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Modifications in dietary and alcohol intakes between before and after cancer diagnosis: Results from the prospective population-based NutriNet-Santé cohort

Philippine Fassier[1], Laurent Zelek[1,2], Lucie Lécuyer[1], Patrick Bachmann[3], Marina Touillaud[3,4], Nathalie Druesne-Pecollo[1], Pilar Galan[1], Patrice Cohen[5], Hélène Hoarau[5], Paule Latino-Martel[1], Emmanuelle Kesse-Guyot[1], Julia Baudry[1], Serge Hercberg[1,6], Mélanie Deschasaux[1] and Mathilde Touvier[1]

[1] Sorbonne Paris Cité Epidemiology and Statistics Research Center, Nutritional Epidemiology Research Team (EREN): Inserm U1153, Inra U1125, Cnam, Paris 5, 7 and 13 Universities, Bobigny F-93017, France
[2] Oncology Department, Avicenne Hospital, Bobigny F-93017, France
[3] Léon Bérard Cancer Center, Lyon F-69008, France
[4] Cancer Research Centre of Lyon UMR Inserm 1052 CNRS 5286 CLB, Lyon F-69003, France
[5] Sociology Department, University of Rouen, DySola, EA 4701, Rouen F-76821, France
[6] Public Health Department, Avicenne Hospital, Bobigny F-93017, France

Postdiagnosis diet and alcohol consumption may be associated with cancer prognosis, recurrence and mortality. Our aim was to investigate food, nutrient and alcohol intake variations between before and after cancer diagnosis and their determinants in a prospective cohort. Subjects ($n = 696$) were incident cancer cases diagnosed in the NutriNet-Santé cohort between 2009 and 2016. Food, nutrient and alcohol intakes were prospectively collected using repeated nonconsecutive 24-hr dietary records since subjects' inclusion (*i.e.* an average of 2 y before diagnosis). Mean number of dietary records per subject was 5.9 before and 8.1 after diagnosis. All dietary data before and after diagnosis were compared by mixed models. Factors associated with the main dietary changes observed were also investigated using multivariable logistic regressions. We observed a decrease in intakes of vegetables (mean decrease in intake in patients who decreased their intake=-102.4 ± 79.8 g/d), dairy products (−93.9 ± 82.8 g/d), meat/offal (−35.5 ± 27.8/d), soy products (−85.8 ± 104.1 g/d), sweetened soft drinks (−77.9 ± 95.4 g/d), and alcoholic drinks (−92.9 ± 119.9 g/d), and an increase in broths (42.1 ± 34.9 g/d) and fats/sauces (18.0 ± 13.4 g/d). We observed a decrease in energy intake (−377.2 ± 243.5 kcal/d) and in intakes of alcohol (−7.6 ± 9.4 g/d) proteins (−17.4 ± 12.5 g/d), and several vitamins ($p < 0.05$) and micronutrients ($p < 0.05$). Conversely, lipid (19.4 ± 14.6 g/d), SFA (9.3 ± 7.0 g/d), MUFA (8.3 ± 6.3 g/d) and vitamin E (3.9 ± 3.3 mg/d) intakes increased after diagnosis. This large prospective study suggests that cancer diagnosis is a key period for nutritional changes. It highlights some healthy behaviors such as a decrease in alcohol and sweetened drink consumption, but also less favorable trends, such as a decrease in vegetable consumption and in many vitamin and mineral intakes. These results provide insights to identify and target recommendations to put forward for better nutritional care of cancer survivors.

Key words: Diet, nutrient intake, alcohol intake, cancer survivors, prospective cohort

Abbreviations: BMI: body mass index; OR: odds ratio; CI: confidence interval; SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids

Additional Supporting Information may be found in the online version of this article.

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Correspondence to: Philippine Fassier; EREN, Inserm U1153, SMBH Paris 13, 74 rue Marcel Cachin, F-93017 Bobigny Cedex, France. Tel.: +33 1 48 38 73 70, Fax: +33 1 48 38 89 31, E-mail: p.fassier@eren.smbh.univ-paris13.fr

What's new?

Postdiagnosis diet and alcohol consumption may be associated with cancer prognosis, recurrence and mortality. In this study, the authors analyzed the socio-demographic, economic, lifestyle and clinical factors associated with these dietary changes. They found that, while there was a decrease in alcohol consumption, there were a number of less favorable trends, such as decreased vegetable consumption and nutrient intake. These results offer insights to identify and target dietary recommendations to improve prognosis and quality of life for cancer patients.

Introduction

An estimated 14.1 million of new cancer cases were diagnosed worldwide in 2012,[1] including 355,000 in France.[2] Today, thanks to earlier diagnosis and better treatments, an estimated 80% of French prostate and breast cancer patients, and 50% of colon-rectum cancer patients can expect to be alive five years after diagnosis.[3]

Postdiagnosis lifestyle habits, including diet and alcohol consumption, have been associated with cancer prognosis, risk of recurrence or second cancer, and mortality[4–7] but also with quality of life.[8] Tertiary prevention, by adopting and maintaining a healthy lifestyle, is crucial for reducing morbidity and mortality and improving the quality of life of cancer patients and survivors. It is becoming increasingly apparent that these nutrition-related lifestyle factors need to be routinely integrated into the delivery of optimal cancer care.[9]

Dietary and alcohol intakes of cancer survivors have received increasing attention in the last decade.[10–29] Overall, these studies tended to suggest an improvement in dietary behavior after cancer diagnosis, as well as a strong motivation of cancer survivors to make lifestyle changes.[4] However, most of these studies were cross-sectional and either compared survivors to cancer-free subjects[11,13,15–18,21,26] or described only postdiagnosis dietary and alcohol intakes in cancer survivors.[10,12,14,19,23] Although a few studies provided information on the variation of dietary and/or alcohol intakes between before and after cancer diagnosis,[20,22,24,25,27–29] they reported retrospective or qualitative self-reported changes, that are possibly prone to recall bias. To our knowledge, only one study conducted in Norway provided prospective information on the variation of dietary and alcohol intakes between before and after cancer diagnosis,[22] focusing on breast and colorectal cancers. Moreover, very few studies provided detailed data on variations of food and nutrient intakes between before and after diagnosis measured by validated quantitative dietary assessment tools.[20,22,27]

The aims of this prospective study were to investigate the modifications of food, nutrient and alcohol intakes between before and after cancer diagnosis in incident cases identified in a large population-based cohort, and to study the socio-demographic, economic, lifestyle and clinical factors associated with the main dietary changes observed.

Material and Methods

The NutriNet-santé cohort

The NutriNet-Santé study is a large ongoing web-based cohort launched in May 2009 to evaluate the determinants of eating behavior and the relationships between nutrition and chronic disease risk in the French general population.[30] Participants are recruited by regular vast multimedia campaigns. Inclusion criteria are age ≥ 18 y and access to the Internet (>80% of the French population). Participants register and are followed-up online using a dedicated website (www.etude-nutrinet-sante.fr). The recruitment is still ongoing. The NutriNet-Santé study was approved by the Institutional Review Board of the French Institute for Health and Medical Research (IRB Inserm n°0000388FWA00005831) and the "Commission Nationale de l'Informatique et des Libertés" (CNIL n°908450/n°909216). To date, 160 116 subjects have been included in the NutriNet-Santé cohort (78% of women, mean age $= 42.4 \pm 14.8$ y, age range = 18–90 y). The geographical repartition of the subjects is close to the one of the French general population.[31]

Data collection

At inclusion in the cohort and each year thereafter, participants completed a set of five self-administered web-based questionnaires on socio-demographic and lifestyle characteristics (sex, age, employment status, monthly income per household unit, educational level, and smoking status), anthropometrics (weight and height), dietary intake (nonconsecutive 24-h dietary records), physical activity (validated 7-day short form of the IPAQ questionnaire[32]), and health status. These instruments have been tested against traditional assessment methods (paper-and-pencil questionnaires or face-to-face interview with a dietitian)[33–35] and validated against biomarkers.[36] Participants also completed an optional questionnaire regarding preferences for organic products two months after inclusion.

