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Variations of physical activity and sedentary behavior between before and after cancer diagnosis

Results from the prospective population-based NutriNet-Santé cohort

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Abstract

Physical activity (PA) but also reduced sedentary behavior may be associated with better prognosis and lower risk of recurrence in cancer patients. Our aim was to quantify the variations in PA and time spent sedentary between before and after diagnosis, relying on prospective data in French adults. We also investigated sociodemographic and lifestyle factors associated with these variations.

Subjects (n = 942) were incident cancer cases diagnosed in the NutriNet-Santé cohort between 2009 and 2015. PA and sedentary behavior were prospectively collected with the 7-day short version of the IPAQ questionnaire every year since subjects' inclusion (i.e., an average of 2 year before diagnosis). All PA and sitting time points before and after diagnosis was compared by mixed model. Factors associated with decrease in PA and increase in sitting time were investigated using logistic regressions.

Overall and vigorous PA decreased after diagnosis ($P = 0.006$, -32.8 ± 36.8 MET-hour/week on average, in those who decreased their overall PA and $P = 0.005$, -21.1 ± 36.8 MET-hour/week for vigorous PA, respectively), especially in prostate (-39.5 ± 36.3 MET-hour/week) and skin (-35.9 ± 38 MET-hour/week) cancers, in men (-40.8 ± 46.3MET-hour/week), and in those professionally inactive (-34.2 ± 37.1 MET-hour/week) (all $P < 0.05$). Patients with higher PA level before diagnosis were more likely to decrease their PA (odds ratio [OR]: 4.67 [3.21–6.81], $P < 0.0001$). Overweight patients more likely to decrease moderate PA (OR: 1.45 [1.11–1.89], $P = 0.006$) and walking (OR: 1.30 [1.10–1.70], $P = 0.04$). Sitting time increased ($P = 0.02$, $+2.44 \pm 2.43$ hour/day on average, in those who increased their sitting time), especially in women ($+2.48 \pm 2.48$ hour/day), older patients ($+2.48 \pm 2.57$ hour/day), and those professionally inactive (2.41 ± 2.40 hour/day) (all $P < 0.05$). Patients less sedentary before diagnosis were more likely to increase their sitting time (OR: 3.29 [2.45–4.42], $P < 0.0001$).

This large prospective study suggests that cancer diagnosis is a key period for change in PA and sedentary behavior. It provides insights to target the subgroups of patients who are at higher risk of decreasing PA and increasing sedentary behavior after cancer diagnosis.

Abbreviations: BMI = body mass index, CI = confidence interval, IPAQ = International Physical Activity Questionnaire, MET = metabolic equivalent task, OR = odds ratio, PA = physical activity.

Keywords: cancer survivors, physical activity, prospective cohort, sedentary behavior, variations

Editor: Scott Langevin.

Funding/support: The present work was supported by the 2013 Research Prize from the French Nutrition Society (SFN) and the French National Cancer Institute (INCa, no. DEPREV14-027). PF and MD were funded by PhD grants from the Cancéropôle Ile-de-France (public funding from the Paris region). The NutriNet-Santé study was supported by the following public institutions: Ministère de la Santé, Institut de Veille Sanitaire (InVS), Institut National de la Prévention et de l'Education pour la Santé (INPES), Fondation pour la Recherche Médicale (FRM), Institut National de la Santé et de la Recherche Médicale (INSERM), Institut National de la Recherche Agronomique (INRA), Conservatoire National des Arts et Métiers (CNAM), and Université Paris 13.

The authors have no conflict of interest to disclose.

Supplemental Digital Content is available for this article.

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Medicine (2016) 95:40(e4629)

Received: 17 March 2016 / Received in final form: 27 June 2016 / Accepted: 22 July 2016

http://dx.doi.org/10.1097/MD.0000000000004629

1. Introduction

Cancer incidence is expected to increase by 75% worldwide by 2030.[1] Previous research showed that cancer survivors are significantly more likely to develop secondary complications – such as new cancers – and to experience decline in their quality of life compared to individuals with no previous experience of cancer.[2,3]

Many studies showed that physical activity (PA) exerts beneficial effects in cancer survivors[2,4–8] potentially through its action on levels of insulin, IGFs, IGFBPs, and inflammatory biomarkers.[9] A recent meta-analysis observed an inverse dose–response association between PA and all-cancer mortality.[2] Several studies on breast cancer patients observed that moderate PA decreased the risk of breast cancer mortality, recurrence, progression, or new primary cancer[6] and improved prognosis.[5] A meta-analysis recently showed that PA performed before or after cancer diagnosis was related to reduced mortality risk among breast and colorectal cancer survivors.[4] Decrease in postdiagnosis PA was also associated with higher fatigue, anxiety, depression, and stress.[7]

