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Cancers related to lifestyle and environmental factors in France in 2015

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Abstract ***Background:*** Cancer is a major cause of premature illness and death in France. To quantify how cancer prevention could reduce the burden, we present estimates of the contribution of lifestyle and environmental risk factors to cancer incidence in France in 2015, comparing these with other high-income countries.
Method: Prevalences of, and relative risks for tobacco smoking, alcohol consumption, inadequate diet, overweight and obesity, physical inactivity, exogenous hormones, suboptimal breastfeeding, infectious agents, ionising radiation, air pollution, ultraviolet exposure, occupational exposures, arsenic in drinking water and indoor benzene were obtained to estimate the population attributable fraction (PAF) and the number of attributable cancers by the cancer site and sex.
Results: In 2015, 41% (or 142,000 of 346,000) of all new cancers diagnosed in France could be attributed to the aforementioned risk factors. The numbers and PAF were slightly higher in

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men than in women (84,000 versus 58,000 cases and 44% versus 37%, respectively). Smoking (PAF: 20%), alcohol consumption (PAF: 8%), dietary factors (PAF: 5%) and excess weight (PAF: 5%) were the most important factors. Infections and occupational exposures each contributed to an additional 4% of the cancer cases in 2015.

Conclusion: Today, two-fifths of cancers in France are attributable to preventable risk factors. The variations in the key amenable factors responsible in France relative to other economically similar countries highlight the need for tailored approaches to cancer education and prevention. Reducing smoking and alcohol consumption and the adoption of healthier diet and body weight remain important targets to reduce the increasing number of new cancer patients in France in the decades to follow.

1. Introduction

Cancer is the leading cause of morbidity and mortality in France, with more than 410,000 new cases and approximately 180,000 deaths because of the disease in 2018 [1]. Increased exposure to risk factors, changes in diagnostic procedures and an ageing population have all contributed to the 100% increase in the number of new cancer cases in France over the past 30 years [2].

Around half of all newly diagnosed cancer cases in Europe are potentially avoidable [3]. At the beginning of the millennium, approximately 35% of cancers diagnosed in France were thought to be attributable to modifiable risk factors [4], and quite recent studies in the U.K., Australia and the U.S. have reported similar results. The evaluation of the carcinogenicity of risk factors needs to be updated periodically, given new carcinogens have been identified since the previous estimations of 2000, which includes dietary factors such as processed and red meats [5], occupational exposures to some pesticides [6], exposure to diesel fumes [7] and air pollution [8]. In addition, new and more robust data on exposures have become available, and methods to estimate the cancers attributable to risk factors have also evolved, thereby warranting an updated assessment.

We, thus, present estimates of the proportion and number of newly occurring cancers in France in 2015 that were attributable to the past exposure(s) to established lifestyle and environmental (including occupational) risk factors. We restrict our estimations to adults aged 30 years and older, presenting a comparison to other countries where similar estimations have recently been performed.

2. Method

2.1. Data sources

The following risk factors were included in our study: tobacco smoking (first- and second-hand smoking), alcohol consumption, inadequate diet (insufficient fruit, vegetables and fibres and excessive red meat, processed meat and dairy consumption), overweight and obesity, physical inactivity, exogenous hormones (hormonal replacement therapy and oral contraceptives [OCs]), suboptimal breastfeeding, infections, ionising radiation (radon and medical diagnostic), outdoor air pollution ($PM_{2.5}$), ultraviolet (UV) exposure (solar and indoor tanning), occupational exposures (34 agents listed in the appendix) and population exposure to arsenic in drinking water and indoor benzene.

The inclusion of risk factors was based on the following criteria: (a) there are confirmed causal relationships in humans (convincing or probable evidence of carcinogenicity according to the IARC Monographs [group 1 and 2A] and/or the Continuous Update Project of the World Cancer Research Fund International WCRF CUP) [9,10]; (b) there is information on exposure to the factor from a nationally representative sample of the population; (c) there are previously reported relative risks that are considered robust. In general, a lag time (latency) of 10 years was assumed between the exposure and the diagnosis of cancer. This time lag was chosen as it is consistent with the average follow-up in cohort studies of the relationship between behavioural risk factors and cancer, and hence exposure data from (around) 2005 was used. Separate sets of lag time were used when evidence has shown otherwise, e.g. occupational exposures or exogenous hormonal intake. Finally, we excluded parity and age at first birth, despite the large impact of these factors on the risk of cancer among women [11,12], on the grounds as modification is neither ethical nor practical.

