual characteristics.

Methods: The analyses included 37,252 adults from the French web-based NutriNet-Santé cohort who completed lockdown-specific questionnaires in April–May 2020. Nutrition-related changes and their sociodemographic, lifestyle, and health-status correlates were investigated using multivariable logistic regression models. Clusters of participants were defined using an ascending hierarchical classification of change profiles derived from multiple correspondence analyses.

Results: During the lockdown, trends of unfavorable changes were observed: decreased physical activity (reported by 53% of the participants), increased sedentary time (reported by 63%), increased snacking, decreased consumption of fresh food (especially fruit and fish), and increased consumption of sweets, cookies, and cakes. Yet, the opposite trends were also observed: increased home cooking (reported by 40%) and increased physical activity (reported by 19%). Additionally, 35% of the participants gained weight (mean weight gain in these individuals, 1.8 kg ± SD 1.3 kg) and 23% lost weight (2 kg ± SD 1.4 kg weight loss). All of these trends displayed associations with various individual characteristics.

Conclusions: These results suggest that nutrition-related changes occurred during the lockdown in both unfavorable and favorable directions. The observed unfavorable changes should be considered in the event of a future lockdown, and should also be monitored to prevent an increase in the nutrition-related burden of disease, should these diet/physical activity changes be maintained in the long run. Understanding the favorable changes may help extend them on a broader scale. This trial was registered at clinicaltrials.gov as NCT03335644. *Am J Clin Nutr* 2020;00:1–15.

Keywords: nutrition, COVID-19 lockdown, diet, physical activity, sedentariness, body weight, cohort study

Introduction

After first being reported in Wuhan, China, in December 2019, the outbreak of coronavirus disease 2019 (COVID-19), caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), was characterized as a pandemic by the World Health Organization on 11 March 2020, following its worldwide spread (1). Considering the numerous unknowns surrounding SARS-CoV-2, as well as the absence of treatment, several countries successively opted for strict lockdown measures in order to curtail the fast-growing transmission of the disease and the associated overload of hospitals and health-care systems.

In France, such lockdown measures came into effect on 17 March 2020; they were partially lifted on 11 May and 2 June 2020. These measures required the temporary closure of all but the most essential public places, businesses, and services.

The population was required to stay at home: going outdoors was monitored by police and was allowed only if the activity took place in the vicinity of the home and was related to meeting essential needs (e.g., grocery shopping, medical care, legal obligations, and quick recreational physical activity). Only employees in "essential" sectors (e.g., health care, food and drug manufacturers and suppliers, waste collection) were allowed to maintain their usual work activities. As a result, the majority of the working population was required to work from home or was placed on partial/technical unemployment. Distance learning was implemented by schools and universities, and parents actually became teacher substitutes. This unprecedented situation resulted in a sudden disruption of daily routines, accompanied by uncertainties and worries related both to the pandemic and to professional and familial organization during and after the lockdown. Nonetheless, the experience was not uniform for the entire population, but rather dependent on a variety of circumstances according to an individual's sociodemographic and economic status and area of residence. Overall, the lockdown likely resulted in disruptions of food-related practices and physical activity (PA), as well as body weight (BW) changes and increased sedentariness, as suggested by reports from surveys in other countries (2–14). Indeed, the lockdown measures altered access to food, prevented mobility and use of green spaces and sports clubs, and impacted daily rhythm and activities.

Given the unprecedented nature of such lockdown measures, as well as the real possibility of future lockdowns, it is important to assess health behavior changes during the lockdown, especially as regards food-related practices, PA, and weight status. It is likewise necessary to investigate whether these changes cluster across individual characteristics and whether they are associated with sociodemographic and economic inequalities. The obtained knowledge could be of critical importance for future public health measures in extreme situations nationally and/or internationally and could also help inform future prevention efforts should changes persist post-lockdown.

Indeed, nutrition (i.e., diet, PA, weight status) is among the main modifiable factors regarding chronic disease risk (e.g., cardiovascular diseases, type 2 diabetes, cancer) (15, 16). Moreover, the mounting evidence showing the importance of nutritional factors in immune function (17, 18) suggests that nutrition may directly impact the risk of SARS-CoV-2 infection and its prognosis (19–22).

The NutriNet-Santé web platform offered a unique opportunity to collect a large amount of nutrition, behavior, and health-status data during the lockdown from >37,000 French adults using online questionnaires and validated dietary records. The primary aim of the present study was to characterize and cluster changes in diet-related practices, PA, and BW during the COVID-19 lockdown in France. The secondary objective was to explore the sources of food supply that were used during that period.

Methods

Study population: the NutriNet-Santé cohort

The NutriNet-Santé cohort was launched in France in 2009 with the objective to examine the associations between nutrition and health, as well as the determinants of nutrition-related behaviors (23). Recruitment of participants (adults aged ≥ 18 years from 2009–2019; individuals aged >15 years since 2020) is still ongoing. The study uses a secure and flexible online platform for recruitment and data collection. It allows for the rapid implementation of ad hoc research protocols. The NutriNet-Santé study is conducted in accordance with the Declaration of Helsinki, and all procedures were approved by the Institutional Review Board of the French Institute for Health and Medical Research (IRB INSERM 0000388FWA00005831) and by the National Commission on Informatics and Liberty (CNIL 908,450 and 909,216). All participants provided informed consent and an electronic signature; this study is registered in ClinicalTrials.gov (#NCT03335644).

Data collection in the NutriNet-Santé cohort

Upon inclusion, NutriNet-Santé participants are asked to complete a set of 5 validated, self-administered web-based questionnaires related to *1*) sociodemographic and lifestyle characteristics (24); *2*) health status; *3*) dietary intake (DI) (25–27); *4*) PA (short form of the International Physical Activity Questionnaire [IPAQ] (28)); and *5*) anthropometrics (29, 30). These questionnaires are readministered every 6 to 12 months during follow-up.

As part of the usual cohort follow-up, DI is assessed every 6 months, each time using a set of 3 nonconsecutive 24-hour dietary records, randomly distributed over 2 weeks, including 2 weekdays and 1 weekend day. These web-based 24-hour dietary records have been validated against dietary records completed via interviews with a dietitian and against plasma/urine biomarkers (25–27). Portion sizes are estimated using validated photographs,

The NutriNet-Santé cohort study was supported by the following public institutions: Ministère de la Santé, Santé Publique France, Institut National de la Santé et de la Recherche Médicale (INSERM), Institut National de Recherche pour l'Agriculture, l'Alimentation et l'Environnement (INRAE), Conservatoire National des Arts et Métiers (CNAM), and Université Sorbonne Paris Nord. The SAPRIS/SAPRIS-SERO (Health, practices, relationships and social inequalities in the general population during the COVID-19 crisis) projects received funding from the French National Research Agency (ANR) "Flash" program of March 2020 (0009/SAPRIS/997/NB), the Fondation pour la Recherche Médicale (FRM), the General Directorate of Research and Innovation (DGRI), and the Gustave Roussy Institute.

Funders had no role in the study design, the collection, analysis, and interpretation of data, the writing of the manuscript, or the decision to submit the article for publication.

Supplemental Tables 1–9, Supplemental Figures 1–2 and Supplemental Material 1 to 3 are available from the "Supplementary data" link in the online posting of the article and from the same link in the online table of contents at https://academic.oup.com/ajcn/.

Address correspondence to MD-T (e-mail: m.deschasaux@eren.smbh.univ-paris13.fr).

Abbreviations used: AHEI, Alternative Healthy Eating Index; BW, body weight; COVID-19, coronavirus disease 2019; DI, dietary intake; GAD-7, Generalized Anxiety Disorder–7 scale; IPAQ, International Physical Activity Questionnaire; MET, metabolic equivalent of task; PA, physical activity; PHQ-9, Patient Health Questionnaire–9 scale; ST, sedentary time; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

Received June 9, 2020. Accepted for publication October 22, 2020.

First published online 0, 2020; doi: https://doi.org/10.1093/ajcn/nqaa336.

standard food/beverage containers, or directly in g/L. Mean daily energy, alcohol, and macro- and micro-nutrient intakes are estimated using a published French food composition table comprising >3500 food items (31). Amounts consumed from composite dishes are estimated using French recipes validated by food and nutrition professionals. Dietary energy under-reporters are detected via the method proposed by Black (32). Usual DIs were calculated as the average intakes per day over all 24-hour dietary records available for the period of interest (i.e., pre-lockdown or during the lockdown). In addition, dietary data are weighted in order to account for weekday and weekend consumption. In turn, the short-form IPAQ is administered annually, assessing PA level (vigorous, moderate, or walking) and time spent seated on an average day (outside mealtimes and sleep) during the past 7 days. Physical activity levels for each participant are computed as metabolic equivalent of task (MET) minutes per week.

Data collection during the COVID-19 lockdown

In April 2020, a set of ad hoc questionnaires was sent to all eligible NutriNet-Santé participants ($n = 152{,}000$) to collect extensive data on diet-related practices and PA during the lockdown. The set included a specific questionnaire on perceived changes in dietary habits (along with associated reasons), consumption of major food groups, snacking, food supply preferences, PA, and ST (details are provided in **Supplementary Material 1**); a series of three 24-hour dietary records randomly assigned over 2 weeks during the strict lockdown period (covering 2 weekdays and 1 weekend day); and the short-form IPAQ (permitting the computation of MET-min/week). The 24-hour dietary records and the short-form IPAQ were the same as those regularly sent to participants as part of their follow-up (described above).

Next, BW measures at the beginning and at the end of the strict lockdown period were collected from self-reports in early April and early May 2020. These anthropometric questionnaires also asked about BW just before the lockdown. Participants were specifically asked whether they had been able to measure their weight with a scale and to provide measured data. Only data from participants who reported that they had used a scale were taken into account when calculating weight changes. The web-based self-reported BW measures had been validated in the cohort by means of comparisons with standardized clinical measurements (29). BMI was computed as weight (kilograms)/height^2 (meters). The following categories of BW status were defined: obese (BMI $\geq$ 30 kg/m^2), overweight (BMI $\geq$ 25 to $<$ 30 kg/m^2), normal weight (BMI $\geq$ 18.5 to $<$ 25 kg/m^2), and underweight (BMI $<$ 18.5 kg/m^2).

Finally, a questionnaire assessing participants' exposure to SARS-CoV-2, COVID-19 infection/diagnosis status, and experience of the lockdown was sent in April 2020 as part of a nationwide multi-cohort project ("Health, practices, relationships and social inequalities in the general population during the COVID-19 crisis," SAPRIS). That questionnaire was used to derive demographic, physical, and mental health information during the lockdown (professional status, presence at home of children and/or grandchildren aged <18 years), including the presence of depressive symptoms (Patient Health Questionnaire–9 scale [PHQ-9] (33)) and anxiety (Generalized Anxiety Disorder–7 scale [GAD-7] (34)). Details about the PHQ-9 and the GAD-7 are provided in **Supplementary Material 2**.