Previous studies described PA of cancer survivors[3,10–32] and some investigated PA variations after cancer diagnosis.[4,10–15,17–23,25–29] Most of them[10–12,14,18,19,21–23,26,27,29] – but not all[13,17,25,28] – suggested an overall deterioration of PA level after diagnosis. Some studies investigated factors associated with these variations of PA and suggested an influence of cancer location,[16] disease stage,[13,14,20,21,29] cancer-related treatments,[10,17–19,21,23,29] age,[10,17,18,20–22,29] sex,[16,23] occupational status,[10,13,14,21,22] education,[10,18,20,23,33,34] PA level before diagnosis,[13,14,18,22,31] weight,[15,18,20,22,23,29] and smoking status.[14,20,21,23] However, these studies had limitations because most of them did not collect data regarding PA before cancer diagnosis and therefore were mostly focused on PA variation after diagnosis.[10–12,14,15,21,25,26,28] Few studies provided information on PA before diagnosis[13,17–20,22,23,29] and most of those that did relied on a retrospective assessment of prediagnosis PA. To our knowledge, only 1 study, focused on prostate cancer,[13] investigated PA changes between before and after cancer diagnosis with PA data collected prospectively, which lowers memory bias and substantially increases data quality. In addition, very few studies investigated a wide range of potential predictors of PA variations in the same dataset.[18,19,22]

Literature regarding sedentary behavior (i.e., any waking behavior characterized by an energy expenditure ≤1.5 metabolic equivalent of tasks [METs]) in cancer patients is limited.[3,14,15,29,34–36] The few available studies focused on postdiagnosis variations only[14,15] or used retrospective prediagnosis data.[29,37] Few studies investigated demographic and lifestyle factors associated with sedentary behavior such as age,[14,19,35,36] sex,[34,35] occupational status,[14,34–36] weight,[14,15,29,34,35] and smoking status.[14,35]

The aim of this study was to quantify the variations in PA and time spent in sedentary behavior (overall and by sex, age, employment status, cancer location, and cancer prognosis) between before and after cancer diagnosis in a large cohort of French adults, relying on prospective data. We also investigated socio-demographic, economic, lifestyle, and clinical factors associated with decrease in PA (overall and by category of intensity) and increase in time spent in sedentary behavior.

2. Material and methods

2.1. The NutriNet-Santé cohort

The NutriNet-Santé study is a large 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.[38] Participants are recruited by vast multimedia campaigns. Inclusion criteria are age ≥18 years and access to the Internet. Participants register 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 no 0000388FWA00005831) and the "Commission Nationale de l'Informatique et des Libertés" (CNIL no 908450/no 909216). Electronic consent was signed by all participants.

2.2. 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).[39] All first incident cancers were considered as cases in this study, except basal cell carcinoma, which were not considered as cancer.

For the 4 main cancer locations represented in this study (breast, prostate, skin, and colon-rectum), 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, human epidermal growth factor receptor 2 status, Ki67, and treatment (chemotherapy, surgery, radiotherapy, and/or hormonotherapy); for prostate cancer: tumor size, lymph node status, PSA, Gleason score, and treatment; for melanoma: Breslow index and Clark level; for squamous cell carcinoma: type of tumor (invasive or in situ); for colorectal cancer: tumor size, lymph node status, and treatment. Given the small number of advanced stages for each tumor location, the use of tumor nodes metastases/union for international cancer control stages was not discriminating, thus, patients were classified into 2 categories (favorable prognosis/poor prognosis, available for 85% of breast cancers, 68% of prostate cancers, 92% of skin cancers, and 70% of colon-rectum cancers) according to cancer-specific clinically relevant factors, as described in footnotes to Table 1.

2.3. Data collection

At baseline and each year thereafter, participants completed a set of 5 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 (3 nonconsecutive 24-hour dietary records), PA (validated 7-day short form of the International Physical Activity Questionnaire [IPAQ] questionnaire),[37] and health status. These

Table 1

Sociodemographic, economic, anthropometric, and lifestyle characteristics of incident cancer cases, NutriNet-Santé cohort, 2009 to 2015 (N=942).

	Mean	SD
Age at diagnosis, years	58.8	10.7
Delay between inclusion and diagnosis, months	25.4	14.5
Total PA (MET-hour/week) before cancer diagnosis	53.4	47.3
Physical activity of vigorous intensity (MET-hour/week) before cancer diagnosis	24.4	30.1
Physical activity of moderate intensity (MET-hour/week) before cancer diagnosis	14.3	16.7
Walking (MET-hour/week) before cancer diagnosis	14.7	14.9
Total PA (MET-hour/week) after cancer diagnosis	48.6	41.7
Physical activity of vigorous intensity (MET-hour/week) after cancer diagnosis	20.9	27.1
Physical activity of moderate intensity (MET-hour/week) after cancer diagnosis	13.9	15.4
Walking (MET-hour/week) after cancer diagnosis	13.8	13.1
Sitting time (hour/day) before cancer diagnosis	5.25	3.40
Sitting time (hour/day) after cancer diagnosis	5.47	2.94
	N	**%**
Sex		
Male	315	33.4
Female	627	66.6
Professionally active after diagnosis		
Yes	282	29.9
No*	660	70.1
Monthly income (€ per household unit)†		
<1800	320	34.0
1800–2700	275	29.2
>2700	347	36.8
Educational level†		
Up to secondary education	419	44.5
Under graduate	238	25.3
Postgraduate	285	30.3
Smoking status		
Never smoker	833	88.4
Former smoker (stopped at cancer diagnosis)	31	3.3
Smoker after cancer diagnosis	78	8.3
Overweight after diagnosis‡		
No	563	59.8
Yes	379	40.2
Energy intake variation before/after cancer diagnosis§		
<−100 kcal/day	269	44.5
[−100 to +100] kcal/day	145	24.0
>+100 kcal/day	190	31.5
Cancer location		
Breast‖	342	36.3
Favorable prognosis	190	65.1
Poor prognosis	102	34.9
Prostate¶	152	16.1
Favorable prognosis	59	57.3
Poor prognosis	44	42.7
Skin#	102	10.8
Favorable prognosis	18	19.1
Poor prognosis	76	80.9
Colon-rectum**	67	7.1
Favorable prognosis	9	19.2
Poor prognosis	38	80.9
Other††	279	29.6