At inclusion and twice a year thereafter, participants were invited to complete three nonconsecutive 24-h dietary records, randomly assigned over a 2-week period (two weekdays and one week-end day). For the present analysis, we selected participants who completed at least two 24-h dietary records before cancer diagnosis and at least two after cancer diagnosis. Participants reported all foods and beverages consumed at each eating occasion. They estimated the amounts

eaten using validated photographs of portion sizes,[37] household measures or by indicating the exact quantity (grams) or volume (milliliters). Since the French official recommendation for fish and seafood is expressed in times per Week,[38] a specific frequency question was used to assess intake per week for this food group. Nutrient intakes were estimated using the published NutriNet-Santé composition table including >3,300 foods.[39] Dietary underreporting was identified on the basis of the method proposed by Black.[40] Participants detected as under-reporters were excluded from the analysis.

We also assessed the level of adherence to French National Nutrition and Health Program dietary guidelines for fruits and vegetables (≥5 servings/day), fish (≥2 servings/week), dairy products (3 servings/day below 55 y and 3–4 servings/day ≥55 y) and meat/fish/eggs (1–2 servings/day).

Case ascertainment

Participants self-declared any cancer diagnosis during follow-up through regular questionnaires and a web-interface with permanent access. Anatomopathological reports and medical records collected from patients and/or their physicians were used by an independent physician expert committee to validate all cancer cases. Cases were classified using the International Chronic Diseases Classification, 10th Revision, Clinical Modification (ICD-10).[41] All first incident cancers were considered as cases in this study, except basal cell carcinoma.

For the most common cancer locations represented in this study, tumor characteristics and treatments were extracted from medical records: for breast cancer: tumor size, lymph node status, tumor type (invasive or *in situ*), estrogen and progesterone receptor status, HER2 status, Ki67 and treatment (chemotherapy, surgery, radiotherapy, and/or hormonotherapy); for prostate cancer: tumor size, lymph node status, PSA, Gleason score and treatment; for colon-rectum cancer: tumor size, lymph node status and treatment. Digestive cancers included: 48 colon-rectum, 11 lip, mouth and tongue, 5 pancreas, 3 liver, 2 stomach and 2 esophagus cancers. Given the small number of advanced stages for each tumor location, the use of TNM/UICC stages was not discriminating, thus, patients were classified into two categories (favorable prognosis/poor prognosis) according to cancer-specific clinically relevant factors, as described in footnotes to Table 1.

Statistical analysis

Among the 1987 incident cancer cases diagnosed in the NutriNet-Santé study between May 2009 and December 2015 and followed at least 6 months after diagnosis, 1635 cases were first cancers. We excluded 938 patients with less than two dietary records before or after cancer diagnosis and 1 pregnant woman, leaving 696 cancer cases for analysis. Flow chart is presented in Supporting Information material 1.

For descriptive purpose, mean dietary intake (food groups, energy, alcohol and nutrients) before (respectively after) diagnosis was calculated for each subject as the average of daily intake before (respectively after) diagnosis. Similarly, physical activity variation (in MET.h/week) between before and after diagnosis was calculated. Dietary intake data declared in the timeframe [3 months before to 6 months after cancer diagnosis] were excluded from the calculation to focus on stable periods. Mean body mass index (BMI = weight (kg)/[height (m)]^2) before diagnosis was calculated as the mean of all BMI data available from baseline to 3 months before diagnosis. Baseline socio-demographic data, smoking status and income variation were used in the present analysis. For all covariates (except physical activity and cancer prognosis), <5% of the values were missing. These missing values were imputed to the modal category (for categorical variables) or to the median value (for quantitative variables). For physical activity and cancer prognosis, a "missing" category was created, as detailed in Table 1.

We fit mixed models using all available information on food and nutritional intakes provided before and after diagnosis (excluding the 3 months pre- and 6-months postdiagnosis window) with cancer diagnosis and time points as random effects and adjusted for daily energy intake at the date of each dietary record. Mixed models included (*i*) a "cancer term" to test if there were some variations between before and after cancer diagnosis and (*ii*) a "time term," to investigate if there was a variation in dietary intakes between the different values measured before diagnosis (respectively, between the different values measured after diagnosis). These models were performed overall and specifically for breast, prostate and digestive cancer cases. Due to the high number of food groups and nutrients considered, these analyses were performed with adjustment for multiple testing: all the p values from the mixed models were included in the SAS PROC MULTTEST to perform a False Discovery Rate adjustment.[42]

The proportions of subjects who met each nutritional recommendation were assessed before and after diagnosis and compared by McNemar's tests. (*i*) changes in compliance to nutritional recommendations for fruits/vegetables, dairy products, meat/seafood/eggs, and fish/seafood (yes to no/no to yes/no modification between before and after cancer diagnosis (reference)) and (*ii*) cancer location, sex, age and number of dietary records, have now been investigated using polytomous logistic regression analysis.

Age and sex-adjusted and multivariable unconditional logistic regression analyses were used to investigate the factors associated with a variation of >5% of the initial value before diagnosis, for the main dietary changes observed. Odds ratios (OR) and 95% confidence intervals (CI) were computed. Studied socio-demographic, economic, anthropometric, lifestyle and clinical factors were: sex, age at diagnosis, cancer location, cancer prognosis, baseline occupational status and educational level, overweight status (including obesity) before diagnosis, dietary intakes before diagnosis, and variation of daily energy intake, physical activity, monthly income, and smoking status between before and after diagnosis. All these parameters were simultaneously entered into the

Table 1. Sociodemographic, economic, anthropometric, and lifestyle characteristics of incident cancer cases, NutriNet-Santé cohort, 2009–2015 ($N = 696$).

	N	%	Mean	SD
Age at diagnosis (years)			59.0	10.6
Delay between inclusion and diagnosis (months)			23.0	13.8
Follow up (months)[1]			49.0	12.6
Number of 24-hr dietary records per subject				
Before cancer diagnosis			5.9	3.9
After cancer diagnosis			8.1	5.1
Overall			13.8	5.5
Sex				
Male	236	33.9		
Female	460	66.1		
Baseline educational level				
Up to secondary education	315	45.3		
Undergraduate	168	24.1		
Postgraduate	213	30.6		
Professionally active after diagnosis				
Yes	309	44.4		
No[2]	387	55.6		
Monthly income decrease>10% after diagnosis				
Yes	144	20.7		
No	552	73.3		
Overweight before diagnosis[3]				
No	443	63.7		
Yes	253	36.3		
Energy intake variation after/before cancer diagnosis				
< -100 kcal/d	303	43.5		
$[-100 - +100]$ kcal/d	167	24.0		
$> +100$ kcal/d	226	32.5		
Occasional-to-frequent consumption of organic vegetables				
Yes	479	68.8		
No	217	31.2		
Decrease in physical activity>5% after diagnosis[4,5]				
Yes	278	44.6		
No	345	55.4		
Smoking status				
Non-smoker	632	90.8		
Former smoker (stopped at cancer diagnosis)	21	3.0		
Smoker after cancer diagnosis	43	6.2		
Cancer location				
Breast	246	35.3		
Favorable prognosis[6]	143	65.9		
Poor prognosis[6]	74	34.1		
Prostate	119	17.1		
Favorable prognosis[7]	46	54.1		
Poor prognosis[7]	39	45.9		
Digestive[8]	71	10.2		