Statistical analyses

A total of 37,252 participants residing in metropolitan France completed the specific questionnaire related to nutrition during the COVID-19 lockdown: those data served as a basis for the main analyses (full sample). In that sample, 27,658 participants had valid data regarding DI before the lockdown (usual DI sample); 30,032 had valid data from the short-form IPAQ on PA levels before and during the lockdown (PA sample); 30,022 had valid data regarding sedentary time (ST) before and during the lockdown (ST sample); and 22,042 participants reported having access to a BW scale and provided measured values of BW before the lockdown and on May 2020 (BW sample). In addition, in the full sample, valid DI data from 24-hour dietary records consistently completed during the month of April during the 3 years preceding the lockdown were available for 1264 participants from 2017, 1075 from 2018, and 991 from 2019; DI data from 24-hour dietary records completed in April 2020 during the lockdown were available for 10 617 participants. Overall, 1548 participants had valid DI data from 24-hour dietary records from 2 time points, with 1 of them being in April 2020 during the lockdown and the other being during the month of April in 1 of the previous 3 years (2017–2019). More details are available in the flowchart provided as **Supplementary Figure 1**.

Based on the DIs of food and nutrients before and during the lockdown, 2 indicators of diet quality were calculated. The Alternative Healthy Eating Index (AHEI)-2010 score (35) was calculated, taking into account intake of vegetables, fruit, whole grains, sugar-sweetened beverages, nuts and legumes, red/processed meat, long-chain (n-3) polyunsaturated fatty acids, total polyunsaturated fatty acids, sodium, and alcohol (details are available in **Supplementary Material 3**). The percentage (by relative weight) of ultra-processed foods in the diet was assessed using the NOVA classification, as previously described (36).

Overall, the collected data were summarized using numbers and percentages for categorical variables and mean values and SDs (or median values and IQRs) for continuous variables. Student paired-sample t-tests were used to compare quantitative variables before and during the lockdown (i.e., DI of food groups, macro- and micronutrients in g/day, AHEI-2010 score in points, proportion of ultra-processed foods as percentages, PA in MET-min/week, and ST in hours). Changes in continuous variable values (during versus before the lockdown) were computed as raw values and as percentage changes ([value during lockdown−value before lockdown]/value before lockdown). Increased or decreased DIs were defined as changes of at least 10% between the average intake as reported in April 2020 (i.e., during the lockdown) and the average intake as reported during the month of April before the lockdown (2017–2019).

A multiple correspondence analysis was carried out in the BW sample ($n = 22{,}042$) using the following parameters assessed during the lockdown: change in BW, perceived changes in ST and PA levels, main reasons for modifying diet-related practices, perceived change in diet quality, perceived change in the types of food consumed (fresh products: fruit, vegetables,

fish and red meat, potatoes, sandwiches/pizzas/savory pies, cheese, sweets/chocolate, cookies/cakes, alcohol, tea), food-storing behavior, snacking, and stress related to a potential food shortage. After considering eigenvalues, scree test results and the relevance/interpretability of the profiles of nutrition-related changes during the lockdown reflected by the dimensions, 2 dimensions (i.e., latent factors) were retained (respectively explaining 10.6% and 6.4% of the variance) (37, 38). The coordinates of the nutrition-related changes along these 2 dimensions are shown in **Supplementary Table 1**. An ascending hierarchical classification was then applied on the individual scores along these 2 dimensions to identify clusters of participants displaying similar nutrition-related changes during the lockdown. The characteristics of participants associated with each cluster (modeled as dummy variables; i.e., cluster X vs. all others combined) were studied using multivariable logistic regression models including the following characteristics (the variable categories are detailed in **Table 1**): age, sex, current weight status (in April 2020), smoking status, educational level, household monthly income, professional activity during the lockdown, marital status during the lockdown, presence of children and/or grandchildren aged <18 years at home during the lockdown, region of residence during the lockdown, urban or rural residential area during the lockdown, depressive symptoms during the lockdown (PHQ-9 score), anxiety during the lockdown (GAD-7 score), and self-reported chronic disease. For participants for whom data on usual DI pre-lockdown were available ($n = 16{,}562$), the adjusted models additionally included the AHEI-2010 score and the proportion of ultra-processed foods in the usual diet.

In a secondary analysis, individual characteristics associated with specific nutrition-related changes were studied using multivariable-adjusted logistic regression models (binary or multinomial) for categorical variables and ANCOVA models for variations in continuous variables. These models included the same covariables as those detailed above and additionally included perceived changes in sedentary behaviors and PA during the lockdown.

A 2-level weighting scheme was developed to take into account and correct for potential bias owing to differences in the sociodemographic variable distributions (sex, age, area of residence, occupational category) between the study sample ($n = 37{,}252$) and *1*) the entire NutriNet-Santé cohort and *2*) the general French population, using the SAS (SAS Institute Inc.) macro %CALMAR and French national Census data 2016 from the National Institute of Statistics and Economic Studies (INSEE). The calculated weights were then applied in all analyses in order to allow for some extrapolation of the results to the general French adult population.

All tests were 2-sided and a P value < 0.05 was considered statistically significant. Analyses were carried out using SAS 9.4 (SAS Institute Inc.).

Results

After weighting, our study population was composed of 37,252 participants (52.3% women) with a mean age of 52.1 years (SD, 16.6 years). Descriptive characteristics of the participants are shown in Table 1.

TABLE 1 Characteristics of the study population after weighting ($n = 37{,}252$), NutriNet-Santé cohort, March–May 2020

	% or mean (SD)
Sex	
Women	52.3
Men	47.7
Age, years	
18–25	4.4
25–50	42.5
50–65	26.3
65–80	25.0
>80	1.8
Current weight status[1]	
Underweight	4.0
Normal	58.9
Overweight	26.0
Obesity	11.1
Smoking status	
Never smoker	45.1
Former smoker	40.6
Current smoker	14.2
Educational level	
<High school degree	17.2
High school degree	15.2
Undergraduate degree	32.7
Graduate degree	34.2
Unknown	0.7
Monthly income, € per household	
<1430	8.5
1430–2700	24.5
2700 to <4800	39.1
>4800	14.5
Unknown	3.3
Did not wish to answer	10.1
Professional activity during the lockdown	
No professional activity prior to lockdown: unemployed, retired, homemaker	40.4
Working outside home	12.3
Partially unemployed	15.7
Working from home full-time	19.8
Working from home part-time	5.2
Student, trainee	3.2
Other	3.4
Marital status during the lockdown	
Never married	16.3
In a relationship	16.3
Married or registered partnership	56.7
Divorced or separated	7.6
Widowed	3.1
Children and/or grandchildren aged under 18 y at home during the lockdown? [Yes]	24.6
Residential area during the lockdown: city size, number of inhabitants	
Rural area	35.4
City < 20,000	23.1
City ≥ 20,000 to 100,000	21.6
City > 100,000	19.8
Regional residential area during the lockdown[2]	
Paris Basin	15.8
Center-East	12.9
East	9.2
Mediterranean	13.5
North	5.7
West	14.1
Paris region	17.4
Southwest	11.3

(*Continued*)

TABLE 1 (*Continued*)

	% or mean (SD)
GAD-7, anxiety disorders[3]	3.2 (4.0)
PHQ-9, depressive symptoms[4]	3.8 (4.4)
Chronic disease[5] [Yes]	27.9

Abbreviations: AHEI, Alternative Healthy Eating Index; GAD-7, Generalized Anxiety Disorder–7 scale; PHQ-9, Patient Health Questionnaire–9 scale.

[1]Calculated from current weight reported in April 2020.

[2]Regional Zones for Study and Development (ZEAT) as defined by the French National Institute of Statistics and Economic Studies (INSEE). Paris region: Ile de France; Paris basin: Burgundy, Center, Champagne-Ardenne, Lower and Upper Normandy, Picardie; North: Nord Pas-de-Calais; East: Alsace, Franche-Comté, Lorraine; West: Brittany, Pays de la Loire, Poitou-Charentes; South-West: Aquitaine, Limousin, Midi-Pyrénées; Center-East: Auvergne, Rhône-Alpes; and Mediterranean: Languedoc-Roussillon, Provence-Alpes-Côte d'Azur, Corsica.

[3]The GAD-7 scores range from 0 to 21 points and measure the increasing severity of anxiety (minimal: 0–4; mild: 5–9; moderate: 10–14; severe: 15–21).

[4]The PHQ-9 scores range from 0 to 27 points and measure the increasing presence and severity of depressive symptoms (minimal: 0–4; mild: 5–9; moderate: 10–14; moderately severe: 15–19; severe: 20–27).

[5]Includes diabetes, cardiovascular diseases, hypertension, dyslipidemia, cancer, liver diseases, kidney diseases, thyroid diseases, digestive disorders, gynecological disorders, arthritis, and immune system disorders.

Diet-related practices during the lockdown

Overall, 56.2% of the participants (full sample) reported that they modified their diet-related practices during lockdown. The main reasons for these modifications (shown in **Supplementary Figure 2**) were related to inherent lifestyle changes during the lockdown (change in routine, 47.6%; spending more time cooking homemade meals, 40.4%; no longer eating out, 20.5%; trouble keeping a regular mealtime schedule, 10.1%), alterations in the food supply (buying less fresh products, 27.4%; difficulty going to usual stores, 25.9%; difficulty finding preferred products, 13.7%; difficulty buying organic food, 12.3%), voluntary behavior changes (trying to avoid weight gain, 21.1%; compensating for the decrease in PA, 16.9%; opportunity to balance diet, 14.2%), and emotional reasons (eating out of boredom, 18.2%; eating due to anxiety, 10.8%). Regarding perceived diet quality during the lockdown compared to before, 74.4% reported that their diet quality had not changed, 14.1% reported that it was improved, and 10.5% reported that it had deteriorated (full sample). During the lockdown, 5.6% of participants (full sample) reported snacking at least 3 times a day, every day (vs. 3.1% in a previous study dealing with snacking behaviors in the NutriNet-Santé cohort, although not in the same sample (39)); 22.3% reported snacking once or twice a day, every day (vs. 18.6% in a previous study); 11.4% reported snacking 4 to 6 times a week (vs. 11.5% in a previous study); 22.7% reported snacking 1 to 3 times a week (vs. 29.6% in a previous study); 17% reported snacking less than once a week (vs. 21.8% in a previous study); and 21.1% reported never snacking (vs. 15.4% in a previous study). Snacking more than usual was reported by 21.1% of participants (full sample), among which 18.9% reported snacking at least 3 times a day, every day. In turn, snacking less than usual was reported by 9.4% of the sample, while 69.5% reported snacking as usual. Moreover, 27.1% of participants reported that they felt stressed by the hypothetical possibility of lacking some food during the lockdown (full sample). However, only 3.3% of participants reported that they stored more food than usual to prevent food shortages, while 45% stored more food due to a reduced frequency of grocery shopping. Characteristics of participants associated with perceived changes in diet-related practices during the lockdown, along with the associated reasons for these changes, are shown in **Supplementary Tables 2 and 3**, respectively (full sample).