BMI=body mass index, ER=estrogen receptor, MET=metabolic equivalent task, PA=physical activity, PR=progesterone receptor, PSA=prostate specific antigen, SD=standard deviation.

* Professionally inactive included: homemakers, sick leave, unemployed and retired subjects.

† At baseline, that is at inclusion in the NutriNet-Santé cohort study.

‡ BMI ≥ 25 kg/m^2.

§ Available for 604 participants.

‖ Tumor size <2 cm or node-negative or (tumor size <1 cm and negative ER/PR receptors)=favorable prognosis; tumor size ≥2 cm or node-positive or (tumor size ≥1 cm and positive ER/PR receptors)=poor prognosis. Data available for 292 participants.

¶ 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 103 participants.

\# Squamous cell carcinoma=favorable prognosis; melanoma=poor prognosis. Data available for 94 participants.

** (Cancer T1/T2 and node-negative) or no chemotherapy=favorable prognosis; (cancer T3/T4 and node-positive) or chemotherapy=poor prognosis. Data available for 47 participants.

†† Other cancer locations were: 36 thyroid, 28 non-Hodgkin lymphomas, 23 bladder, 21 lung, bronchus or pleura, 19 cervix, 26 other uterus, 19 leukemia, 14 kidney, 17 lip, mouth, tongue, pharynx or larynx, 10 ovary, 10 pancreas, 7 Hodgkin lymphomas, 4 brain, 4 liver or gallbladder, 4 esophagus, 1 stomach, and 36 representing less than 1% of cancer locations (ex: liposarcoma).

instruments have been tested against traditional assessment methods (paper-and-pencil questionnaires or interview by a dietitian).[40–42] Intermediate self-administered questionnaires were also used to collect weight, height, and dietary data every 6 months.

The IPAQ questionnaire[37] is a validated tool, based on 3 specific types of PA: walking, activities of moderate intensity (e.g., cycling at a regular pace, carrying light loads), and activities of vigourous intensity (e.g., heavy lifting, aerobics, and fast cycling). Each activity was assigned a MET score based on the classification by Ainsworth et al[43]: 3.3 for walking, 4 for moderate, and 8 for vigorous intensity activities. The total of MET-hour/week was computed overall and for each type of PA. As usually done, time spent sitting (in hour/day) was taken as an indicator of overall sedentary behavior.[44] Additional information on the IPAQ is provided in Appendix 1, http://links.lww.com/MD/B337.

2.4. Statistical analysis

All available information on PA and time spent sitting provided before and after diagnosis were used, so long as such data were provided sooner than 3 months prior to diagnosis and 6 months or more following diagnosis, in order to focus on stable periods. In other words, we did not use data provided during a 9-month window (3 months prediagnosis and 6 months postdiagnosis).

From the 1842 cancer cases diagnosed in the NutriNet-Santé study between May 2009 and August 2015 and with at least 6 months of follow-up after diagnosis, 1516 cases were 1st incident cancers. We excluded 552 patients with missing IPAQ before or after cancer diagnosis (among which 352 subjects who provided PA data only in the 3 months prediagnosis and 6 months postdiagnosis window) and 22 pregnant women, leaving 942 cancer cases for analysis.

For each subject, mean PA before (respectively after) diagnosis was calculated as the average of all PA data (in MET-hour/week, overall and by intensity) before (respectively after) diagnosis. Similarly, variations between before and after diagnosis in sitting time (hour/day) and in mean daily energy intake (kcal/day) were calculated. Analysis of variance models were used to verify the stability of PA and sitting time measurements before (respectively after) cancer diagnosis. Mean body mass index (BMI = weight (kg)/height (m)^2) was calculated as the mean of all BMI data available since 6 months after diagnosis. Otherwise mentioned, baseline socio-demographic data were used for the present analysis. Less than 5% of values were missing for all covariates and were replaced by the mode, except for energy intake, and tumor characteristics, for which a "missing" class was created, as detailed in Table 1.

We fit mixed models using all available information on PA and time spent sitting provided before and after diagnosis (excluding the 3 months prediagnosis and 6 months postdiagnosis window), with cancer diagnosis and time points as random effects. These models were used overall and by sex, age at diagnosis, occupational status after diagnosis (professionally active or not), and cancer location. We also assessed the percentages of subjects who reached or exceeded 150 minute/week of "moderate" or "vigorous" PA before and after diagnosis, which corresponds to the recommendation for the general population[45] as for cancer survivors[46] in several countries.