Table 1. Sociodemographic, economic, anthropometric, and lifestyle characteristics of incident cancer cases, NutriNet-Santé cohort, 2009–2015 ($N = 696$). (Continued)

	N	%	Mean	SD
Favorable prognosis[10]	7	21.2		
Poor prognosis[10]	26	78.8		
Other[11]	260	37.4		

[1]Duration of follow up for breast cancer = 48.30 ± 12.74 months; for prostate cancer: 50.20 ± 11.91 months; for digestive cancer: 49.25 ± 11.93 months.
[2]Professionally inactive included: homemakers, sick leave, unemployed and retired subjects.
[3]BMI ≥ 25 kg/m^2.
[4]Decrease in physical activity by 5% or more of the value before diagnosis calculated in Met.h/week.
[5]Available for 623 participants.
[6]Tumor size <2 cm or node-negative or (tumor size <1 cm and positive ER/PR receptors) = favorable prognosis; tumor size ≥2 cm or node-positive or (tumor size ≥1 cm and negative ER/PR receptors) = poor prognosis. Data available for 217 participants out 246 of breast cancers.
[7]PSA ≤20 ng/ml or Gleason ≤7 or cancer ≤ T2b= favorable prognosis; PSA >20 ng/ml or Gleason >7 or cancer >T2b = poor prognosis. Data available for 85 participants out of 119 prostate cancers.
[8]Digestive cancers included: 48 colon-rectum cancers, 11 lip, mouth, tongue, 5 pancreas cancers, 3 liver cancers, 2 stomach cancers, 2 esophagus cancers.
[9](Cancer T1/T2 and node-negative) or no chemotherapy = favorable prognosis; (cancer T3/T4 and node-positive) or chemotherapy = poor prognosis. Data available for 33 participants out of 71 digestive cancers.
[10]Other cancer locations were: 87 skin, 25 thyroid, 18 non-Hodgkin lymphomas, 18 bladder, 15 leukemia, 15 cervix, 15 other uterus, 13 lung, 11 kidney, 8 ovary, 8 Hodgkin lymphomas, 2 brain and 25 representing <1% of cancer locations (ex: liposarcoma).

multivariate models, as well as the number of 24-h dietary records.

p values < 0.05 was considered statistically significant. All tests were two-sided. Analyses were carried out with SAS 9.3 (SAS Institute Inc, Cary, NC).

Results

Women represented 66% of the subjects. Mean age at diagnosis was 59.0 ± 10.6 years. Mean time between inclusion in the cohort and cancer diagnosis was 23 ± 13.8 months and mean time of follow-up after diagnosis was 49.0 ± 12.6 months. Other characteristics of the study population are presented in Table 1. Main cancer locations were: breast ($n = 246$), prostate ($n = 119$), and digestive ($n = 71$). Mean 24-h dietary records per subject was 13.8 ± 5.5 (5.9 ± 3.9 before cancer diagnosis, and 8.1 ± 5.1 after cancer diagnosis). Compared to excluded cases ($n = 939$), included cases ($n = 696$) were more likely to be older (85.5% *vs.* 77.2% >55 y, $p < 0.0001$), male (33.9% *vs.* 26.8%, $p = 0.0009$) and to have prostate cancer (17.1% *vs.* 10.2%, $p = 0.0002$). Besides, food intakes after cancer diagnosis were similar between included cancer cases ($n = 696$) and excluded cases with at least one 24 hr dietary record after cancer diagnosis ($n = 102$) (data not tabulated). Supporting Information Tables 1 and 2 display food and nutritional intakes of cancer patients after diagnosis.

Food intake variations between before and after cancer diagnosis are described in Table 2. In mixed models, no "time effect" was observed, which indicated that there was no major variation in dietary intakes before (respectively after) diagnosis, while several "cancer terms" were statistically significant. Indeed, a decrease in intake after diagnosis was observed for vegetables ($p = 0.04$; mean decrease in subjects who decreased their vegetable intake = −102.36 g/d), dairy products ($p = 0.0007$; −93.87 g/d)—especially in prostate cancers ($p = 0.02$), meat/offal ($p = 0.04$; −35.47 g/d), soy products ($p = 0.02$; −85.82 g/d), sweetened soft drinks ($p = 0.009$; −77.85 g/d) - especially in breast cancers ($p = 0.002$), and alcoholic drinks ($p = 0.007$; −92.93 g/d)—especially in prostate cancers ($p = 0.03$). In contrast, increased intakes were observed for broths ($p = 0.001$) +42.08 g/d) – especially in breast ($p = 0.005$) cancers; and fats/sauces ($p = 0.007$; +17.99 g/d) –. An increase in fruit intakes ($p = 0.04$) was observed specifically in prostate cancer patients.

The decrease in vegetable intake was more specifically observed in subjects who declared not consuming organic vegetables before diagnosis ($p = 0.01$), while no decrease was observed in organic vegetables consumers ($p = 0.2$) (data not tabulated).

When analyses were conducted separately in patients who lost or gained weight (Supporting Information Material 3), alcohol and soy products decreased in both groups; sweetened soft drinks decreased in patients who lost weight; while patients who gained weight were more inclined to decrease vegetable and dairy product intakes and increase broth and fat/sauce intakes.

Table 3 describes the variations in energy, alcohol and nutrient intakes between before and after cancer diagnosis. We observed a decrease in energy ($p = 0.0002$), alcohol ($p = 0.005$), proteins ($p < 0.0001$), B vitamins (B2, B3, B5, B6, B9, all $p < 0.05$), iron ($p = 0.001$), potassium ($p = 0.004$) and zinc ($p = 0.002$) intakes. In contrast, intakes of lipids ($p < 0.0001$), SFA ($p < 0.0001$), MUFA ($p = 0.0004$) and vitamin E ($p = 0.03$) increased after cancer diagnosis.

As shown in Table 4, the proportions of subjects who complied with the food-based recommendations before diagnosis were 65% for fruit and vegetables, 37% for dairy

Table 2. Variations in food intake (g/d) between before and after cancer diagnosis, Nutrinet-Santé cohort, 2009–2015 ($N = 696$).