Perceived changes in the consumption of major food groups during the lockdown are reported in **Figure 1** (full sample). An overall decrease in the consumption of fresh products was observed: 17% of participants reported a decrease for fresh fruit, 18% for fresh vegetables, 22% for fresh red meat, and 31% for fresh fish. In parallel, 14% of participants reported having increased their consumption of frozen or canned vegetables (that proportion was much lower for frozen or canned fruit, fish, or red meat). In addition, we noted increased consumption of other products with long shelf lives, such as potatoes (reported by 15% of the participants), legumes (15%), and nuts (12%). Other noteworthy results include increased consumption of sweets and chocolate (reported by 22% of the participants), cookies and cakes (20%), and cheese (18%), and decreased consumption of sandwiches, pizzas, or savory pies (17%). As regards beverage products, 15% of the participants reported increased alcohol consumption, 12% reported decreased alcohol consumption, 20% reported increased consumption of tea, and 13% reported increased consumption of tap water.

Quantitative DIs reported in April 2020 (via 24-hour dietary records completed during the lockdown; $n = 10{,}617$) were compared to the quantitative DIs reported during the month of April over the past 3 years (via repeated 24-hour dietary records completed in 2017, $n = 1264$; 2018, $n = 1075$; and 2019, $n = 991$). We observed relatively stable intakes between 2017 and 2019 and a drop in 2020 for total energy, carbohydrate, fish, and vitamin B12 intakes; there was a trend towards decreasing protein intake during 2017–2019 (reflecting the current decrease in consumption of animal products in France) and a further drop in 2020. Few changes between 2017 and 2020 were found regarding the AHEI score, the proportion of ultra-processed foods in the diet, or intakes in dietary fat, fiber, fruit, and vegetables. These results are summarized in **Figure 2** and a detailed account of DIs as regards macro- and micronutrients, food groups, AHEI scores, and proportion of ultra-processed foods in the diet is provided in **Supplementary Table 4**. Overall, the quantitative estimates reflected most of the perceived changes, with the few discrepancies likely owing to the profiles of participants who completed the dietary records during the lockdown ($n = 10{,}617$) compared to the full sample (more likely to be older, men, normal-weight, to have a higher income, and to have no professional activity pre-lockdown; details are provided in **Supplementary Table 5**). On one hand, when comparing energy intakes in April 2020 to those reported in April 2017–2019 ($n = 1548$), an increase was observed for 25% of participants, with +468 kcal/day (SD, 274) on average: that is, +26%. On the other hand, a decrease in energy intake was observed for 33% of participants, with -510 kcal/day (SD, 267) on average: that is, -23% (**Figure 3**). Comparisons between April 2020 and April 2017–2019 regarding DIs ($n = 1548$) are presented in **Supplementary Table 6**.

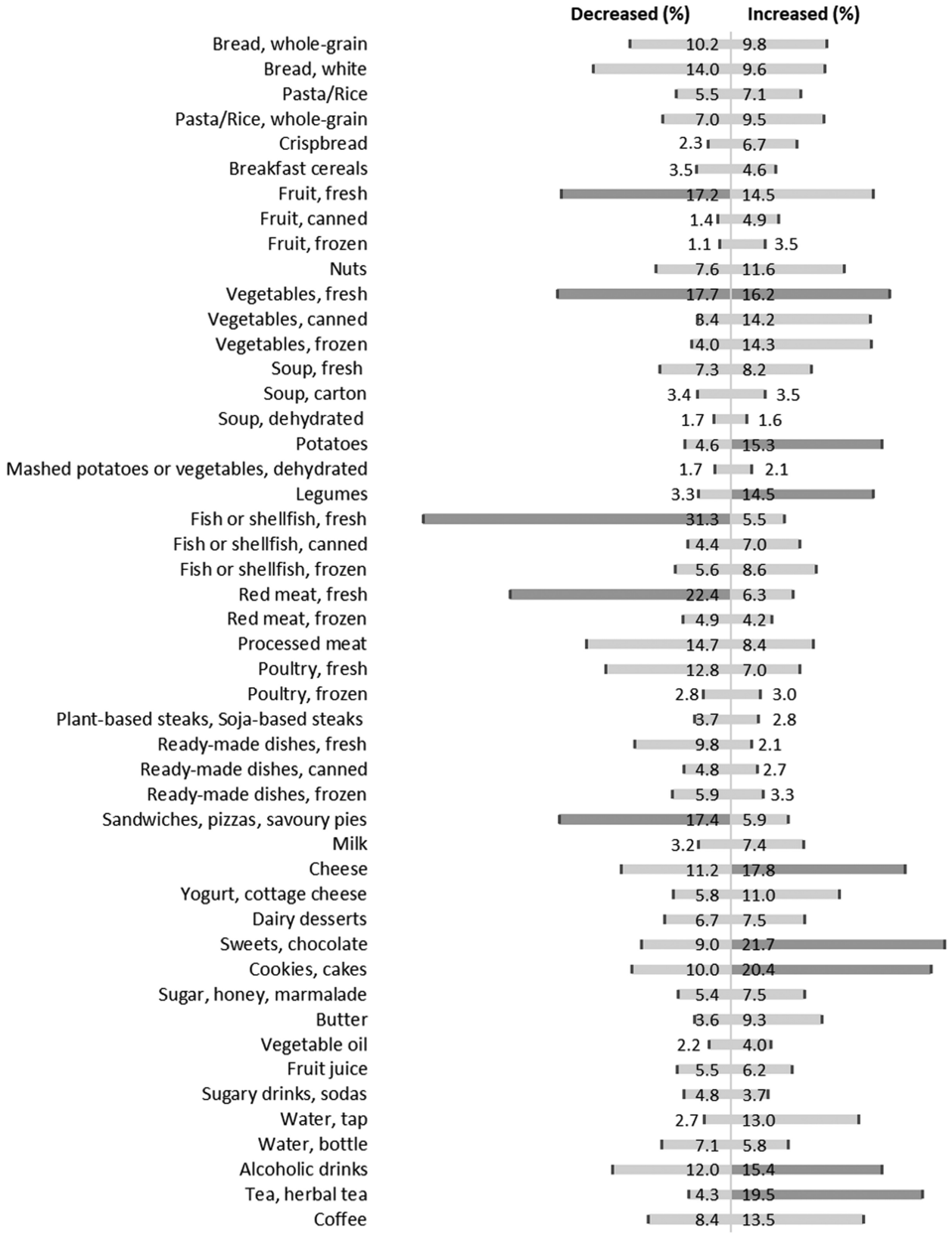

FIGURE 1 Modifications in the consumption of major food groups during lockdown, NutriNet-Santé cohort study ($n = 37{,}252$), March–May 2020. Bars indicate the percentage of participants who reported having increased or decreased the consumption of the food group of interest during lockdown (corresponding number shown on the respective bars); darker colors represent percentages above 15% and/or a difference of percentages between those who increased and those who decreased of more than 10%. The 95% CIs are displayed at the extremity of the bars.

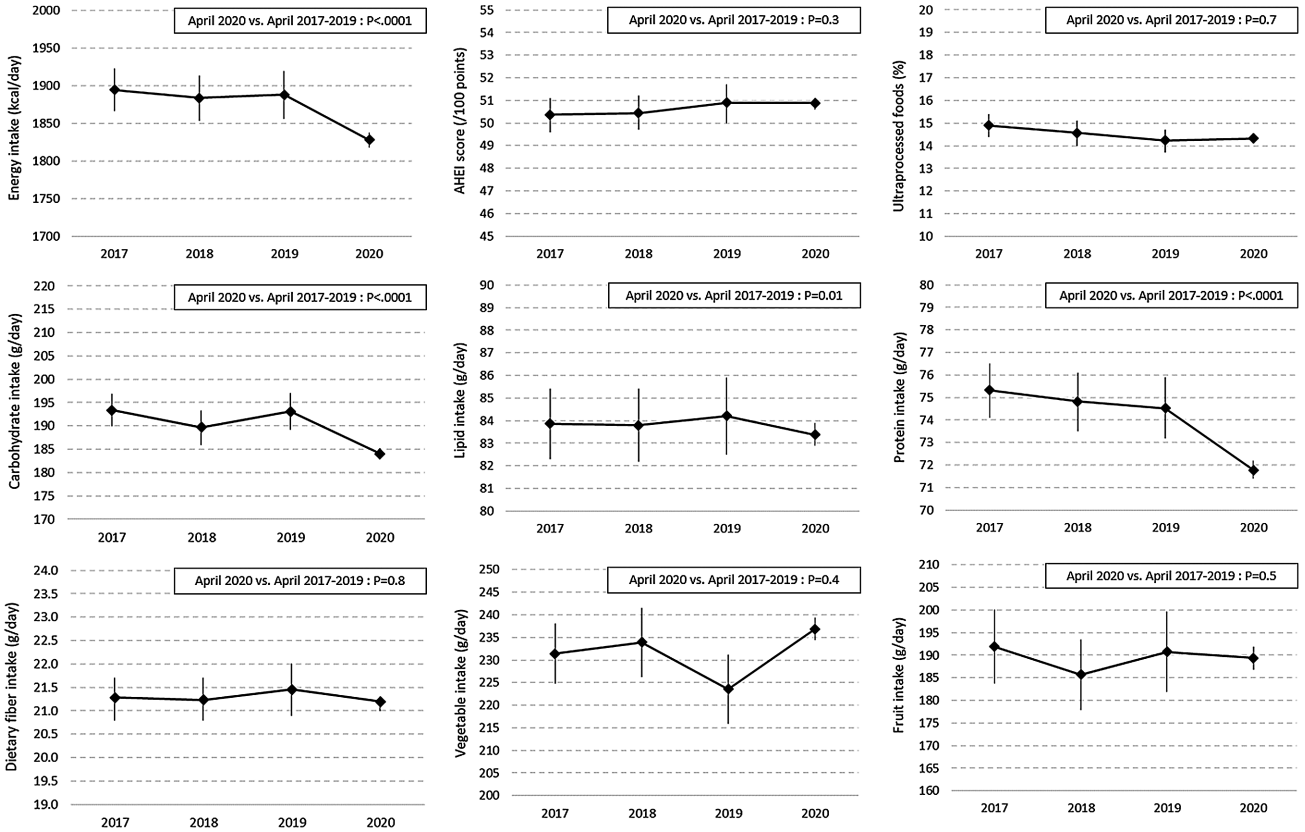

FIGURE 2 Dietary intakes reported in the month of April from 2017 to 2020, NutriNet-Santé cohort study, France, March–May 2020. Quantitative dietary intakes reported in April 2020 (via 24-hour dietary records completed during the lockdown; $n = 10{,}617$) and during the month of April over the past 3 years (repeated 24-hour dietary records completed in 2017: $n = 1264$; 2018: $n = 1075$; and 2019: $n = 991$), shown as mean values (diamond) and 95% CIs (vertical bar). *P* values from Student paired t-tests are provided for the comparison between intakes in April 2020 and the average intakes reported during the month of April in the previous 3 years (2017–2019; $n = 1548$).