Age and sex-adjusted unconditional logistic regression analyses were used to investigate the factors associated with a substantial decrease in PA and an increase in sitting time (i.e., more than 10% of the initial value before diagnosis). Odds ratios (ORs) and 95% confidence intervals (CIs) were computed. Studied socio-demographic, economic, lifestyle, and clinical factors were: PA level and sitting time before diagnosis, baseline monthly income and educational level, variation of daily energy intake and smoking status between before and after diagnosis, excess weight after diagnosis, and for main cancer locations, cancer-related treatments, and clinical characteristics (as listed above). Tests for linear trends were performed across categories in logistic regression models with the use of the ordinal value of the following variables: sitting time before diagnosis, income, educational level, and variation of energy intake.

P-value < 0.05 was considered statistically significant. All tests were 2-sided. Analyses were carried out with SAS 9.3 (SAS Institute Inc, Cary, NC).

3. Results

Characteristics of the study population are presented in Table 1. Women represented 67% of the subjects. Mean age at diagnosis was 59 years (SD = 10.7). Mean time between inclusion in the cohort and cancer diagnosis was 25 months (SD = 14.5) and mean time of follow-up after diagnosis was 42 months (SD = 16.7). Mean number of completed IPAQ questionnaires per subject was 2.03 ± 1.08 before and 2.01 ± 1.08 after cancer diagnosis. Main cancer locations were: breast (n = 342), prostate (n = 152), skin (n = 102), and colon-rectum (n = 64). Mean PA level was 53.0 MET-hour/week before and 48.2 MET-hour/week after diagnosis. Mean time spent sitting was 5.25 hour/day before 5.47 hour/day after diagnosis. Age at diagnosis was similar between included and excluded cases but the proportions of breast (35.9% vs 34.5%), prostate (16.0% vs 7.4%), and skin (10.6%s 8.3%) cancers, as well as the proportions of men (33.4% vs 25.2%) and of cancers of favorable prognosis (59.9% vs 48.3%) were higher in included cases compared to excluded cases (P < 0.05).

Variations in PA between before and after cancer diagnosis are described in Table 2. Total PA significantly decreased after diagnosis (P = 0.006), especially in patients diagnosed after 60 years (P = 0.03), in men (P = 0.005), in those who were professionally inactive after diagnosis (P = 0.01), and in patients with prostate (P = 0.02) or skin cancers (P = 0.01). These results were clearly driven by vigorous PA, while no variation was observed for PA of moderate intensity (P = 0.3) or walking (P = 0.5). Variations in PA between before and after diagnosis were similar according to the severity of the cancer. Figure 1 presents the variations of PA (overall and by intensity) before and after cancer diagnosis. The PA values before diagnosis were not statistically different. Similarly there was no difference between PA values after cancer diagnosis.

A total of 66.5% of the participants complied with the recommendation of 150 minute/week of moderate-to-vigorous PA before cancer diagnosis. Among them, 74.3% still complied with this recommendation after diagnosis, while 25.7% no longer attained this recommended level. Conversely, 33.5% of the participants did not attain the recommendation before diagnosis. Among them, 39.9% complied with the recommendation after diagnosis, while 60.1% still did not attain this recommended level (data not tabulated).

Table 3 presents the variations in sitting time between before and after cancer diagnosis. Sitting time increased overall (P = 0.02) and especially in those diagnosed after 60 years (P = 0.003), in women (P = 0.002), and in those who were professionally

Table 2

Variation of physical activity in MET-hour/week between before and after cancer diagnosis according to individual and cancer related factors, Nutrinet-santé cohort, 2009 to 2015 (N = 942).