Data on exposure to the aforementioned risk factors, by age and sex, were obtained from national population representative surveys or, for the prevalence of infectious agents among cancer cases, from meta-analyses of cohort and case-control studies (Table 1). The number of cancer cases in France (Metropolitan) in 2015, by age, sex and cancer (sub)site, was estimated using cancer incidence rates provided by the French Cancer Registries Network (FRANCIM) for 2013 [13]. FRANCIM is a network of population-based cancer registries covering 24% of the French population. Rates were applied to

Table 1
Risk factors, sources of prevalence data, reference levels of exposure (theoretical-minimum-risks) and cancer sites, including references to the relative risks used.

Risk factors	Sources of prevalence data	Reference levels of exposure	Cancer sites (references for relative risks)
Tobacco smoking			
First-hand smoking	National lung cancer mortality database (indirect method) [46]	None	Oral cavity and pharynx, oesophagus, stomach, colon and rectum, liver, pancreas, larynx, lung, cervix uteri, ovary (mucinous), kidney, bladder, acute myeloid leukaemia, female breast [47]
Second-hand smoking	2005 Health Barometer [48]	None	Lung [47]
Alcohol	2005 Health Barometer	Lifetime abstinence	Oral cavity, salivary glands, oropharynx and hypopharynx, oesophagus, colon and rectum, liver, larynx, female breast [49]
Dietary factors			
Fibre	2006 National Nutrition and Health Survey [50]	$\geq$25 g/day	Colon and rectum, breast [51]
Fruits		$\geq$300 g/day	Oral cavity, oropharynx, hypopharynx and larynx, lung [51]
Vegetables		$\geq$300 g/day	Oral cavity, oropharynx, hypopharynx and larynx [51]
Dairy products		2 servings/day	Colon and rectum [51]
Red meat		$\leq$300 g/week	Colon and rectum, pancreas [51]
Processed meat		0 g/day	Stomach, colon and rectum [51]
Overweight and obesity (BMI)	2006 National Nutrition and Health Survey [50]	BMI, mean = 22; SD = 1	Oesophagus, stomach, colon, rectum, liver, gallbladder, pancreas, breast (post-menopausal), endometrium, ovary, kidney [52]
Infectious agents	Literature review and meta-analysis [53]	None	Cervix uteri, oropharynx, oral cavity, anus, larynx, vulva, vagina, penis, Hodgkin lymphoma, nasopharynx, mucosa-associated lymphoid tissue gastric lymphoma, stomach, non-Hodgkin lymphoma, liver [53]
Occupational exposures	National surveys, AGRICAN cohort [54], CAREX database [55]	None	See supplementary material [56]
Ultraviolet exposure			
Solar exposure	Skin melanoma incidence from registry (indirect method)	None- Melanoma incidence in a population with low exposure ambient to solar ultraviolet rays	Skin melanoma [57]
Indoor tanning	2010 Cancer Barometer [58]	None	
Ionising radiation			
Radon	Radioprotection and Nuclear Safety Institute [59]	None	Lung [60]
Medical diagnosis	2007 national survey of medical exposures to ionising radiation [61]	None	Oesophagus, stomach, colon, liver, lung, breast, ovary, prostate, bladder, thyroid, leukaemia, salivary glands, rectum, pancreas, kidney, central nervous system [62]
Exogenous hormones			
Hormone replacement therapy	French national health insurance database [63]	None	Ovary, breast, endometrium [64]
Oral contraceptives	National surveys on reproduction [65]	None	Breast, cervix uteri, endometrium, ovary [66]
Insufficient breastfeeding	Perinatal surveys Epifane study	$\geq$6 months per child	Breast [67]
Physical inactivity	2006 National Nutrition and Health Survey	$\geq$30 min of at least moderate physical activity per day	Colon, breast (post-menopausal), endometrium
Air pollution	GAZEL-AIR model [68]	$PM_{2.5}$ = 10 µg/m^3	Lung [69]
Chemical exposures in the general population			
Arsenic in water	National water quality database (SISE-Eaux) [70]	None	Lung, bladder [71,72]
Benzene in indoor pollution	National survey on indoor air quality	None	Acute non-lymphoblastic leukaemia, acute lymphoblastic leukaemia, chronic lymphoid leukaemia, non-Hodgkin lymphoma, multiple myeloma [73]

PM, particulate matter; g, grams; BMI, body mass index; SD, standard deviation.; AGRICAN, AGRIculture et CANcers; CAREX, CARcinogen EXposure; SISE-Eaux, Système d'Information Santé Environnement Eaux.