Details about the participant characteristics associated with changes in energy intake are shown in **Supplementary Table 7**.

Physical activity and sedentary behavior during the lockdown

A majority (52.8%) of participants perceived a decrease in their level of PA during the lockdown (full sample). Among these participants, a quantitative assessment using the IPAQ (PA sample) revealed median PA levels of 1752 MET-min/week (IQR, 742.5–3519), which is 38% lower than before the lockdown (paired Student t-test, $P < 0.0001$). In contrast, a lower proportion (18.7%; full sample) perceived an increase in their level of PA during the lockdown (median, 2832 MET-min/week; IQR, 1632–4944; +18% as compared to before the lockdown; $P < 0.0001$; PA sample). In addition, 63.2% of participants perceived an increase in their ST (full sample). Among them (ST sample), a quantitative assessment highlighted an average of 7.0 h/day spent seated during the lockdown (SD, 3.2), which is 21% higher than the average time spent sitting before the lockdown (paired Student t-test, $P < 0.0001$). In turn, 28.5% (full sample) reported no change in ST (mean, 5.8 h/day spent seated; SD, 3.3; +4%; $P < 0.0001$; ST sample). Participants reporting that they decreased their level of PA (full sample) were also those reporting the longest time spent seated (mean, 6.9 h/day; SD, 3.3; ST sample) and the largest increase in sitting time (+18% compared to before the lockdown; $P < 0.0001$; ST sample). Likewise, participants reporting that they increased their ST (full sample) were also those reporting the lowest PA levels (median, 1857 MET-min/wk; IQR, 840–3570; PA sample) and the largest decrease in PA (-30%; $P < 0.0001$; PA sample). These results are summarized in Figure 3 and displayed in **Supplementary Table 8**. Details about the participant characteristics associated with changes in PA levels and ST are shown in Supplementary Table 7.

Body weight change during the lockdown

Weight gain between the weight just before the lockdown and the weight in May 2020 (after about 2 months of lockdown; BW sample) was observed in 35% of participants, with an average gain of 1.8 kg (SD, 1.3). In turn, weight loss was observed in 23% of participants, with an average loss of 2.0 kg (SD, 1.4). Meanwhile, BW remained stable (no difference in reported values) for 42% of the participants. Details about the participant characteristics associated with weight change are shown in Supplementary Table 7.

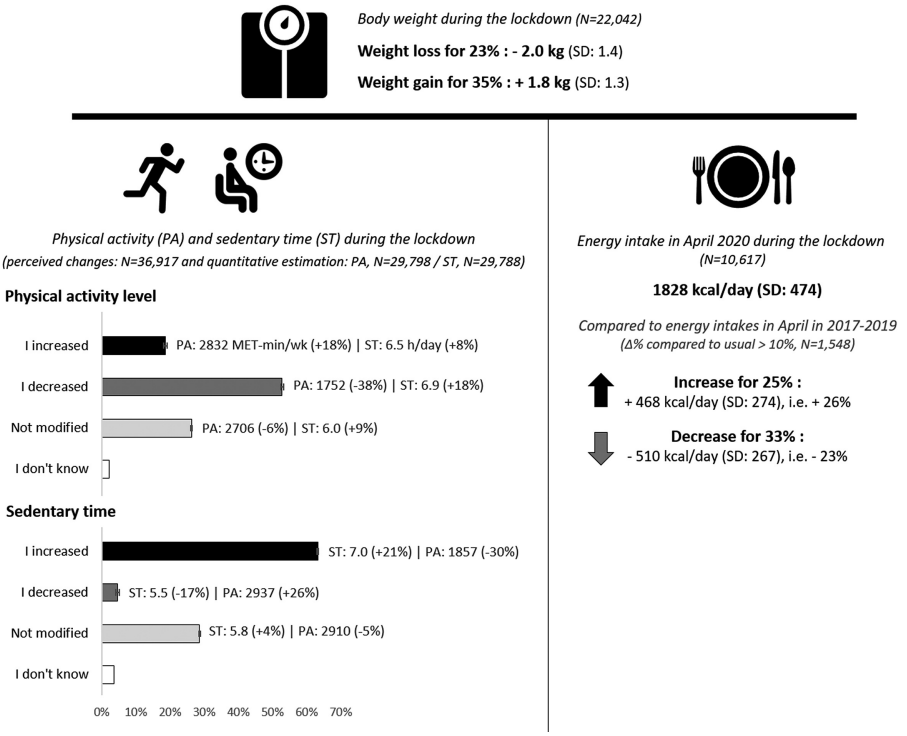

FIGURE 3 PA, ST, energy intake, and body weight changes during the lockdown in the NutriNet-Santé cohort study, March–May 2020. At the top: weight change between the weight just before the lockdown and the weight in May 2020, after about 2 months of lockdown (n = 22,042); values are mean (SD) changes in participants who gained (respectively lost) weight during the lockdown. At the bottom right, daily energy intakes in April 2020 during the lockdown (n = 10,617) and comparisons with intakes observed at the same period of the year before the lockdown (April 2017–2019; n = 1548); increases and decreases were defined as changes (positive or negative, respectively) in energy intake of at least 10%; values are mean (SD) changes in participants who increased (respectively decreased) their energy intake during the lockdown. At the bottom left, modifications in PA and ST: perceived changes (n = 36,917) shown as a bar graph, with 95% CIs displayed at the extremity of the bars; quantitative assessments of changes in PA levels (in MET-min/week) and ST (time spent seated outside sleeping hours) between, before, and during the lockdown were available for subsamples of participants (n = 29,798 for PA; n = 29,788 for ST), and are shown next to each bar as median PA levels and mean ST; corresponding IQRs and SDs are detailed in Supplementary Table 3. Changes in quantitative values are also expressed as percentage changes compared to the value before the lockdown. Pregnant women (n = 335) were excluded from these analyses. Abbreviations: MET, metabolic equivalent of task; PA, physical activity; ST, sedentary time.

Profiles of nutrition-related changes during the lockdown

Using multiple correspondence analysis (BW sample), 2 main latent factors (i.e., dimensions) of nutrition-related changes during the lockdown were identified. The ascending hierarchical classification performed on these 2 dimensions led to the subsequent identification of 3 clusters of participants. Cluster 1 (42.9% of participants) corresponded to those with stable diet-related practices, PA, and BW during the lockdown (**Supplementary Table 9**). This "no change" cluster was associated with older age, male gender, normal weight, current smoking, a lower level of education, working outside the home during the lockdown or not having a professional activity before the lockdown (i.e., unemployed, homemaker, retired), being in a relationship (married or not), living in cities with <100,000 inhabitants or in rural areas, living in regions other than the Paris region or the Eastern part of France (i.e., the regions where the epidemic was the most severe), having less anxiety and/or fewer depressive symptoms, and having a higher diet quality before the lockdown (higher AHEI-2010 score and lower proportion of ultra-processed foods in the diet; **Table 2**).

In turn, Cluster 2 (37.4%) included participants who exhibited unfavorable nutrition-related changes during the lockdown: increased weight; decreased PA and increased ST; trouble keeping a regular mealtime schedule; buying fewer fresh products; snacking more than once a day; being more likely to eat out of boredom and/or due to anxiety; reporting a perceived increase in the consumption of cookies/cakes, sweets/chocolate, sandwiches/pizza/savory pies, potatoes, cheese, and alcoholic drinks; reporting a perceived decrease in their consumption of fresh products (fruit, vegetables, meat); being more likely to report difficulties regarding grocery shopping in preferred stores and/or of preferred food products, including organic foods; experiencing stress related to potential food shortages; and accumulating food products. In this cluster, participants also reported spending more time cooking homemade meals and reported that their diet quality did not change (Supplementary Table 9). This cluster was associated with younger age, female gender, non-smoking, a higher level of education but a lower income, working from home during the lockdown, the presence of children aged under 18 years at home, more anxiety and depressive symptoms, and with pre-lockdown diets featuring a higher proportion of ultra-processed foods (Table 2).

TABLE 2 Individual characteristics of participants belonging to each cluster of diet-related changes during the lockdown period