	Overall N=696						Breast cancer N=246						Prostate cancer N=119						Digestive cancer N=71					
			Dietary decrease[1]		Dietary increase[1]				Dietary decrease[1]		Dietary increase[1]				Dietary decrease[1]		Dietary increase[1]				Dietary decrease[1]		Dietary increase[1]	
	β	p-value	N	Mean ± SD	N	Mean ± SD	β	p-value	N	Mean ± SD	N	Mean ± SD	β	p-value	N	Mean ± SD	N	Mean ± SD	β	p-value	N	Mean ± SD	N	Mean ± SD
Vegetable	−9.4	0.04	324	−102.36 ±79.81	295	80.78 ±64.11	2.6	0.9	99	−97.98 ±70.62	114	78.73 ±58.16	−7.3	0.9	59	−98.27 ±86.13	47	94.36 ±87.86	−31.0	0.1	37	−125.58 ±102.47	30	78.63 ±63.69
Fruit	5.1	0.5	318	−114.91 ±91.82	308	122.49 ±109.19	1.5	0.9	113	−117.37 ±99.26	107	124.61 ±103.59	34.6	0.04	45	−114.61 ±86.2	68	137.64 ±116.05	−5.1	0.9	34	−115.56 ±88.65	27	129.27 ±146.4
Broths	7.6	0.001	233	−44.49 ±38.92	348	42.08 ±34.89	11.1	0.005	82	−38.8 ±31.46	129	45.27 ±37.54	3.9	0.9	42	−53.28 ±52.13	58	43.86 ±40.36	−0.3	0.9	30	−46.77 ±45.75	33	38.3 ±25.46
Potatoes. tubers	0.7	0.9	334	−42.55 ±37.67	323	40.67 ±36.78	−0.8	0.9	121	−37.25 ±35.4	108	33.57 ±24.91	−0.1	0.9	56	−54.38 ±42.93	60	48.37 ±38.56	0.7	0.9	31	−52.16 ±38.5	34	57.56 ±58.51
Pasta. rice	−2.4	0.5	339	−62.95 ±49.3	301	57.37 ±43.96	−9.5	0.1	131	−62.57 ±52.34	93	48.46 ±34.68	0.3	0.9	52	−69.16 ±59.47	56	70.18 ±50.42	14.1	0.3	26	−75.24 ±51.43	40	64.52 ±45.06
Whole grains	−0.5	0.9	291	−33.23 ±32.33	292	30.65 ±29.54	−0.0	0.9	114	−27.67 ±22.78	96	30.89 ±26.12	1.6	0.9	41	−44.22 ±44.64	52	36.51 ±42.53	−12.7	0.08	33	−47.35 ±48.53	26	18.94 ±13.06
Pulses	0.1	0.9	227	−23.98 ±25.84	258	18.82 ±20.97	1.2	0.8	85	−21.28 ±26.32	91	17.76 ±14.44	−0.9	0.9	42	−26.36 ±31.67	48	16.27 ±20.4	−0.2	0.9	21	−24.5 ±20.31	27	20.59 ±31.05
Dairy products	−13.1	0.007	345	−93.87 ±82.75	283	76.06 ±77.6	−13.9	0.2	126	−91.67 ±87.96	96	74.67 ±84.72	−28.9	0.02	59	−103.95 ±80.41	41	56.13 ±43.99	−34.2	0.1	39	−108.2 ±97.94	25	78.95 ±72.01
Meat. offal	−3.6	0.04	346	−35.47 ±27.79	300	32.12 ±27.68	−3.7	0.3	125	−33.77 ±27.04	103	28.29 ±22.1	−1.3	0.9	59	−35.67 ±29.92	54	38.6 ±36.11	−9.1	0.3	35	−40.76 ±34.67	31	36.9 ±36.11
Poultry	−0.7	0.8	314	−29.51 ±23.15	331	26.12 ±23.86	−0.9	0.9	114	−25.98 ±19.38	113	24.86 ±21.5	−1.3	0.9	58	−32.62 ±26.79	54	24.31 ±18.63	0.4	0.9	30	−31.28 ±26.35	34	25.49 ±27.61
Eggs	−0.1	0.9	311	−18.34 ±21.38	329	16.73 ±18.04	0.9	0.8	120	−13.19 ±12.91	109	15.7 ±19.34	−0.8	0.9	46	−25.85 ±25.23	65	16.23 ±13.98	−1.7	0.8	34	−19.72 ±31.03	28	16.89 ±19.07
Fish. seafood	−0.4	0.9	323	−38.68 ±36.76	337	35.82 ±30.95	0.0	0.9	121	−33.85 ±26.37	116	34.17 ±28.74	0.2	0.9	45	−54.41 ±62.82	67	38.71 ±37.74	3.5	0.8	27	−39.91 ±32.11	38	37.48 ±24
Processed meat	0.1	0.9	322	−26.31 ±24.33	332	23.33 ±20.71	−0.1	0.9	123	−23.13 ±22.73	110	20.95 ±15.31	−1.8	0.9	53	−30.89 ±25.33	61	23.64 ±22.9	−1.5	0.9	33	−30.56 ±38.02	34	26.91 ±36.7
Fats. sauces	2.5	0.007	292	−19.42 ±17.95	351	17.99 ±13.35	2.0	0.3	104	−18.51 ±16.53	122	15.6 ±12.27	4.7	0.08	44	−20.93 ±17.79	67	19.36 ±16.58	2.8	0.8	30	−19.19 ±17.3	36	23.75 ±14.76
Breakfast cereals	−0.1	0.9	127	−13.39 ±12.83	129	12.11 ±11.72	0.1	0.9	50	−12.43 ±10.83	47	13.41 ±12.81	0.9	0.6	9	−13.31 ±8.79	18	10.94 ±13.16	1.1	0.8	13	−10 ±9.32	14	15.15 ±12.66
Sugar. confectionary	−2.1	0.5	334	−52.32 ±46.68	322	44.8 ±38.76	0.4	0.9	118	−55.74 ±51.6	114	44.82 ±46.02	−2.1	0.9	54	−46 ±38.44	55	44.57 ±30.34	5.3	0.8	30	−51.71 ±55.32	37	52.93 ±39.4
Cakes. biscuits	2.8	0.1	324	−35.33 ±32.65	315	35.55 ±31.19	4.5	0.3	117	−33.56 ±26.49	114	35.26 ±33.4	2.5	0.9	55	−30.87 ±27.98	52	31.64 ±24.62	3.1	0.8	31	−35.13 ±35.52	34	41.85 ±36.27
Unsweetened soft drinks	−29.2	0.1	327	−334.4	269	311.2	−18.5	0.8	117	−327.98	87	336.02	−52.1	0.6	62	−317.62	42	284.27	−23.6	0.9	37	−308.53	27	403.52

Table 2. Variations in food intake (g/d) between before and after cancer diagnosis, Nutrinet-Santé cohort, 2009–2015 (N = 696). (Continued)

	Overall N=696						Breast cancer N=246						Prostate cancer N=119						Digestive cancer N=71					
			Dietary decrease[1]		Dietary increase[1]				Dietary decrease[1]		Dietary increase[1]				Dietary decrease[1]		Dietary increase[1]				Dietary decrease[1]		Dietary increase[1]	
	β	p-value	N	Mean ± SD	N	Mean ± SD	β	p-value	N	Mean ± SD	N	Mean ± SD	β	p-value	N	Mean ± SD	N	Mean ± SD	β	p-value	N	Mean ± SD	N	Mean ± SD
				±297.22		±241.66				±235.41		±265.36				±435.07		±229.83				±239.05		±237.6
Sweetened soft drinks	−8.0	0.009	194	−77.85	169	49.23	−16.3	0.002	75	−86.2	63	36.61	−9.8	0.4	30	−75.93	30	53.94	0.6	0.9	17	−94.29	17	54.52
				±95.38		±91.21				±99.48		±34.89				±83.3		±60.61				±152.04		±73.01
Alcoholic drinks	−14.1	0.007	334	−92.93	252	68.25	−1.2	0.9	107	−72.25	97	55.59	−33.9	0.03	64	−119.51	43	82.23	−41.2	0.1	46	−96.65	17	103.23
				±119.95		±77.2				±80.83		±63.48				±104.99		±102.88				±116.33		±101.43
Soy products	−3.8	0.02	54	−85.82	35	57.95	−3.5	0.3	17	−81.54	12	63.87	−0.7	0.9	8	−38.2	7	27.3			3	−38.57	4	52.86
				±104.13		±77.69				±55.93		±54.38				±36.44		±25.35				±8.69		±39.19

[1]β for the "cancer term" in mixed models. Mixed models include both fixed and random effects and are the most appropriate statistical models in settings where repeated measurements are made on the same subjects. Since dietary intake before diagnosis was compared to the intake after diagnosis for each subject, no adjustment for individual characteristics was performed (before and after diagnosis values are matched for each cancer patient).
All models were adjusted for daily energy intake at the date of each dietary record.
[2]Decrease in food intake (g/d) in patients who decreased their intake for the specific food group by at least 5%.
[3]Increase in food intake (g/d) in patients who increased their intake for the specific food group by at least 5%.

products, 60% for meat/fish/eggs, and 57% for fish/seafood. Overall, these proportions remained similar after cancer diagnosis. However, many inter-individual variations were observed. For instance, half of the participants who complied with the dairy products recommendation before diagnosis no longer met this recommendation after diagnosis. Younger subjects who were not compliant with the fruit/vegetable ($p = 0.04$) and fish/seafood ($p = 0.04$) recommendations before their cancer diagnosis were more inclined to become compliant with these recommendations after diagnosis than older subjects (data not tabulated), other associations were not statistically significant.