	Total physical activity				Physical activity of vigorous intensity				Physical activity of moderate intensity				Walking			
			PA decrease[‡]	PA increase[§]			PA decrease[‡]	PA increase[§]			PA decrease[‡]	PA increase[§]			PA decrease[‡]	PA increase[§]
	β[*]	*P*[†]	Mean ± SD	Mean ± SD	β[*]	*P*[†]	Mean ± SD	Mean ± SD	β[*]	*P*[†]	Mean ± SD	Mean ± SD	β[*]	*P*[†]	Mean ± SD	Mean ± SD
Overall	−298.36	0.006	−32.8 ± 36.8	27.8 ± 28.8	−215.33	0.005	−21.1 ± 25.8	21.3 ± 24.3	−42.58	0.3	−11.3 ± 14.2	11.4 ± 12.1	−24.29	0.5	−10.5 ± 11.9	8.1 ± 9.2
Age at diagnosis																
≤60y	−261.86	0.07	−32.8 ± 40.6	24.1 ± 25.7	−202.73	0.05	−20.2 ± 27.9	19.6 ± 22.4	−20.89	0.7	−10.2 ± 13.9	10.1 ± 10.5	1.42	0.9	−10.8 ± 13.9	7.5 ± 8.9
>60y	−331.20	0.03	−32.6 ± 33.1	31.5 ± 31.1	−218.01	0.05	−22.1 ± 23.6	22.7 ± 25.6	−60.59	0.3	−12.3 ± 14.4	12.8 ± 13.3	−33.29	0.5	−10.1 ± 9.8	8.7 ± 9.5
Sex																
Male	−605.29	0.005	−40.8 ± 46.3	28.7 ± 30.1	−394.53	0.006	−26.6 ± 30.3	23.6 ± 27.1	−128.59	0.1	−13.5 ± 16.4	12.6 ± 11.5	−58.78	0.3	−11.4 ± 12.2	8.3 ± 9.2
Female	−126.27	0.3	−28.7 ± 30.0	27.4 ± 28.1	−98.62	0.3	−18.3 ± 22.7	20.2 ± 22.7	10.47	0.8	−10.1 ± 12.7	10.9 ± 12.3	−1.84	0.9	−10.0 ± 11.7	8.0 ± 9.3
Professionally active after diagnosis																
No[‖]	−328.87	0.01	−34.2 ± 37.1	29.3 ± 28.8	−228.45	0.01	−22.7 ± 25.1	22.1 ± 23.5	−51.83	0.3	−12.4 ± 15.1	12.8 ± 12.8	−39.15	0.3	−10.4 ± 11.1	8.1 ± 9.0
Yes	−203.11	0.2	−29.3 ± 35.8	24.7 ± 28.6	−167.09	0.2	−17.7 ± 27.1	19.4 ± 26.0	−18.51	0.8	−8.3 ± 10.8	8.9 ± 10.1	42.59	0.5	−10.5 ± 13.7	8.2 ± 9.7
Main cancer locations																
Breast	95.34	0.5	−26.2 ± 27.7	28.3 ± 29.7	16.43	0.9	−17.6 ± 21.5	23.0 ± 25.9	61.50	0.3	−9.1 ± 11.5	10.9 ± 11.9	68.49	0.2	−9.3 ± 9.9	8.3 ± 9.3
Prostate	−584.35	0.02	−39.5 ± 36.3	28.0 ± 26.6	−294.73	0.1	−25.9 ± 25.3	20.8 ± 23.5	−180.94	0.1	−13.5 ± 14.9	13.5 ± 11.9	−109.73	0.2	−10.9 ± 10.5	7.5 ± 7.1
Skin	−745.50	0.01	−35.9 ± 38.0	22.8 ± 22.6	−745.50	0.0009	−22.9 ± 29.5	12.9 ± 13.9	−130.71	0.8	−10.9 ± 11.7	11.1 ± 12.6	−74.77	0.5	−12.0 ± 13.3	8.9 ± 9.4
Colon–rectum	33.77	0.9	−27.3 ± 26.5	25.3 ± 24.4	40.64	0.8	−15.4 ± 16.8	21.1 ± 19.8	61.23	0.6	−8.5 ± 9.8	11.4 ± 13.6	−37.37	0.7	−9.9 ± 11.3	7.9 ± 11.7

PA = physical activity, MET = metabolic equivalent task, SD = standard deviation.

[*] β for the "cancer diagnosis" 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 the PA level before diagnosis is compared to the level after diagnosis for each subject, no adjustment for individual characteristics is performed (before and after diagnosis values are matched for each cancer patient).

[†] p-value for cancer effect in mixed model.

[‡] Decrease in MET-hour/week in patients who decreased their physical activity (N = 507 [53.8%] for total physical activity, 551 [(58.5%] for vigorous intensity, 491 [52.1%] for moderate intensity, and 456 [48.4%] for walking).

[§] Increase in MET-hour/week in patients who increased their physical activity (N = 435 [46.2%] for total physical activity, 391 [41.5%] for vigorous intensity, 451 [47.9%] for moderate intensity, and 486 [(51.6%] for walking).

[‖] Professionally inactive included: homemakers, sick leave, unemployed, and retired subjects.

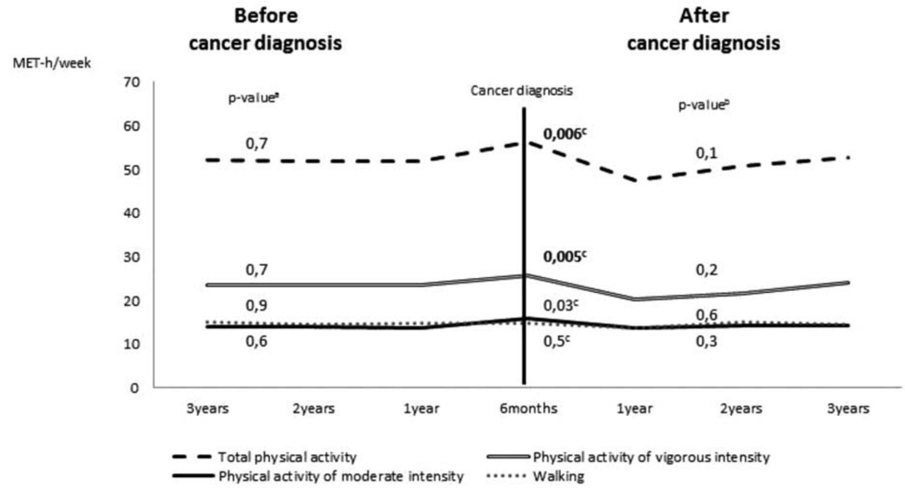

Figure 1. Variation in physical activity (overall and by intensity) before and after cancer diagnosis, [a]analysis of variance (ANOVA) test comparing all physical activity values before cancer diagnosis, [b]ANOVA test comparing all physical activity values after cancer diagnosis, and [c]P for the comparison of physical activity levels between before and after cancer diagnosis by mixed models.