	Cluster 1, "no change," $n = 8813$; 42.9%				Cluster 2, "unfavorable changes," $n = 7679$; 37.4%				Cluster 3, "favorable changes," $n = 4065$; 19.8%			
	% or Mean (SD)	Difference	OR[1]	95% CI	% or Mean (SD)	Difference	OR	95% CI	% or Mean (SD)	Difference	OR	95% CI
Age, years, ref: 25–50	18.5	ref	1.00	ref	55.0	ref	1.00	ref	26.5	ref	1.00	ref
18–25	28.3	+9.9	0.92	0.69–1.24	46.2	-8.9	1.41	1.11–1.79	25.5	-1.0	0.80	0.60–1.05
50–65	42.9	+24.5	1.40	1.27–1.55	35.6	-19.4	0.92	0.83–1.00	21.4	-5.1	0.74	0.67–0.83
65–80	58.3	+39.8	2.02	1.78–2.30	29.1	-25.9	0.76	0.67–0.86	12.6	-13.9	0.50	0.43–0.58
>80	57.3	+38.8	2.10	1.67–2.64	31.1	-24.0	0.76	0.60–0.97	11.6	-14.9	0.47	0.34–0.64
Sex, ref: Women	38.7	ref	1.00	ref	42.0	ref	1.00	ref	19.3	ref	1.00	ref
Men	47.3	+8.6	1.31	1.23–1.40	32.4	-9.6	0.76	0.71–0.81	20.3	+1.0	0.99	0.92–1.07
Current weight status,[2] ref: Normal	44.8	ref	1.00	ref	37.3	ref	1.00	ref	18.0	ref	1.00	ref
Obesity	34.0	-10.8	0.63	0.56–0.70	41.7	+4.5	1.09	0.99–1.21	24.3	+6.3	1.62	1.44–1.81
Overweight	42.3	-2.5	0.73	0.68–0.79	35.7	-1.6	1.06	0.99–1.14	22.0	+4.0	1.43	1.32–1.56
Underweight	43.8	-1.0	1.58	1.33–1.87	38.6	+1.4	0.72	0.61–0.84	17.6	-0.4	0.89	0.72–1.08
Smoking status, ref: Never smoker	41.6	ref	1.00	ref	39.2	ref	1.00	ref	19.2	ref	1.00	ref
Former smoker	45.1	+3.5	0.86	0.80–0.92	35.6	-3.7	1.03	0.97–1.10	19.4	+0.2	1.19	1.10–1.29
Current smoker	39.4	-2.2	1.16	1.05–1.29	37.4	-1.9	0.77	0.69–0.85	23.2	+4.0	1.16	1.04–1.30
Educational level, ref: < High school degree	54.9	ref	1.00	ref	29.5	ref	1.00	ref	15.6	ref	1.00	ref
High school degree	42.6	-12.4	0.75	0.68–0.84	37.4	+8.0	1.22	1.10–1.36	20.0	+4.4	1.21	1.06–1.38
Undergraduate degree	40.2	-14.7	0.74	0.68–0.81	38.0	+8.5	1.15	1.05–1.26	21.8	+6.2	1.35	1.21–1.51
Graduate degree	38.3	-16.7	0.71	0.64–0.78	41.6	+12.2	1.31	1.19–1.45	20.1	+4.5	1.20	1.07–1.35
Unknown	42.1	-12.8	0.65	0.43–0.97	31.2	+1.8	0.94	0.61–1.42	26.7	+11.1	2.16	1.38–3.37
Monthly income, € per household, ref: <1430	32.1	ref	1.00	ref	47.6	ref	1.00	ref	20.3	ref	1.00	ref
1430–2700	42.0	+9.9	1.03	0.89–1.20	38.8	-8.8	0.87	0.76–0.99	19.2	-1.1	1.15	0.98–1.35
2700–4800	44.5	+12.4	1.03	0.89–1.19	35.9	-11.7	0.83	0.73–0.95	19.6	-0.7	1.23	1.04–1.45
≥4800	41.3	+9.2	0.95	0.81–1.13	36.1	-11.5	0.75	0.64–0.88	22.6	+2.3	1.57	1.30–1.89
Unknown	40.0	+7.8	1.40	1.09–1.81	42.0	-5.6	0.79	0.63–1.00	18.1	-2.2	0.90	0.67–1.21
Did not wish to answer	47.8	+15.7	1.15	0.98–1.36	34.5	-13.1	0.77	0.66–0.90	17.7	-2.6	1.15	0.95–1.39
Professional activity during lockdown, ref: no professional activity prior to lockdown[3]	54.5	ref	1.00	ref	31.7	ref	1.00	ref	13.8	ref	1.00	ref
Working outside home	51.9	-2.6	1.40	1.23–1.58	35.1	+3.4	0.92	0.81–1.04	12.9	-0.9	0.68	0.58–0.80
Partially unemployed	26.2	-28.3	0.43	0.38–0.48	39.6	+7.9	1.06	0.95–1.19	34.2	+20.4	2.51	2.21–2.85
Working from home full-time	24.7	-29.8	0.47	0.42–0.53	49.1	+17.4	1.44	1.29–1.61	26.2	+12.4	1.59	1.39–1.81
Working from home part-time	29.3	-25.2	0.58	0.49–0.69	46.7	+14.9	1.33	1.14–1.56	24.1	+10.3	1.39	1.16–1.67
Student, trainees	11.2	-43.3	0.24	0.16–0.36	52.6	+20.9	1.06	0.80–1.41	36.3	+22.5	2.96	2.18–4.02
Other	42.6	-11.9	0.96	0.78–1.17	37.9	+6.2	0.95	0.78–1.16	19.5	+5.7	1.15	0.91–1.46
Marital status, ref: Never married	30.8	ref	1.00	ref	45.5	ref	1.00	ref	23.7	ref	1.00	ref
In a relationship	38.0	+7.2	1.14	1.00–1.30	38.5	-7.0	0.87	0.77–0.98	23.5	-0.2	1.04	0.91–1.20
Married or registered partnership	46.6	+15.8	1.14	1.01–1.27	34.7	-10.8	0.96	0.86–1.07	18.7	-5.0	0.91	0.80–1.03
Divorced or separated	40.6	+9.8	0.89	0.77–1.03	42.2	-3.3	1.15	1.00–1.32	17.2	-6.5	1.01	0.85–1.20
Widowed	46.6	+15.7	0.87	0.72–1.04	37.7	-7.8	1.10	0.92–1.32	15.7	-8.0	1.22	0.97–1.54

(*Continued*)

TABLE 2 (*Continued*)

	Cluster 1, "no change," $n = 8813$; 42.9%				Cluster 2, "unfavorable changes," $n = 7679$; 37.4%				Cluster 3, "favorable changes," $n = 4065$; 19.8%			
	% or Mean (SD)	Difference	OR[1]	95% CI	% or Mean (SD)	Difference	OR	95% CI	% or Mean (SD)	Difference	OR	95% CI
Children and/or grandchildren under 18 y at home during the lockdown, ref: No	45.8	ref	1.00	ref	35.1	ref	1.00	ref	19.1	ref	1.00	ref
Yes	31.8	-14.0	0.93	0.84–1.02	45.8	+10.6	1.38	1.26–1.52	22.4	+3.4	0.71	0.64–0.79
Residential area during the lockdown: city size, number of inhabitants, ref: City > 100,000	35.4	ref	1.00	ref	42.5	ref	1.00	ref	22.2	ref	1.00	ref
City ≥ 20,000 to 100,000	39.4	+4.0	1.15	1.04–1.27	40.6	-1.9	0.92	0.84–1.01	20.1	-2.1	0.94	0.84–1.05
City < 20,000	43.7	+8.3	1.28	1.16–1.41	38.3	-4.2	0.92	0.84–1.01	18.1	-4.1	0.82	0.73–0.92
Rural area	48.2	+12.8	1.47	1.34–1.61	32.3	-10.2	0.73	0.67–0.80	19.5	-2.7	0.91	0.82–1.02
Regional residential area during the lockdown,[4] ref: Paris Basin	44.4	ref	1.00	ref	35.1	ref	1.00	ref	20.4	ref	1.00	ref
Center-East	43.6	-0.8	0.91	0.82–1.02	35.5	+0.4	1.04	0.93–1.17	20.8	+0.4	1.06	0.93–1.21
East	36.3	-8.1	0.76	0.67–0.86	38.1	+2.9	1.10	0.98–1.25	25.6	+5.2	1.24	1.08–1.42
Mediterranean	48.7	+4.3	1.11	0.99–1.24	33.9	-1.2	0.98	0.88–1.10	17.4	-3.1	0.88	0.76–1.00
North	41.7	-2.8	1.09	0.93–1.27	39.0	+3.9	1.01	0.87–1.17	19.4	-1.1	0.90	0.75–1.07
West	46.8	+2.3	1.07	0.96–1.20	36.5	+1.3	1.06	0.94–1.18	16.8	-3.7	0.83	0.73–0.95
Paris region	35.8	-8.6	0.82	0.73–0.92	43.4	+8.2	1.24	1.12–1.39	20.8	+0.4	0.97	0.85–1.10
Southwest	45.2	+0.7	0.98	0.87–1.10	37.1	+2.0	1.12	1.00–1.26	17.8	-2.7	0.87	0.76–1.00
GAD-7, anxiety disorders[5]	2.0 (3.1)	/	0.97	0.96–0.98	3.9 (4.2)	/	1.01	1.00–1.02	3.2 (4.0)	/	1.03	1.02–1.04
PHQ-9, depressive symptoms[6]	2.1 (3.1)	/	0.89	0.88–0.90	4.8 (4.5)	/	1.12	1.11–1.13	3.6 (4.0)	/	0.97	0.96–0.98
Chronic disease,[7] ref: No	42.4	ref	1.00	ref	37.3	ref	1.00	ref	20.4	ref	1.00	ref
Yes	44.0	-1.6	0.89	0.83–0.96	37.5	-0.2	1.14	1.06–1.22	18.5	+1.8	1.00	0.92–1.09
Diet quality before the lockdown, $n = 16,562$												
AHEI-2010 score,[8] per 10-point increment	52.7 (11.8)	/	1.06	1.03–1.10	50.0 (11.4)	/	0.99	0.96–1.03	48.9 (12.0)	/	0.92	0.89–0.96
Ultraprocessed foods, per 10% increment	15.2% (6.4%)	/	0.93	0.88–0.99	16.8% (7.3%)	/	1.06	1.01–1.12	16.8% (7.4%)	/	0.99	0.93–1.05

Data were calculated using multivariable logistic regression models. Models included all variables presented in the table, with corresponding categories. For participants for whom such data was available, variables relating to the diet quality before the lockdown were additionally included in the models. Abbreviations: AHEI, Alternative Healthy Eating Index; GAD-7, Generalized Anxiety Disorder–7 scale; PHQ-9, Patient Health Questionnaire–9 scale.

[1]ORs are for each cluster as a dummy variable (i.e., cluster X vs. all others combined).

[2]Calculated from current weight reported in April 2020.

[3]Unemployed, retired, or housemaker.

[4]Regional Zones for Study and Development (ZEAT) as defined by the French National Institute of Statistics and Economic Studies (INSEE). Paris region: Ile de France; Paris basin: Burgundy, Center, Champagne-Ardenne, Lower and Upper Normandy, Picardie; North: Nord Pas-de-Calais; East: Alsace, Franche-Comté, Lorraine; West: Brittany, Pays de la Loire, Poitou-Charentes; Southwest: Aquitaine, Limousin, Midi-Pyrénées; Center-East: Auvergne, Rhône-Alpes; and Mediterranean: Languedoc-Roussillon, Provence-Alpes-Côte d'Azur, Corsica.

[5]The GAD-7 scores range from 0 to 21 points and measure the increasing severity of anxiety (minimal: 0–4; mild: 5–9; moderate: 10–14; severe: 15–21).

[6]The PHQ-9 scores range from 0 to 27 points and measure the increasing presence and severity of depressive symptoms (minimal: 0–4; mild: 5–9; moderate: 10–14; moderately severe: 15–19; severe: 20–27).