Factors associated with a decrease in vegetable intake and in alcohol consumption (*i.e.* the main dietary changes observed) are presented in Table 5. A decrease in vegetable intake of at least 5% after cancer diagnosis was observed in 47% ($n = 324$) of the subjects. It was more frequent in patients who consumed more vegetables before diagnosis (OR = 5.56 (3.93; 7.86), $p < 0.0001$) and in those who decreased their energy intake (OR = 1.88 (1.22; 2.88), $p = 0.01$).

Twenty % ($n = 137$) of the participants did not consume alcohol before cancer diagnosis, among them, 53% ($n = 73$) declared alcohol intake after diagnosis, with an average of 5 g/d of ethanol (1/2 glass). Among those who consumed alcohol before diagnosis ($n = 559$), 61% ($n = 340$) decreased their alcohol intake by at least 5%. This was especially the case for patients who consumed more alcohol before diagnosis (OR = 2.26 (1.50; 3.40), $p \leq 0.0001$) and for those who decreased their energy intake (OR = 2.05 (1.28; 3.28), $p < 0.0001$).

Clinical characteristics recorded for main cancer types (type of treatments, overall indicator of cancer prognosis, tumor size, lymph node status, invasive/*in situ* tumor type, hormone receptor status, PSA and Gleason [for prostate cancer]) were not associated with the variation in vegetable and alcohol intakes in this study, nor was weight variation before/after diagnosis (all $p > 0.05$, data not tabulated).

In sensitivity analyses, all results were similar after excluding subjects who had a second primary cancer or cancer recurrence during follow-up ($n = 29$). Besides, since a 6-month window after diagnosis of a digestive cancer may be insufficient because of a long treatment period, we also tested an exclusion of dietary data during 12 months after diagnosis. Results were unchanged, excepted for the decrease in alcoholic drinks, which became statistically significant (data not shown).

Discussion

This study investigated the variations in food, nutrient and alcohol intakes between before and after cancer diagnosis in a large population-based cohort. While previous studies used only postdiagnosis dietary data or retrospective prediagnosis data, our results are based on prospective information, with a follow-up beginning on average two years before cancer

Table 3. Variations in energy, alcohol and dietary nutrient intakes between before and after cancer diagnosis, Nutrinet-Santé cohort, 2009–2015 ($N = 696$).

	Overall N=696						Breast cancer N=246						Prostate cancer N=119						Digestive cancer N=71					
			Dietary decrease[2]		Dietary increase[3]				Dietary decrease[2]		Dietary increase[3]				Dietary decrease[2]		Dietary increase[3]				Dietary decrease[2]		Dietary increase[3]	
	β	p-value[1]	N	Mean ± SD	N	Mean ± SD	β	p-value[1]	N	Mean ± SD	N	Mean ± SD	β	p-value[1]	N	Mean ± SD	N	Mean ± SD	β	p-value[1]	N	Mean ± SD	N	Mean ± SD
Energy (kcal/d)	−55.9	0.0002	308	−377.24	231	326.08	−101.8	<.0001	116	−359.46	68	252.02	−28.6	0.7	47	−426.82	49	186.8	36.4	0.7	29	−428.87	28	505.93
				±243.5		±233.33				±229.65		±163.21				±289.24		±330.22				±315.92		±378.75
Alcohol (g/d)	−1.0	0.005	340	−7.63	262	5.77	−0.2	0.8	112	−6.21	99	4.58	−2.8	0.05	69	−9.60	41	8.28	−3.4	0.08	43	−8.92	19	8.10
				±9.14		±6.61				±7.18		±5.40				±9.52		±9.52				±11.56		±8.14
Total Carbohydrates (g/d)	−1.5	0.2	328	−41.41	231	38.28	−2.0	0.3	119	−42.47	72	32.55	1.9	0.7	52	−42.7	48	22.45	0.0	0.9	29	−46.87	33	43.25
				±26.67		±25.2				±25.8		±23.82				±30.85		±44.18				±32.38		±33.17
Sugar (g/d)	0.1	0.9	326	−22.8	267	21.78	−0.0	0.9	118	−23.72	84	22.34	1.4	0.7	45	−25.65	57	15.13	−0.4	0.9	31	−24.04	33	25.85
				6 ± 15.64		±16.29				±16.95		±15.73				±16.01		±20.79				±14.18		±21.07
Starch (g/d)	−1.6	0.1	353	−26.5	251	24.6	−2.5	0.1	134	−25.07	77	20.34	0.6	0.8	57	−28.69	49	16.71	0.7	0.9	29	−33.64	34	28.74
				7 ± 20.05		±16.42				±21.12		±13.02				±19.44		±29.05				±25.76		±20.31
Fibers (g/d)	−0.3	0.1	333	−5.09	241	4.74	−0.1	0.8	126	−4.92	86	5.05	0.4	0.6666	46	−5.86	49	5.02	−1.6	0.08	38	−6.46	26	4.91
				±3.4		±3.45				±3.3		±3.14				±3.59		±5.62				±4.65		±2.71
Proteins (g/d)	−2.2	<.0001	338	−17.42	213	15.21	−2.3	0.005	126	−16.47	63	13.16	−1.9	0.3	47	−19.41	43	9.44	−3.0	0.2	35	−20.98	28	22.1
				±12.47		±11.56				±10.18		±8.06				±13.2		±13.29				±18.62		±17.92
Lipids (g/d)	2.5	<.0001	303	−20.31	302	19.43	2.2	0.005	120	−18.56	94	15.75	2.4	0.2	45	−23.46	59	14.57	3.9	0.1	28	−21.58	34	28.54
				±14.26		±14.55				±13.03		±10.16				±17.03		±19.55				±18.44		±19.81
SFA (g/d)	1.4	<.0001	291	−9.71	312	9.34	0.8	0.1	114	−9.88	98	7.31	1.8	0.05	46	−9.98	58	6.94	0.6	0.7	32	−9.77	33	13.41
				±6.98		±7.04				±6.63		±4.55				±7.42		±9.45				±8.67		±10.01
MUFA (g/d)	0.9	0.0004	297	−8.84	308	8.34	1.2	0.02	114	−8.36	99	7.63	0.6	0.5	42	−10.74	55	6.51	2.3	0.08	27	−8.23	40	10.47
				±6.44		±6.34				±6.15		±5.56				±6.35		±8.94				±7.47		±7.02
PUFA (g/d)	0.0	0.9	332	−4.05	298	3.56	0.2	0.5	124	−3.18	101	3.06	0.0	0.9	49	−5.25	55	3.69	0.7	0.4	33	−3.96	34	4.7
				±3.68		±3.25				±2.22		±2.35				±5.14		±4.12				±3.43		±4.29
Vitamin B1 (mg/d)	0.0	0.09	345	−0.3	256	0.31	0.0	0.5	125	−0.32	95	0.27	0.0	0.7	58	−0.31	41	0.27	−0.0	0.9	31	−0.42	27	0.43
				3 ± 0.26		±0.27				±0.24		±0.22				±0.19		±0.34				±0.41		±0.4
Vitamin B2 (mg/d)	−0.1	<.0001	353	−0.48	212	0.38	−0.1	0.0006	131	−0.47	70	0.3	−0.1	0.05	59	−0.42	28	0.3	−0.1	0.3	34	−0.53	24	0.46
				±0.42		±0.31				±0.42		±0.22				±0.31		±0.38				±0.47		±0.34
Vitamin B3 (mg/d)	−0.8	0.0001	355	−5.15	238	4.59	−0.7	0.08	123	−5.03	83	4.29	−0.9	0.2	65	−4.98	38	2.49	−1.1	0.1	38	−5.8	22	5.48
				±3.79		±3				±4.05		±2.38				±2.83		±4.84				±4.43		±3.4
Vitamin B5 (mg/d)	−0.1	0.008	322	−1.31	233	1.1	−0.2	0.03	116	−1.32	79	0.87	−0.1	0.3	54	−1.23	37	0.79	0.0	0.9	34	−1.49	30	1.55
				±0.93		±1.05				±0.83		±0.52				±0.68		±1.12				±1.23		±1.61
Vitamin B6 (mg/d)	0.0	0.03	331	−0.47	244	0.39	0.0	0.3	114	−0.43	88	0.32	0.0	0.5	60	−0.47	40	0.35	0.0	0.7	35	−0.54	24	0.45
				±0.4		±0.3				±0.46		±0.21				±0.3		±0.5				±0.4		±0.35
Vitamin B9 (µg/d)	−12.3	0.002	348	−100.45	249	84.63	−11.4	0.09	124	−97.4	90	66.95	1.6	0.9	52	−95.08	47	77	−27.8	0.09	37	−121.21	25	97.56
				±71.66		±70.95				±73.09		±40.98				±54.99		±100.73				±78.41		±66.06
Vitamin B12 (µg/d)	−0.1	0.6	332	−4.08	312	3.65	0.0	0.9	121	−3.43	105	2.92	−0.3	0.7	54	−5.18	54	4.63			28	−6.47	38	2.97