inactive after diagnosis ($P=0.005$). Variations in sitting time before/after diagnosis were similar according to the severity of the cancer (data not tabulated).

Socio-demographic, economic, and lifestyle factors associated with a decrease in PA are presented in Table 4. Patients who were highly physically active before cancer diagnosis (OR=4.67, 95% CI: 3.21–6.81, $P_{trend}<0.0001$) were more likely to decrease their total PA after diagnosis. Overweight patients were more likely to decrease their moderate PA (OR=1.45, 95% CI: 1.11–1.89, $P=0.006$) and walking (OR=1.30, 95% CI: 1.10–1.70, $P=0.04$) after diagnosis, compared to normal-weight patients. The association between the same socio-demographic, economic and lifestyle factors, and increase in sitting time has also been investigated. None was observed, except that patients who were less sedentary before cancer diagnosis were more inclined to increase their sitting time after diagnosis ($P<0.0001$, OR ≤ 5 vs >5 hour/day=3.29, 95% CI [2.45–4.42], data not tabulated).

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], and Breslow index and Clark level [for skin melanoma]) were not associated with the

Table 3

Variation of sitting time (in hour/day) between before and after cancer diagnosis according to individual and cancer-related factors, NutriNet-santé cohort, 2009 to 2015 (N=942).

			Sitting time variation, hour/day	
			Decrease in sitting time‡	Increase in sitting time§
	β*	P†	Mean ± SD	Mean ± SD
Overall	0.3	0.02	−1.72 ± 1.75	2.44 ± 2.43
Age at diagnosis				
≤60 years	0.06	0.8	−1.98 ± 1.84	2.40 ± 2.29
>60 years	0.41	0.002	−1.48 ± 1.62	2.48 ± 2.57
Sex				
Male	0.06	0.7	−1.72 ± 1.85	2.34 ± 2.34
Female	0.36	0.02	−1.72 ± 1.69	2.48 ± 2.48
Professionally active after diagnosis				
No‖	0.35	0.005	−1.54 ± 1.67	2.41 ± 2.40
Yes	0.04	0.9	−2.15 ± 1.85	2.51 ± 2.54
Main cancer locations				
Breast	0.35	0.07	−1.75 ± 1.63	2.50 ± 2.43
Prostate	0.09	0.9	−1.84 ± 2.11	2.24 ± 2.54
Skin	0.51	0.08	−1.68 ± 1.66	2.17 ± 2.32
Colon-rectum	0.46	0.2	−1.22 ± 1.23	2.70 ± 2.59

SD=Standard deviation.

* β for the “cancer diagnosis” 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 sitting time before diagnosis is compared to sitting time after diagnosis for each subject, no adjustment for individual characteristics is performed (before and after diagnosis values are matched for each cancer patient).

† P-value for cancer effect in mixed model.

‡ In patients who decreased their sitting time N=502 (53.3%).

§ In patients who increased their sitting time N=440 (46.7%).

‖ Professionally inactive included: homemakers, sick leave, unemployed, and retired subjects.

Table 4

Socio-demographic, economic and lifestyle factors associated with a decrease in physical activity[*] between before and after cancer diagnosis, by unconditional logistic regression analyses[†], NutriNet-Santé cohort, 2009 to 2015 (N=942).