[7]Includes diabetes, cardiovascular diseases, hypertension, dyslipidemia, cancer, liver diseases, kidney diseases, thyroid diseases, digestive disorders, gynecological disorders, arthritis, and immune system disorders.

[8]The AHEI-2010 scores range from 0 to 100 points and measure increasing diet quality.

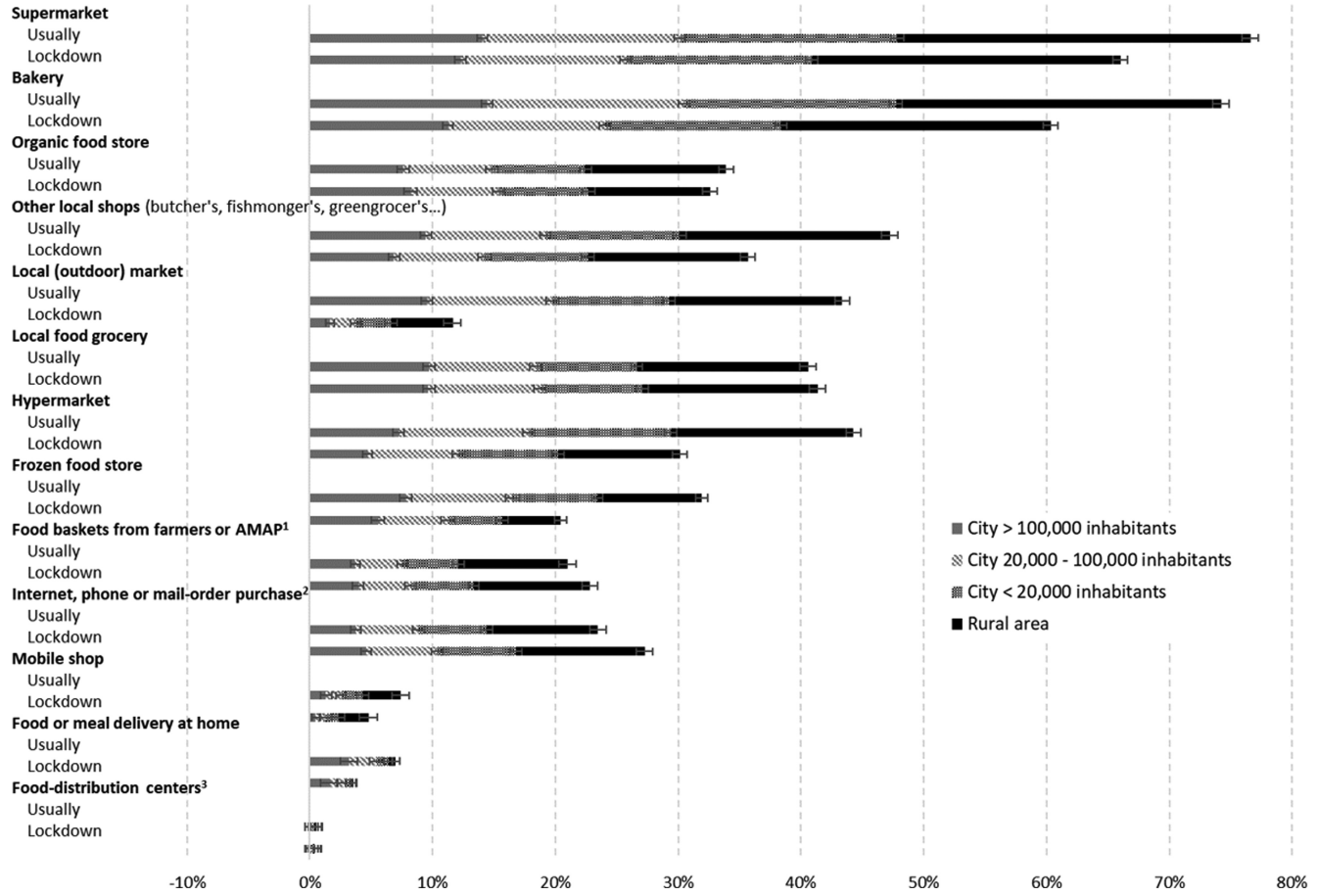

FIGURE 4 Usual and lockdown-specific sources of food supply, according to the urban level of the residential area during the lockdown. NutriNet-Santé cohort study ($n = 37{,}252$), March–May 2020. [1]AMAP: associations supporting small farming. [2]Followed by delivery or drive-by pick-up. [3]Meals, packages, subsidized grocery stores. 95% CIs are displayed at the extremity of the bars.

Finally, Cluster 3 (19.8%) included participants who reported favorable nutrition-related changes during the lockdown, such as a perceived decrease in the consumption of cookies/cakes, sweets/chocolate, sandwiches/pizza/savory pies, and alcoholic drinks; increased consumption of fresh fruit, vegetables, and fish; a better self-perceived diet quality; avoidance of some foods or drinks for weight management purposes; a willingness to balance their diets; and spending more time than usual cooking homemade meals (Supplementary Table 9). This cluster was associated with younger age, overweight/obesity, smoking, a higher level of education and income, being partially/technically unemployed, being a student or working from home during the lockdown, having no children aged under 18 years in the household, experiencing more anxiety but fewer depressive symptoms, and displaying a lower usual diet quality (lower AHEI-2010 score; Table 2).

Sources of food supply

During the lockdown, individuals (full sample) used on average 3.6 (SD, 1.7) different sources of food supply, which is 1.1 less than usual (paired Student t-test, $P < 0.0001$). The top 3 sources of supply during the lockdown (**Figure 4**) were the supermarket (66%), the bakery (60.3%), and the local grocery store (41.3%), the latter owing its third place to decreased visits (compared to usual) of local outdoor food markets (which showed the sharpest reduction, especially in cities with >20,000 inhabitants, as such markets were prohibited during the lockdown), hypermarkets, and local shops, such as the butcher's, fishmonger's, or greengrocer's. Contrary to the observed overall reduction in the number of sources of food supply, slight increases were observed for Internet, phone, and/or mail-order purchases and for orders of food baskets from local farmers or associations supporting small local farming. Only a slight decrease was observed for use of organic food stores. Finally, 6.3% of participants reported that they did not live in their usual home during the lockdown, which may have impacted the sources of food supply available to them.

Discussion

This study, conducted in a sample of >37,000 adults, provided an overview of diet-related changes during the COVID-19 nationwide lockdown from March to May 2020. Overall, our results highlighted divergent changes in food-related practices, PA, ST, and BW. Specifically, we observed expected "unfavorable" changes but also some "favorable" changes, as well as no changes

for some groups of individuals. Overall, these patterns reflected socioeconomic inequalities.

The cluster displaying unfavorable changes during the lockdown (Cluster 2) was characterized by decreased PA levels and increased ST. Such a pattern, also observed in other countries (2–5), was largely automatically induced by the "stay-at-home" measures, including the prohibition of daily work-related or leisure-related mobility. In line with prior reports (6–10), our results also showed increased snacking behaviors and a consistent trend reflecting increased consumption of sweets, chocolate, cookies, cakes, alcoholic drinks, and total energy. Individuals in that cluster also reported buying fewer fresh products, likely due to less frequent grocery shopping and/or difficulties accessing their usual food stores or finding their preferred food products. Likewise, and as observed elsewhere (6, 11), participants reported decreased consumption of fresh vegetables, fruit, and fish: that is, food groups for which pre-lockdown consumption by the French population was already below the national dietary recommendations (40). Even though increased consumption of frozen and/or canned vegetables was reported, which likely partly compensated for the decrease in fresh vegetable consumption, such a compensation did not appear for fruit (although there may have been a compensation with fruit purées) or fish. As a result of changes in PA and food consumption during the lockdown, weight gain expectedly occurred during the lockdown: this outcome was also reported in other countries (2, 6, 8, 9, 12, 41). Although not fully comparable, studies dealing with the health effects of vacation periods—that is, periods of disrupted daily habits, especially regarding PA and food consumption—have similarly shown weight gain over short periods of time; such weight gain may become permanent in some individuals and, if the unfavorable trends regarding insufficient PA and unhealthy food consumption are not reversed, might even lead to more weight gain in the future (42). Other studies focusing on the impact of several weeks of decreased PA and modified food consumption have shown metabolic consequences (increased insulin resistance, inflammation, fat accumulation) even over such a short period of time (43). In our study, these unfavorable changes seemed associated with being female, working from home, and the presence of children at home: that is, parents who maintained their work activities while taking care of their children. The pattern was also associated with lower income, higher pre-lockdown consumption of ultra-processed foods, and more depressive symptoms. This profile suggests less opportunity (e.g., time, financial or technical means) to engage in health behaviors and may explain the observed snacking behaviors and consumption of "comfort" foods (sweets, cookies, cakes) (44, 45). In particular, the lockdown situation may have led to overeating and snacking in response to the accumulation of working, teaching, and child care (46) responsibilities. In fact, having children in the household has been associated with both healthier and unhealthier nutritional profiles for parents (47–50).

In contrast, the cluster of favorable changes during the lockdown (Cluster 3) reflected increased consumption of fruit and vegetables and decreased consumption of sandwiches, savory pies and pizza, sweets and chocolate, cookies and cakes, and alcoholic drinks. Participants in that cluster reported that they worked on balancing their diet during the lockdown to improve its quality or to compensate for the loss of PA. Reports from other countries (3, 6, 11, 13) also showed improved diet quality during the lockdown in certain population subgroups. These changes in food consumption may be attributed either to a willingness to improve one's diet or to a disruption of eating habits related to the temporary closure of workplace cafeterias and restaurants (hence reduced eating out). Increased PA levels were also observed in our study and elsewhere (4, 5, 11). This may have resulted from increased at-home training. It should be noted, however, that in France, individuals were allowed to engage in outdoor PA (within a 1-km radius for 1 hour) during the lockdown, which may have encouraged some people to do so. Finally, some participants also lost some weight, echoing the conscious striving for a more balanced diet and PA. These favorable changes were associated with a higher level of education and income, partial/technical unemployment, or working from home during the lockdown. Yet, in contrast to Cluster 2, individuals in Cluster 3 were less likely to have children at home. Overall, these characteristics outline a profile of individuals more likely to have the financial means, knowledge, and time to invest in health-promoting behaviors. It should be noted that some individuals experiencing partial/technical unemployment during the lockdown maintained their work position and part of their salary while being at home. The temporary nature of the unemployment may partly explain why it was associated with favorable nutrition-related changes in our study, while typically unemployment is usually associated with poorer nutritional profiles (51–53). In addition, the cluster of favorable nutrition-related changes was associated with unhealthy pre-lockdown characteristics, such as overweight/obesity, smoking, and a lower diet quality. Although prior reports have suggested that overweight or obese individuals tended to adopt unfavorable diet-related changes during the lockdown (8, 14, 54), our results suggested a profile of individuals with an increased potential for improvement, with an awareness regarding the need to adopt healthier lifestyles (including diet), or experiencing concerns regarding the risk of COVID-19 infection or prognosis (55).