Table 3. Variations in energy, alcohol and dietary nutrient intakes between before and after cancer diagnosis, Nutrinet-Santé cohort, 2009–2015 ($N = 696$). (Continued)

	Overall N=696						Breast cancer N=246						Prostate cancer N=119						Digestive cancer N=71					
				Dietary decrease[2]		Dietary increase[3]				Dietary decrease[2]		Dietary increase[3]				Dietary decrease[2]		Dietary increase[3]				Dietary decrease[2]		Dietary increase[3]
	β	p-value[1]	N	Mean ± SD	N	Mean ± SD	β	p-value[1]	N	Mean ± SD	N	Mean ± SD	β	p-value[1]	N	Mean ± SD	N	Mean ± SD	β	p-value[1]	N	Mean ± SD	N	Mean ± SD
				±6.1		±5.44				±5.15		±3.72				±6.92		±4.22				±8.67		±3.03
Retinol (µg/d)	20.7	0.6	312	−411.48	334	414.47	−17.5	0.8	118	−319.68	108	259.29	−0.3	0.7	52	−410.4	61	657.8			34	−698.42	33	325.33
				±729.1		±902.24				±607.34		±409.18				±654.54		±523.91				±1087.96		±519.01
β–Carotene (µg/d)	−90.9	0.4	330	−2019.84	311	1780.39	88.2	0.8	108	−2096.38	118	1874.92	−108.7	0.7	58	−1996.53	55	1340.34	−268.8	0.6	35	−1917.95	29	1999.01
				±2190.16		±1809.19				±2442.42		±2035.68				±2273.09		±1451.58				±1549.25		±2347.09
Vitamin C (mg/d)	−3.5	0.1	339	−48.94	295	42.18	−1.2	0.8	113	−48.75	110	38	5.3	0.5	51	−41.98	63	32.57	−6.9	0.6	38	−48.14	26	58.12
				±46.48		±31				±43.83		±26.71				±29.51		±45.33				±38.85		±45.21
Vitamin D (µg/d)	0.1	0.2	334	−1.82	327	1.98	0.1	0.6	119	−1.71	119	1.82	0.2	0.7	53	−2.17	60	3.07			33	−2.05	30	2.57
				±2.08		±2.49				±1.68		±2.06				±2.56		±2.16				±2.59		±2.67
Vitamin E (mg/d)	0.4	0.03	306	−3.79	308	3.94	0.6	0.06	110	−3.34	104	3.85	0.4	0.5	48	−4.4	57	3.56	1.6	0.08	26	−3.36	40	4.67
				±3.18		±3.26				±2.73		±3.09				±4.24		±4.34				±2.03		±3.29
Calcium (mg/d)	−13.6	0.1	335	−234.51	242	232.68	−29.8	0.06	135	−223.63	70	189.13	−34.1	0.2	62	−231.42	40	128.85	−15.2	0.8	33	−291.61	30	315.84
				±166.03		±211.54				±141.35		±134.44				±149.68		±210.11				±274.08		±326.71
Iron (mg/d)	−0.5	0.001	348	−4.1	256	3.26	−0.3	0.3	131	−3.65	85	2.85	−0.4	0.5	55	−4.19	44	2.89	−1.0	0.2	34	−5.78	29	4.13
				±3.03		±2.45				±2.48		±1.74				±3.36		±3.68				±4.54		±2.94
Magnesium (mg/d)	−4.1	0.2	327	−78.58	246	76.67	2.8	0.8	119	−74.75	91	76.38	−8.3	0.5	53	−81.58	40	64.36	−6.9	0.7	34	−94.66	28	101.06
				±54.79		±61.26				±56.71		±60.94				±55.4		±73.55				±62.77		±72.12
Phosphorus (mg/d)	1.0	0.9	311	−274.12	250	271.41	6.5	0.8	122	−255.76	77	272.07	−36.3	0.2	50	−306.61	39	147.73	−12.1	0.9	30	−352	27	415.03
				±180.09		±226.27				±159.61		±193.04				±161.79		±228				±266.83		±408.86
Potassium (mg/d)	−64.5	0.004	332	−644.53	220	577.04	−17.7	0.8	115	−596.03	80	540.23	−31.2	0.7	51	−730.67	45	519.49	−183.9	0.09	35	−801.28	22	779.77
				±410.7		±418.97				±333.31		±375.59				±446.99		±672.67				±575.52		±583.3
Zinc (mg/d)	−0.4	0.002	339	−3.17	240	2.79	−0.4	0.07	130	−2.99	74	2.44	−0.3	0.5	49	−4.12	50	2.42	−0.5	0.3	32	−3.82	31	3.51
				±2.64		±2.44				±2.5		±2.35				±3.83		±2.9				±2.66		±2.93

SFA = Saturated Fatty Acids, MUFA = MonoUnsaturated Fatty Acids, PUFA= PolyUnsaturated Fatty Acids.
[1]β for the "cancer term" effect in mixed models. Mixed models include both fixed and random effects and are the most appropriate statistical models in settings where repeated measurements are made on the same subjects. Since nutrient intake before diagnosis was compared to the intake after diagnosis for each subject, no adjustment for individual characteristics was performed (before and after diagnosis values are matched for each cancer patient).
All models were adjusted for daily energy intake at the date of each dietary record.
[2]Decrease in intake in patients who decreased their intake for the specific nutrient by at least 5%.
[3]Increase in intake in patients who increased their intake for the specific nutrient by at least 5%.

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Table 4. Variation of compliance with dietary recommendation between before and after cancer diagnosis, Nutrinet-Santé cohort, 2009–2015 ($N = 696$).