	Overall physical activity		Physical activity of vigorous intensity		Physical activity of moderate intensity		Walking	
	OR [95%CI]	*P*	OR [95%CI]	*P*	OR [95%CI]	*P*	OR [95%CI]	*P*
Classification of the subjects according to their total level of PA before cancer diagnosis[‡]		<0.0001[§]		<0.0001[§]		0.02[§]		<0.0001[§]
1	4.67 [3.21–6.81]		1.89 [1.32–2.81]		1.48 [1.04–2.10]		2.11 [1.47–3.02]	
2	1.43 [0.99–2.07]		0.91 [0.64–1.29]		1.06 [0.75–1.50]		1.33 [0.93–1.90]	
3	1		1		1		1	
Monthly income (€ per household unit)[||]		0.06[§]		0.7[§]		0.09[§]		0.4[§]
<1800	1.37 [1.01–1.86]		0.95 [0.69–1.29]		1.33 [0.98–1.82]		1.14 [0.84–1.55]	
1800–2700	0.92 [0.67–1.26]		0.91 [0.66–1.26]		0.69 [0.50–0.95]		0.78 [0.57–1.08]	
>2700	1		1		1		1	
Educational level[||]		0.6[§]		0.4[§]		0.9[§]		0.6[§]
Up to secondary education	1.08 [0.80–1.46]		1.13 [0.83–1.54]		1.01 [0.74–1.36]		1.09 [0.81–1.48]	
Under graduate	1.01 [0.71–1.42]		0.99 [0.70–1.41]		1.05 [0.74–1.48]		1.19 [0.84–1.68]	
Post graduate	1		1		1		1	
Overweight after cancer diagnosis[¶]		0.1		0.3		0.006		0.04
No	1		1		1		1	
Yes	1.24 [0.95–1.61]		1.16 [0.89–1.51]		1.45 [1.11–1.89]		1.30 [1.10–1.70]	
Smoking status		0.1		0.04		0.9		0.1
Never smoker	1		1		1		1	
Former smoker (stopped at cancer diagnosis)	0.61 [0.29–1.30]		0.51 [0.24–1.06]		0.86 [0.42–1.78]		0.79 [0.38–1.66]	
Smoker after cancer diagnosis	1.43 [0.89–2.30]		1.51 [0.92–2.50]		0.97 [0.61–1.56]		1.63 [1.01–2.62]	
Energy intake variation before/after cancer diagnosis[#]		0.3[§]		0.3[§]		0.06[§]		0.7[§]
<−100 kcal/day	0.83 [0.55–1.24]		1.17 [0.78–1.76]		0.78 [0.52–1.17]		0.81 [0.54–1.22]	
[−100 to +100] kcal/day	1		1		1		1	
>+100 kcal/day	0.66 [0.42–1.02]		0.95 [0.61–1.46]		1.11 [0.72–1.72]		0.74 [0.48–1.15]	

BMI=body mass index, CI=confidence interval, IPAQ=International Physical Activity Questionnaire, OR=odds ratio PA=physical activity.

[*] The probability of decreasing physical activity by 10% or more of the value before diagnosis is modelled.

[†] Age and sex-adjusted.

[‡] Computed from the IPAQ questionnaire, reference[37]: 1, subjects highly physically active; 2, subjects with intermediate level of total PA; and 3, subjects with low level of total PA.

[§] *P*-trend. Tests for linear trend were performed with the use of the ordinal score on the categories of these variables.

[||] At baseline, that is, at inclusion in the NutriNet-Santé cohort study (before cancer diagnosis).

[¶] BMI ≥ 25 kg/m^2.

[#] Data available for 604 participants.

variation in PA or sitting time in this study (all $P > 0.05$, data not tabulated).

In sensitivity analyses, all results were similar after excluding subjects who had a 2nd primary cancer or cancer recurrence during follow-up (n = 32). Similar trends were observed when excluding PA or sitting time data collected less than 1 year after cancer diagnosis, although some results became nonsignificant, probably due to loss of statistical power (data not shown).

4. Discussion

This study investigated the variations in PA and sitting time between before and after cancer diagnosis. Although previous studies used only postdiagnosis PA data or retrospective prediagnosis data, our results are based on prospective data with a follow-up beginning on average 2 years before diagnosis. We observed a decline in overall and vigorous PA after diagnosis, especially in prostate and skin cancers, in men, professionally inactive patients, and in those with higher PA level before diagnosis. Overweight patients were more likely to decrease their moderate PA and walking compared to normal weight patients. Concomitantly, we observed an increase in sitting time after diagnosis, especially in women, older subjects, professionally inactive patients, and in those less sedentary before diagnosis.

Although PA has been recognized as a key modifiable factor for limiting cancer recurrence and mortality, our study highlighted a substantial decrease in PA – mostly vigorous PA – after cancer diagnosis. Besides, this trend was not offset by any increase in moderate PA or walking. Although a few studies observed an increase in PA,[13,17,25,28] most were consistent with our results and observed a decrease in PA after cancer diagnosis.[10–12,14,18,19,21–23,26,27] For instance, Littman et al[22] observed that mean PA levels decreased by 50% within 12 months after breast cancer diagnosis. Irwin et al[29] observed that cancer-diagnosed patients decreased their total PA and estimated the decrease to 2.0 hour/week postdiagnosis. Huy et al[19] showed that patients decreased PA during cancer treatment from 36 to 14 MET-hour/week. Several studies consistently observed that the decline in PA after diagnosis was mainly related to vigorous activities.[17,19,22,26] These results are consistent with the fact that it might be more difficult for cancer survivors to achieve the PA recommendations due to cancer itself and/or long-term cancer-related treatment effects. Figure 1 visually suggests an increase in overall and vigorous PA at the end of follow-up (from 2 years after cancer diagnosis). However, this trend was not statistically significant in analysis of variance models ($P = 0.1$ and 0.2, respectively) and deserves further investigation in a few years, when 3 to 5 years of follow-up will be reached for all cancer cases.

A recent meta-analysis[47] of randomized controlled trials showed very promising results regarding PA interventions in cancer patients, leading to significant improvements in PA level, BMI, and quality of life. The present study identified several characteristics of cancer patients more specifically at risk of decreasing their PA level after cancer diagnosis. This could help oncologists and patient care program coordinators to better target PA interventions.