Spending more time cooking homemade meals during the lockdown was observed in our study and in prior reports (11, 12). Interestingly, this behavior was associated with both Cluster 2 and Cluster 3. Even though cooking is considered a favorable food-related practice (e.g., suggesting a better knowledge of food, avoidance of ultra-processed foods) and is recommended by health authorities (56), it may not necessarily lead to healthy DIs. As reflected by our results, cooking likely led to increased consumption of cheese, potatoes, cookies, and cakes for those in Cluster 2, while it may have contributed to achieving a more balanced diet for those in Cluster 3. In addition, home cooking might have been practiced due to having more free time or it might have been viewed as a constraint, given the absence of other options (e.g., cafeterias, restaurants).

Finally, Cluster 1 displayed stable diet-related practices, PA, and BW during the lockdown. This "no change" cluster was associated with older age, living in small cities or rural areas, and unchanged professional activity during the lockdown: that is, individuals with no professional activity pre-lockdown (i.e., unemployed, housemaker, retired) or those who maintained their regular work outside the home (i.e., "essential" sectors). This profile represented individuals with probably less lifestyle/environment disruption during the lockdown or those with well-established habits.

Strengths of our study pertained to the flexibility of the NutriNet-Santé web platform, which allowed the administration of ad hoc questionnaires and the collection of a large amount of data regarding multiple aspects of the lockdown experience. Further, we studied a large sample of participants for whom in-depth characterization pre-lockdown was available and for whom the health behavior trajectories post-lockdown will be monitored (contrary to "1-shot" surveys). However, some limitations should be acknowledged. First, a number of changes reported here were based on self-perceptions, and misreporting may therefore have occurred. Still, quantitative comparisons between data collected before and during the lockdown (e.g., food intakes, BW, PA, and ST) were carried out and confirmed the perceived changes. Second, NutriNet-Santé is a long-term, prospective cohort focusing on nutrition and health. This implies an over-representation of women and individuals of overall higher socioeconomic status compared to the general French population (57, 58). To account for this bias, all analyses were weighted to correct for the differences in sociodemographic and economic distributions, although this cannot lead to complete representativeness. In particular, our study does not accurately capture the experiences of more disadvantaged subgroups (e.g., immigrants, students) who may have suffered from additional diet-related distress during the lockdown (59). Overall, NutriNet-Santé participants are likely to display healthier nutritional profiles compared to the general French population. Hence, the observed trends of unfavorable nutrition-related changes were likely underestimated in this "health-conscious" sample, which raises even more concerns for the general population.

In conclusion, our study provides divergent results regarding the nutrition consequences of the COVID-19 lockdown in France. Even though unhealthy nutrition-related changes were observed, they nonetheless coexisted with no nutrition-related changes (evidenced in the majority of our sample), as well as favorable changes in some subgroups. These different experiences of the lockdown were linked to specific individual characteristics, echoing socioeconomic inequalities in nutrition (60–63). Future studies are needed to better understand the mechanisms behind the observed nutrition-related changes. Meanwhile, the present findings are consistent with changes observed in other national lockdown settings, and can inform public health authorities about the consequences of a lockdown on the population level, should such exceptional measures be needed again in the future. Considering the importance of nutrition in the prevention of chronic diseases (15) and in the immune response (17, 18), unfavorable nutrition-related changes should be monitored post-lockdown to prevent them from becoming established habits in the long run. The leverages behind the favorable nutrition-related changes should be studied to help improve the nutritional status on a global scale. As a research perspective, data collected as part of the SAPRIS project, combined with the detailed characterization of participants in the NutriNet-Santé cohort, will permit the investigation of the link between nutrition and risks of COVID-19.

We thank all the volunteers of the NutriNet-Santé cohort for their continuous participation in the study and for participating in this coronavirus disease 2019 (COVID-19)–specific project. We thank the SAPRIS ("Health, practices, relationships and social inequalities in the general population during the COVID-19 crisis") project working group (management board: Dr Nathalie Bajos, co–principal investigator; Dr Fabrice Carrat, co–principal investigator; Dr Marie Zins; Dr Gianluca Severi; Dr Marie-Aline Charles; Dr Pierre-Yves Ancel; and Dr Mathilde Touvier). We also thank Thi Hong Van Duong, Régis Gatibelza, Jagatjit Mohinder, and Aladi Timera (computer scientists); Nathalie Arnault, Julien Allegre, and Laurent Bourhis (data managers/statisticians); Cédric Agaesse (dietitian); and Fatoumata Diallo, Roland Andrianasolo, and Sandrine Kamdem (physicians) for their technical contributions to the NutriNet-Santé study.

Author disclosures: MD-T, ND-P, YE, FSdE, BA, VAA, JB, HC, VD, ME, LKF, PG, CJ, EK-G, PL-M, J-MO, SP, CV, SH, and MT, no conflicts of interest.

The authors' responsibilities were as follows – MD-T, MT: conceptualized the study, defined the analytical strategy, had primary responsibility for the final content, and are the guarantors; MD-T: performed statistical analyses, drafted the manuscript, and attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted; MT: supervised analyses and writing; ND-P, YE, FSdE, PG, SH, MT: played key roles in the acquisition of the data; and all authors: critically helped in the interpretation of results, revised the manuscript, provided relevant intellectual input, and read and approved the final manuscript.

Data Availability

Data described in the manuscript will be made available upon request to the study's operational manager, Nathalie Druesne-Pecollo (n.pecollo@eren.smbh.univparis13.fr), and review by the steering committee of the NutriNet-Santé study.

References

1. WHO. Coronavirus disease (COVID-19) pandemic [Internet]. Available from: https://www.who.int/emergencies/diseases/novel-coronavirus-2019
2. He M, Xian Y, Lv X, He J, Ren Y. Changes in body weight, physical activity, and lifestyle during the semi-lockdown period after the outbreak of COVID-19 in China: An online survey. Disaster Med Public Health Prep. 2020;1–6, doi:10.1017/dmp.2020.237.
3. Gallè F, Sabella EA, Da Molin G, De Giglio O, Caggiano G, Di Onofrio V, Ferracuti S, Montagna MT, Liguori G, Orsi GB, et al. Understanding knowledge and behaviors related to COVID-19 epidemic in Italian undergraduate students: The EPICO study. Int J Environ Res Public Health. 2020;17:3481.
4. Constandt B, Thibaut E, De Bosscher V, Scheerder J, Ricour M, Willem A. Exercising in times of lockdown: An analysis of the impact of COVID-19 on levels and patterns of exercise among adults in Belgium. Int J Environ Res Public Health. 2020;17:4144.
5. Lesser IA, Nienhuis CP. The impact of COVID-19 on physical activity behavior and well-being of Canadians. Int J Environ Res Public Health. 2020;17:3899.
6. Scarmozzino F, Visioli F. COVID-19 and the subsequent lockdown modified dietary habits of almost half the population in an Italian sample. Foods. 2020;9:675.
7. Romeo-Arroyo E, Mora M, Vázquez-Araújo L. Consumer behavior in confinement times: Food choice and cooking attitudes in Spain. Int J Gastron Food Sci. 2020;21:100226.
8. Sidor A, Rzymski P. Dietary choices and habits during COVID-19 lockdown: Experience from Poland. Nutrients. 2020;12:1657.
9. Ghosh A, Arora B, Gupta R, Anoop S, Misra A. Effects of nationwide lockdown during COVID-19 epidemic on lifestyle and other medical issues of patients with type 2 diabetes in north India. Diabetes Metab Syndr. 2020;14:917–20.
10. Ammar A, Brach M, Trabelsi K, Chtourou H, Boukhris O, Masmoudi L, Bouaziz B, Bentlage E, How D, Ahmed M, et al. Effects of COVID-19 home confinement on eating behaviour and physical activity: Results of the ECLB-COVID19 international online survey. Nutrients. 2020;12:1583.
11. Di Renzo L, Gualtieri P, Pivari F, Soldati L, Attinà A, Cinelli G, Leggeri C, Caparello G, Barrea L, Scerbo F, et al. Eating habits and lifestyle changes during COVID-19 lockdown: An Italian survey. J Transl Med. 2020;1:229. doi: 10.1186/s12967-020-02399-5