	Overall proportions of subjects							Interclass variations			
	Complied with the recommendation before diagnosis[1]			Complied with the recommendation after diagnosis[1]			p-value[2]	Complied with the recommendation before diagnosis[1]	Complied with the recommendation after diagnosis[1]		
		N	%		*N*	%				*N*	%
Fruit and Vegetables	Yes	454	65.2	Yes	431	61.9	0.07	Yes	Yes	360	79.0
									No	94	21.0
	No	242	34.8	No	265	38.1		No	Yes	71	29.3
							No	171	70.7		
Dairy products	Yes	256	36.8	Yes	233	33.5	0.1	Yes	Yes	129	50.4
									No	127	49.6
	No	440	63.2	No	463	66.5		No	Yes	104	23.6
							No	336	76.4		
Meat, fish, eggs	Yes	418	60.1	Yes	429	61.6	0.5	Yes	Yes	279	66.7
									No	139	33.3
	No	278	39.9	No	267	38.4		No	Yes	150	54.0
							No	128	46.0		
Fish and seafood	Yes	272	56.7	Yes	338	56.5	0.5	Yes	Yes	186	78.8
									No	50	21.2
	No	208	43.3	No	260	43.5		No	Yes	44	26.2
							No	124	73.8		

[1]Recommendation from the French National Nutrition and Health Program for fruits and vegetables (≥5/day), fish and seafood (≥2 servings/week), dairy products (3 servings/day below 55 y and 3–4 servings/day ≥55 y) and meat/fish/eggs (1–2 servings/day).
[2]p values from McNemar's tests.

diagnosis. We observed a substantial decrease in intakes of vegetables, soy products, dairy products, and sweetened soft and alcoholic drinks, while broth and fat/sauce intakes tended to increase. The consequences in terms of nutrient intakes were a decrease in energy, alcohol, proteins, B vitamins, potassium and zinc intakes, and an increase in total lipid, SFA, MUFA and vitamin E intakes.

While previous studies globally reported an improvement of dietary behavior after cancer diagnosis,[9] our results were more contrasted. The prospective design and the quantitative assessment of dietary intake probably contributed to more accurately reflect the complexity of dietary changes.

Some healthy trends were observed. First, 61% of cancer patients who consumed alcohol before diagnosis stopped or decreased their alcohol consumption by at least 5%, with a mean decrease of 7.6 g/d of ethanol (about $^1/_2$ standard glass). This result was consistent with previous studies.[10,11,13,15–17] For instance, Park *et al.* recently reported that 39% of cancer patients who previously consumed alcohol stopped after diagnosis.[17] Logically, individuals with higher alcohol intake before diagnosis (thus with a greater magnitude for decrease) were more likely to reduce their alcohol intake postdiagnosis. Conversely, alcohol reduction did not seem to be restricted to a specific sociodemographic, economic, lifestyle or clinical pattern in this study. This decrease in alcohol consumption may reflect a proactive change toward healthier behaviors among cancer patients. It may also be related to adverse effects of cancer treatments causing nausea and vomiting and limiting the desire to drink alcohol.[43] It was not surprising that a very small part of the subjects did not follow this trend observed at the population level. However, the proportion of subjects who declared no alcohol consumption before diagnosis and non-null alcohol intake after diagnosis was very limited (10%), as expected. There may be a possibility that some of these subjects reported no alcohol consumption before diagnosis because they stopped drinking alcohol due to disease symptoms. However, to avoid this type of reverse causality, we have excluded dietary and alcohol intakes measured during a 3-month period before diagnosis and results were unchanged when this period was extended to 6 months before diagnosis (data not tabulated). Besides, the mean delay between the last prediagnosis 24-h record and cancer diagnosis was about 1 year in these patients.

Second, the consumption of sweetened soft drinks decreased in this study (by −77.9 g/d in average), especially in women with breast cancer. Consistently, Yaw *et al.* observed that breast cancer patients decreased their intake of foods with a high sugar content.[28]

Third, patients decreased their meat consumption. While the effect of meat intake on cancer prognosis or recurrence

Table 5. Sociodemographic, economic, and lifestyle factors associated with a decrease in vegetable and in alcohol intakes[1] between before and after cancer diagnosis, by unconditional logistic regression analyses, NutriNet-Santé cohort, 2009–2015 ($N = 696$).

	Decrease in vegetable intake				Decrease in alcohol intake			
	Age and sex-adjusted		Multivariable[2]		Age and sex-adjusted		Multivariable[2]	
	OR [95%CI]	*p*-value	OR [95%CI]	*p*-value	OR [95%CI]	*p*-value	OR [95%CI]	*p*-value
Sex		0. 3		0.6		0.9		0.2
Male	1		1		1		1	
Female	0.84 (0.61; 1.16)		1.15 (0.68; 1.93)		0.99 (0.69; 1.44)		1.48 (0.81; 2.71)	
Age at diagnosis		0.4		0.5		0.9		0.7
≤60y	1		1		1		1	
>60y	1.18 (0.80; 1.73)		0.84 (0.53; 1.35)		1.02 (0.64; 1.62)		1.12 (0.64; 1.96)	
Cancer location		0.3		0.2		0.7		0.4
Other	1		1		1		1	
Breast	0.75 (0.51; 1.09)		0.87 (0.53; 1.44)		1.08 (0.69; 1.68)		0.88 (0.50; 1.53)	
Prostate	1.11 (0.65; 1.91)		1.67 (0.86; 3.24)		1.28 (0.71; 2.30)		1.38 (0.68; 2.80)	
Digestive	1.21 (0.71; 2.06)		1.64 (0.88; 3.04)		1.36 (0.75; 2.47)		1.52 (0.78; 2.97)	
Cancer prognosis[3]		0.9		0.4		0.8		0.9
Favorable prognosis	1		1		1		1	
Poor prognosis	0.96 (0.60; 1.54)		0.97 (0.61; 1.55)		0.95 (0.58; 1.53)		0.79 (0.47; 1.34)	
Educational level[4]		0.4[7]		0.2[7]		0.1[7]		0.07[7]
No higher education	1.15 (0.81; 1.63)		1.27 (0.85; 1.89)		1.34 (0.89; 2.01)		1.50 (0.96; 2.34)	
Undergraduate	0.84 (0.56; 1.26)		0.79 (0.50; 1.25)		1.02 (0.65; 1.60)		1.11 (0.68; 1.81)	
Postgraduate	1		1		1		1	
Professionally active after diagnosis		0.8		0.1		0.8		0.7
No[5]	1		1		1		1	
Yes	1.05 (0.74; 1.47)		1.35 (0.91; 2.00)		1.04 (0.70; 1.55)		1.11 (0.71; 1.72)	
Monthly income decrease>10% after diagnosis		0.9		0.9		0.2		0.2
No	1		1		1		1	
Yes	0.98 (0.68; 1.41)		0.99 (0.65; 1.50)		0.78 (0.52; 1.17)		0.77 (0.50; 1.21)	
Excess weight before cancer diagnosis[6]		0.4		0.5		0.9		0.7
No	1		1		1		1	
Yes	1.15 (0.84; 1.57)		1.13 (0.80; 1.60)		1.00 (0.70; 1.44)		1.08 (0.73; 1.61)	
Vegetable intake before diagnosis		<.0001		<.0001				
<245g/d (median)	1		1					
≥245g/d	4.91 (3.53; 6.83)		5.56 (3.93; 7.86)					
Alcohol intake before diagnosis						<0.0001		<0.0001
<10.3/d (median)					1		1	
≥10.3/d					2.08 (1.43; 3.03)		2.26 (1.50; 3.40)	
Energy intake variation after/before cancer diagnosis		0.03		0.01		<.0001		<.0001
< −100 kcal/d	1.65 (1.12; 2.42)		1.88 (1.22; 2.88)		2.13 (1.35; 3.36)		2.05 (1.28; 3.28)	
[−100 – +100] kcal/d	1		1		1		1	
> +100 kcal/d	1.27 (0.84; 1.91)		1.44 (0.91; 2.26)		0.51 (0.32; 0.81)		0.45 (0.28; 0.73)	

Table 5. Sociodemographic, economic, and lifestyle factors associated with a decrease in vegetable and in alcohol intakes between before and after cancer diagnosis, by unconditional logistic regression analyses, NutriNet-Santé cohort, 2009–2015 ($N = 696$). (Continued)