Patients who were professionally inactive after diagnosis were more inclined to reduce their PA level. This result is consistent with previous studies[10,14,21] and may be explained by the fact that professional activity allows the patients to maintain an active life, including a part of occupational PA.

As observed before,[15,18,20,22,23,29] the fact that overweight patients were more inclined to decrease their moderate PA and walking after cancer diagnosis is of concern since these patients are more at risk of poor prognosis and cancer recurrence and since PA contributes to weight management.

Logically, patients who had a higher level of PA before diagnosis – and thus a larger room for decrease – were more inclined to reduce PA after cancer diagnosis, in line with previous findings.[14,22] This is consistent with the fact that men – who were those with higher levels of prediagnosis PA – were more likely to reduce PA after diagnosis, as shown in previous studies.[10,16,17,21–23,29,33] Consistently, this may explain why men with prostate cancer showed substantial decrease in PA after diagnosis.

Unlike previous studies that observed a relationship with cancer-related treatments,[10,17–19,21,23,29] we did not find any association between cancer treatments and variations in PA, which is consistent with some other studies.[20,24,33,34] Similarly, we did not observe any association with other clinical cancer characteristics. However, medical records were available for all cancer cases but exhaustive clinical data were not systematically recorded in these files. Missing values for clinical factors lead to reduced statistical power for these analyses, which may have impaired our ability to detect some of the hypothesized associations.

Sedentary behavior has also been suggested as an independent risk factor of poorer prognosis.[48] We observed an increase in sitting time (as a proxy of sedentary behavior) after cancer diagnosis, which is consistent with the few available previous studies.[14,29] A recent French survey on 60 breast cancer patients found that sitting and lying time increased by 30 minute/day between diagnosis and chemotherapy onset.[14] A US study on 812 breast cancer survivors observed that time spent in sedentary behavior increased from pre- to postdiagnosis, in the range of 1.3 to 8.0 hour/week.[29] In our study, women, older subjects, professionally inactive patients, and those who spent less time sitting before diagnosis were more inclined to increase their sitting time. These results are consistent with previous studies that found associations between time spent in sedentary behavior and sex,[34] age,[14,29,36] and professional activity.[14,34,36]

Strengths of this study pertained to a large population-based cohort with incident cancer cases, prospective data on PA and sedentary behavior collected before and after cancer diagnosis, details regarding the intensity of PA, and information on a number of socio-demographic, economic, lifestyle, and clinical indicators.

However, several limitations should be acknowledged. First, caution is needed when extrapolating our results to all French cancer cases, since the NutriNet-Santé study involved people who voluntarily accepted to take part in a survey on nutrition and health. Compared to national estimates,[49] this cohort included more women and individuals belonging to higher socio-professional categories. Then, this study overestimated the proportion of cancers with better prognosis. Besides, a number of cancer cases were excluded due to missing PA data before or after diagnosis and some of their characteristics (cancer location, sex, and cancer prognosis) were different from those of included cases. Next, the IPAQ questionnaire did not allow us to distinguish between the different types of walking (slow vs brisk walking). Thus, only the IPAQ categories corresponding to "moderate" and "vigourous" intensities were considered to calculate the proportion of subjects who complied with the recommendation of 150 minute/week of moderate-to-vigorous PA. This probably underestimated the proportion of subjects who reached the recommendation.

However, a strong underestimation is unlikely since the IPAQ rather tends to overestimate daily PA overall.[50] Finally, sedentary behavior was only assessed by a single question on time spent sitting.

In conclusion, this large cohort of cancer patients provided detailed prospective results on the variations of PA and sitting time between before and after cancer diagnosis and their correlates. Our results suggest that cancer diagnosis is a key period for change in PA and sedentary behavior. The substantial decrease in vigorous PA and increase in sedentary behavior observed in this study were not compensated by a parallel increase in moderate PA or walking, which remained stable. Since PA and sedentary behaviors have been recognized as key modifiable risk factors for recurrence and 2nd cancer, and for many aspects related to fatigue and quality of life, efforts are needed to encourage cancer survivors to maintain or improve their level of PA after cancer diagnosis. This could be achieved by recommendations provided by health care professionals and well-designed PA programs, as proposed by the US National Comprehensive Cancer Network.[46] Efforts could possibly be directed toward the improvement in PA of moderate intensity, in order to offset the decrease in PA of vigorous intensity. Results of the present study provide insights to identify and target the subgroups of patients who are more specifically at-risk of decreasing PA and increasing time spent to sedentary behaviors after a diagnosis of cancer.

Acknowledgments

The authors thank Ludivine Ursule for her assistance to the medical team. The authors also thank Younes Esseddik, Paul Flanzy, Mohand Ait Oufella, Yasmina Chelghoum, Than Duong Van, and Mac Rakotondrazafy (computer scientists); Nathalie Arnault, Véronique Gourlet, Dr. Fabien Szabo, Charlie Ménard, Laurent Bourhis, and Stephen Besseau (data-manager/biostatisticians) for their technical contribution to the NutriNet-Santé study;and all the volunteers of the NutriNet-Santé cohort.

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