12. Zhengxia D, Stefanovski D, Galligan D, Lindem M, Rozin P, Chen T, Chao A. The COVID-19 pandemic impacting household food dynamics: A cross-national comparison of China and the U.S. SocArXiv. 2020. [cited September 25, 2020], doi: 10.31235/osf.io/64jwy.
13. Rodríguez-Pérez C, Molina-Montes E, Verardo V, Artacho R, García-Villanova B, Guerra-Hernández EJ, Ruíz-López MD. Changes in dietary behaviours during the COVID-19 outbreak confinement in the Spanish COVIDiet study. Nutrients. 2020;12:1730.
14. Pellegrini M, Ponzo V, Rosato R, Scumaci E, Goitre I, Benso A, Belcastro S, Crespi C, De Michieli F, Ghigo E, et al. Changes in weight and nutritional habits in adults with obesity during the "lockdown" period caused by the COVID-19 virus emergency. Nutrients. 2020;12:2016.
15. Afshin A, Sur PJ, Fay KA, Cornaby L, Ferrara G, Salama JS, Mullany EC, Abate KH, Abbafati C, Abebe Z, 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;393:1958–72.
16. World Cancer Research Fund / American Institute for Cancer Research. Diet, nutrition, physical activity and cancer: A global perspective. Continuous update project expert report. Washington, DC: AICR; 2018.
17. Kau AL, Ahern PP, Griffin NW, Goodman AL, Gordon JI. Human nutrition, the gut microbiome and the immune system. Nature. 2011;474:327–36.
18. Tilg H, Moschen AR. Food, immunity, and the microbiome. Gastroenterology. 2015;148:1107–19.
19. Dhar D, Mohanty A. Gut microbiota and COVID-19 –Possible link and implications. Virus Res. 2020;285:198018.
20. Butler MJ, Barrientos RM. The impact of nutrition on COVID-19 susceptibility and long-term consequences. Brain Behav Immun. 2020;87:53–4.
21. Naja F, Hamadeh R. Nutrition amid the COVID-19 pandemic: A multi-level framework for action. Eur J Clin Nutr. 2020;74(8):1117–21.
22. Calder PC, Carr AC, Gombart AF, Eggersdorfer M. Optimal nutritional status for a well-functioning immune system is an important factor to protect against viral infections. Nutrients. 2020;12:1181.
23. Hercberg S, Castetbon K, Czernichow S, Malon A, Mejean C, Kesse E, Touvier M, Galan P. The NutriNet-Santé Study: A web-based prospective study on the relationship between nutrition and health and determinants of dietary patterns and nutritional status. BMC Public Health. 2010;10:242. doi: 10.1186/1471-2458-10-242
24. Vergnaud A-C, Touvier M, Méjean C, Kesse-Guyot E, Pollet C, Malon A, Castetbon K, Hercberg S. Agreement between web-based and paper versions of a socio-demographic questionnaire in the NutriNet-Santé study. Int J Pub Health. 2011;56:407–17.
25. Touvier M, Kesse-Guyot E, Méjean C, Pollet C, Malon A, Castetbon K, Hercberg S. Comparison between an interactive web-based self-administered 24 h dietary record and an interview by a dietitian for large-scale epidemiological studies. Br J Nutr. 2011;105: 1055–64.
26. Lassale C, Castetbon K, Laporte F, Camilleri GM, Deschamps V, Vernay M, Faure P, Hercberg S, Galan P, Kesse-Guyot E. Validation of a web-based, self-administered, non-consecutive-day dietary record tool against urinary biomarkers. Br J Nutr. 2015;113: 953–62.
27. Lassale C, Castetbon K, Laporte F, Deschamps V, Vernay M, Camilleri GM, Faure P, Hercberg S, Galan P, Kesse-Guyot E. Correlations between fruit, vegetables, fish, vitamins, and fatty acids estimated by web-based nonconsecutive dietary records and respective biomarkers of nutritional status. J Acad Nutr Dietetics. 2016;116: 427–38.e5.
28. Craig CL, Marshall AL, Sjöström M, Bauman AE, Booth ML, Ainsworth BE, Pratt M, Ekelund U, Yngve A, Sallis JF, et al. International physical activity questionnaire: 12-country reliability and validity. Med Sci Sports Exerc. 2003;35:1381–95.
29. Lassale C, Péneau S, Touvier M, Julia C, Galan P, Hercberg S, Kesse-Guyot E. Validity of web-based self-reported weight and height: Results of the Nutrinet-Santé study. J Med Internet Res. 2013;15:e152.
30. Touvier M, Méjean C, Kesse-Guyot E, Pollet C, Malon A, Castetbon K, Hercberg S. Comparison between web-based and paper versions of a self-administered anthropometric questionnaire. Eur J Epidemiol. 2010;25:287–96.
31. NutriNet-Sant é Coordination. Table de composition des aliments– Etude NutriNet-Sant é. Paris, France: Economica; 2013.
32. Black AE. Critical evaluation of energy intake using the Goldberg cut-off for energy intake:basal metabolic rate. A practical guide to its calculation, use and limitations. Int J Obes. 2000;24:1119–30.
33. Kroenke K, Spitzer RL, Williams JBW. The PHQ-9: Validity of a brief depression severity measure. J Gen Intern Med. 2001;16:606–13.
34. Spitzer RL, Kroenke K, Williams JBW, Löwe B. A brief measure for assessing generalized anxiety disorder: The GAD-7. Arch Intern Med. 2006;166:1092–7.
35. Varraso R, Chiuve SE, Fung TT, Barr RG, Hu FB, Willett WC, Camargo CA. Alternate Healthy Eating Index 2010 and risk of chronic obstructive pulmonary disease among US women and men: Prospective study. BMJ. 2015;350:h286.
36. Srour B, Fezeu LK, Kesse-Guyot E, Allès B, Debras C, Druesne-Pecollo N, Chazelas E, Deschasaux M, Hercberg S, Galan P, et al. Ultraprocessed food consumption and risk of type 2 diabetes among participants of the NutriNet-Santé prospective cohort. JAMA Intern Med. 2020;180:283–91.
37. Hatcher L, O'Rourke N. A step-by-step approach to using SAS for factor analysis and structural equation modeling. Cary, NC: SAS Institute; 2013.
38. Costa PS, Santos NC, Cunha P, Cotter J, Sousa N. The use of multiple correspondence analysis to explore associations between categories of qualitative variables in healthy ageing. J Aging Res. 2013;2013: 1–12.
39. Ducrot P, Méjean C, Bellisle F, Allès B, Hercberg S, Péneau S. Adherence to the French Eating Model is inversely associated with overweight and obesity: Results from a large sample of French adults. Br J Nutr. 2018;120:231–9.
40. Torres MJ, Salavane B, Verdot C, Deschamps V. Adequation to the new dietary recommendations in French adults aged 18 to 54 years –Esteban study. [Adéquation aux nouvelles recommandations alimentaires des adultes âgés de 18 à 54 ans vivant en France. Étude Esteban 2014 –2016]. French. Volet Nutrition –Surveillance épidémiologique. [Internet]. Saint-Maurice, France : Santé Publique France; 2019. Available from: www.santepubliquefrance.fr
41. Ghosal S, Arora B, Dutta K, Ghosh A, Sinha B, Misra A. Increase in the risk of type 2 diabetes during lockdown for the COVID19 pandemic in India: A cohort analysis. Diabetes Metab Syndr. 2020;14:949–52.
42. Bhutani S, Cooper JA. COVID-19 related home confinement in adults: Weight gain risks and opportunities. Obesity. 2020;28:1576–77.
43. Martinez-Ferran M, de la Guía-Galipienso F, Sanchis-Gomar F, Pareja-Galeano H. Metabolic impacts of confinement during the COVID-19 pandemic due to modified diet and physical activity habits. Nutrients. 2020;12:1549.
44. Si Hassen W, Castetbon K, Péneau S, Tichit C, Nechba A, Lampuré A, Bellisle F, Hercberg S, Méjean C. Socio-economic and demographic factors associated with snacking behavior in a large sample of French adults. Int J Behav Nutr Phys Act. 2018;15:25. doi: 10.1186/s12966-018-0655-7.
45. Arora T, Grey I. Health behaviour changes during COVID-19 and the potential consequences: A mini-review. J Health Psychol. 2020;25:1155–63.
46. Duxbury L, Halinski M. When more is less: An examination of the relationship between hours in telework and role overload. Work. 2014;48:91–103.
47. Roos E, Lahelma E, Virtanen M, Prättälä R, Pietinen P. Gender, socioeconomic status and family status as determinants of food behaviour. Soc Sci Med. 1998;46:1519–29.
48. Berge JM, Larson N, Bauer KW, Neumark-Sztainer D. Are parents of young children practicing healthy nutrition and physical activity behaviors? Pediatrics. 2011;127:881–7.
49. Sam L, Craig T, Horgan GW, Macdiarmid JI. Association between hours worked in paid employment and diet quality, frequency of eating out and consuming takeaways in the UK. Public Health Nutr. 2019;22:3368–76.
50. Umberson D, Liu H, Mirowsky J, Reczek C. Parenthood and trajectories of change in body weight over the life course. Soc Sci Med. 2011;73:1323–31.
51. Kwak L, Berrigan D, Van Domelen D, Sjöström M, Hagströmer M. Examining differences in physical activity levels by employment status and/or job activity level: Gender-specific comparisons between the United States and Sweden. J Sci Med Sport. 2016;19:482–7.
52. Macassa G, Ahmadi N, Alfredsson J, Barros H, Soares J, Stankunas M. Employment status and differences in physical activity behavior during

times of economic hardship: Results of a population-based study. Int J Med Sci Public Health. 2016;5:102–8.
53. Smed S, Tetens I, Bøker Lund T, Holm L, Ljungdalh Nielsen A. The consequences of unemployment on diet composition and purchase behaviour: A longitudinal study from Denmark. Public Health Nutr 2018;21:580–92.
54. Trivedy Rogers N, Waterlow N, Brindle H, Enria L, Egoo R, Lees S, Roberts CH. Behavioural change towards reduced intensity physical activity is disproportionately prevalent among adults with serious health issues or self-perception of high risk during the UK COVID-19 lockdown. Front Public Health. 2020;8:575091.
55. Simonnet A, Chetboun M, Poissy J, Raverdy V, Noulette J, Duhamel A, Labreuche J, Mathieu D, Pattou F, Jourdain M, et al. High prevalence of obesity in severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) requiring invasive mechanical ventilation. Obesity. 2020;28:1195–9.
56. Santé Publique France. Recommandations sur l'alimentation, l'activité physique & la sédentarité pour les adultes. Paris, France: Santé Publique France; 2019, Available at: https://www.santepubliquefrance.fr/determinants-de-sante/nutrition-et-activite-physique/documents/rapport-synthese/recommandations-relatives-a-l-alimentation-a-l-activite-physique-et-a-la-sedentarite-pour-les-adultes.
57. Andreeva VA, Salanave B, Castetbon K, Deschamps V, Vernay M, Kesse-Guyot E, Hercberg S. Comparison of the sociodemographic characteristics of the large NutriNet-Sante e-cohort with French Census data: The issue of volunteer bias revisited. J Epidemiol Community Health. 2015;69:893–8.
58. Andreeva VA, Deschamps V, Salanave B, Castetbon K, Verdot C, Kesse-Guyot E, Hercberg S. Comparison of dietary intakes between a large online cohort study (Etude NutriNet-Santé) and a nationally representative cross-sectional study (Etude Nationale Nutrition Santé) in France: Addressing the issue of generalizability in e-epidemiology. Am J Epidemiol. 2016;184:660–9.
59. Niles MT, Bertmann F, Belarmino EH, Wentworth T, Biehl E, Neff R. The early food insecurity impacts of COVID-19. Nutrients. 2020;12:2096.
60. Galobardes B, Morabia A, Bernstein MS. Diet and socioeconomic position: Does the use of different indicators matter? Int J Epidemiol. 2001;30:334–40.
61. Si Hassen W, Castetbon K, Cardon P, Enaux C, Nicolaou M, Lien N, Terragni L, Holdsworth M, Stronks K, Hercberg S, et al. Socioeconomic indicators are independently associated with nutrient intake in French adults: A DEDIPAC study. Nutrients. 2016;8:158.
62. Livingstone K, Olstad D, Leech R, Ball K, Meertens B, Potter J, Cleanthous X, Reynolds R, McNaughton S. Socioeconomic inequities in diet quality and nutrient intakes among Australian adults: Findings from a nationally representative cross-sectional study. Nutrients. 2017;9:1092.
63. Sommer I, Griebler U, Mahlknecht P, Thaler K, Bouskill K, Gartlehner G, Mendis S. Socioeconomic inequalities in non-communicable diseases and their risk factors: An overview of systematic reviews. BMC Public Health. 2015;15:914. doi: 10.1186/s12889-015-2227-y