	Decrease in vegetable intake				Decrease in alcohol intake			
	Age and sex-adjusted		Multivariable[2]		Age and sex-adjusted		Multivariable[2]	
	OR [95%CI]	*p*-value	OR [95%CI]	*p*-value	OR [95%CI]	*p*-value	OR [95%CI]	*p*-value
Decrease in physical activity>5% after diagnosis [7,8]		0.6		0.9		0.3		0.3
No	1		1		1		1	
Yes	1.09 (0.79; 1.49)		1.10 (0.77; 1.56)		0.82 (0.57; 1.17)		0.73 (0.49; 1.08)	
Smoking status		0.9		0.9		0.4		0.3
Non-smoker	1		1		1		1	
Former smoker (stopped at cancer diagnosis)	1.07 (0.45; 2.57)		1.19 (0.46; 3.05)		1.20 (0.44; 3.32)		0.96 (0.33; 2.86)	
Smoker after cancer diagnosis	1.01 (0.54; 1.88)		0.87 (0.44; 1.72)		1.64 (0.77; 3.48)		1.84 (0.79; 4.27)	

Abbreviations: OR, Odds ratio, CI, Confidence interval.
[1]The probability of decreasing vegetable or alcohol intake by ≥5% of the intake before diagnosis is modelled.
[2]Adjusted for all variables of the table, as well as the number of 24-h dietary records.
[3]Data available for 383 participants.
[4]At baseline, that is, at inclusion in the NutriNet-Santé cohort study (before cancer diagnosis).
[5]Professionally inactive included: homemakers, on sick leave, unemployed and retired subjects.
[6]BMI ≥ 25 kg/m^2.
[7]Computed from the IPAQ questionnaire. Decrease in physical activity by 5% or more of the value before diagnosis calculated in MET .h/week.
[8]Data available for 623 participants.
[9]P-trend. Tests for linear trend were performed with the use of the ordinal score on the categories of these variables.

has not been elucidated yet, red and processed meat have been recognized as pro-carcinogens for colorectal cancer by several expert groups.[44,45] This information has been widespread by the media in occidental countries, which may explain the reduction in meat intake in digestive cancer patients.

Fourth, an increase in fruit consumption was observed in prostate cancer patients, consistent with previous studies.[21,23,24]

In contrast, less healthy dietary changes were observed in this study. Half of cancer survivors reduced their vegetable intake by at least 5% after diagnosis. Among them, the decrease in vegetable intake was about 102 g/d (>1 serving of 80 g). Previous studies generally observed an increase in vegetable intake among cancer survivors.[15,20–24,26,28] However, most of them were based on qualitative and/or retrospective data. The decrease in vegetable intake observed in our study was not associated with a degradation of monthly income following cancer diagnosis. Among possible explanations of the decrease in vegetable intake are gastrointestinal/oral symptoms[43] or fear of dietary pesticide exposure[46] which have been associated with some cancer (prostate and hematopoietic) among professional users.[47] Indeed, this trend was more specifically observed in nonorganic vegetable consumers. The latter aspect deserves further investigation to better understand motivations, fears and believes of cancer patients related to nutrition and health issues.

Similarly, cancer survivors decreased their dairy product consumption by 94 g/d after diagnosis. Steinhilper *et al.*[23] consistently found that 42% of cancer survivors decreased their dairy intake. This reduction was no compensated by an increase in soy milk or other soy product intake, which also decreased in our study. Dairy products have been subject to controversies in the last 5–10 years, with several alarming messages conveyed by the media, which may explain the observed trends. This decrease in dairy intakes should be monitored since some patients (*e.g.* breast cancers) may be at higher risk of osteoporosis due to cancer treatments.

These changes in food consumption resulted in decreased energy intake, as shown in previous studies,[12,20,25,26] but also in poorer micronutrient and fiber intakes. Only 3 studies quantified nutrient intake variations between before and after diagnosis.[20,22,27] They rather suggested a decrease in fatty acids and an increase in vitamin intakes, however, two of these studies were retrospective and the other focused on breast and colorectal cancers.

Other observed dietary changes may reflect nutritional advice received by cancer patients to prevent malnutrition during cancer treatment.[48] This might be the case for the increased intake of broths (easy to swallow and absorb in patients with digestive impairment) and sauces/fats (calorie-dense and flavor enhancer). Increase in total lipid, SFA, MUFA and vitamin E intakes are consistent with these changes in food consumption.

Despite substantial individual variations, the proportions of subjects complying with dietary recommendations were overall similar between before and after cancer diagnosis. They were higher than in the French general population, as

assessed by the ENNS study[49] (62% *vs*. 43% for fruits and vegetables, 34% *vs*. 29% for dairy products, 62% *vs*. 52% for meat/fish/eggs, and 57% *vs*. 30% for fish and seafood). However, even in this rather health-conscious population of cancer survivors, these proportions remained moderate, with a large progression margin.[50]

Strengths of this study pertained to a large population-based cohort with incident cancer cases, prospective and quantitative dietary data collected with repeated 24 hr records before and after cancer diagnosis, and information on a number of socio-demographic, economic, lifestyle and clinical indicators.

Several limitations should be acknowledged. First, caution is needed in extrapolating our results to all French cancer cases, since the NutriNet-Santé study involved volunteers who accepted to participate in a long-term survey on nutrition and health. Compared to national estimates,[51] this cohort included more women and individuals belonging to higher socio-professional categories. Besides, this study over-represented the proportion of cancers with better prognosis. Moreover, a number of cancer cases were excluded due to insufficient dietary data before or after diagnosis and some of their characteristics (cancer location, age and sex) differed from those of included cases, however food intakes after cancer diagnosis were similar between included and excluded cases with at least one 24 hr dietary record after cancer diagnosis. Finally, despite the use of validated dietary assessment tools, misreporting of dietary and alcohol intakes (due to social desirability, memory bias, or other sources or errors) could not be excluded. However, in a comparison study between a traditional interview with a dietitian and our web-based dietary assessment tool, the declared intake of cakes/biscuits/pastries was higher using the web-based method, suggesting a lower judgment bias.[34]

In conclusion, this large prospective population-based cohort provided detailed results on the variations of dietary and alcohol intakes between before and after cancer diagnosis. These results suggest that cancer diagnosis is a key period for nutritional changes, and highlight some healthy behaviors such as a decrease in alcohol and sweetened drinks consumption, while less favorable trends were also observed such as a decrease in vegetable consumption and in many vitamin and mineral intakes. An ongoing anthropological study based on biographical interviews within the NutriNet-Santé cohort will provide insights to elucidate the motivations of these dietary changes. Since dietary and alcohol consumption have been recognized as key modifiable risk factors for cancer recurrence and second cancer and for many aspects related to fatigue and quality of life, efforts are needed to encourage cancer survivors to maintain or improve their adherence to dietary recommendations.[52] The results of this study provide insights to identify and target recommendations to put forward.

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Author Contributions

The authors' responsibilities were as follows—P.F. and M.T.: designed the research; P.F. wrote the manuscript; S.H., P.G., N.D.P., E.K.G. and M.T.: conducted the research; P.F.: performed the statistical analysis; L.Z., L.L., P.B., M.T., N.D.P., P.G., P.C., H.H., P.L.M., E.K.G., J.B., S.H., M.D., M.T.: contributed to the data interpretation and revised each draft of the manuscript for important intellectual content; P.F. and M.T.: had primary responsibility for the final content of the manuscript; and all authors: read and approved the final manuscript. None of the authors reported a conflict of interest related to the study. The funders had no role in the design, implementation, analysis, or interpretation of data.

Conflict of Interest

The authors declare that they have no conflict of interest.

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