2015 population data to estimate the number of cancer cases in 2015. Population data were derived from the National Institute of Statistics and Economic Studies (INSEE) [14].

2.2. Statistical methods

Population attributable fractions (PAFs) were estimated by the cancer site, sex and age using previously described methods [15], illustrated in Equation (1) which uses the exposure distribution of the continuous risk factor prevalence. The alternative scenario was to use the exposure distribution that would result in the lowest population risk of cancer (or the theoretical-minimum-risk, see Table 1).

$$PAF = \frac{\int_{x=0}^{m} RR(x)P(x)dx - \int_{x=0}^{m} RR(x)P'(x)dx}{\int_{x=0}^{m} RR(x)P(x)dx} \quad (1)$$

In Equation (1), $RR(x)$ is the relative risk at the exposure level x, $P(x)$ is the population distribution of exposure, $P'(x)$ is the counterfactual distribution of exposure and m is the maximum exposure level. If continuous data on the risk factor were not available, categorical estimates of the prevalence and relative risks were used to estimate the PAF (Equation (2)), where n is the number of categories.

$$PAF = \frac{\sum_{i=1}^{n} P_i RR_i - \sum_{i=1}^{n} P'_i RR_i}{\sum_{i=1}^{n} P_i RR_i} \quad (2)$$

For some factors where there were other established methods to estimate the PAF, these methods were used. First, the PAF for tobacco smoking was modelled using the Lopez and Peto methodology [16], where lung cancer rates in France were compared with the reported rates among non-smokers. With respect to solar UV exposure, the PAF for skin melanoma was estimated based on the incidence rate of melanoma in France compared with a population where UV exposure was assumed to be negligible [17]. Differences between the observed incidence rates of lung cancer and skin melanoma and the corresponding rates in the respective reference populations were assumed to be attributable to exposures to tobacco smoking and solar UV, respectively. Second, using the method previously described by de Martel *et al.*, the PAFs for infectious agents were based on the prevalence of infection in the current cancer cases, rather than using data on the prevalence of infection in the general population [18].

In cases of overlapping exposures, one cannot merely add the PAF. Therefore, when two or more risk factors were linked to a cancer site, the attributable fractions PAF_i, (i = 1, 2, … n) for each risk factor were combined using Equation (3) to estimate the total attributable fraction. This equation adjusts for overlapping risk factors and assumes that the effect of each risk factor on cancer risk is independent [19].

$$PAF_T = 1 - \prod_{i=1}^{n} (1 - PAF_i) \quad (3)$$

To derive attributable cases, the PAFs were multiplied by the number of cancer cases by sex and age group in 2015. As most cancers occur in people aged 30 years and older, and cancers which occur earlier in life often have complex aetiologies with hereditary factors sometimes playing a role [20], all estimates were limited to adults confined to this age range.

3. Results

Of the 346,000 cancer cases in France in 2015 among adults aged 30 years and older, an estimated 142,000 were attributable to the studied risk factors—representing 41% of all cases. Tobacco smoking was responsible for the largest number of incident cases—approximately 69,000 cases or 20% of the total—while alcohol, diet and overweight and obesity were the second-to-fourth leading risk factors for cancer in France, responsible for 8.0%, 5.4% and 5.4% of all new cases, respectively, (see Fig. 1 and Tables 2 and 3). Both the number of new cancer cases and the percentage of all cancer cases attributable to the studied risk factors were higher among men than in women: 84,000 cases (PAF: 44%) versus 58,000 cases (PAF: 37%), respectively.

The leading causes of cancer among men in France in 2015 were tobacco smoking, alcohol and dietary factors, responsible for 28.5%, 8.5% and 5.7% of all new cases, respectively. Among women, the leading causes of cancer were tobacco, alcohol drinking and overweight and obesity, responsible for 9.3%, 7.5% and 6.8% of all cases, respectively. Following these factors, infectious agents and occupational exposures contributed to 4.0% and 3.6% of the cancer incidence in France, respectively. In total, the four leading contributors—tobacco, alcohol drinking, dietary factors and excess weight—explained 90% of the total attributable cancer cases in France in 2015.

Fig. 2 shows, for each cancer site, the number of cancers attributable or not attributable to the risk factors included in the study. Lung, breast and colorectal cancers were the three most common cancers that could be attributed to the studied risk factors, with 35,000, 20,000 and 19,000 attributable cases, respectively, representing 10.2%, 5.7% and 5.6% of the total number of new cancer cases estimated in France in 2015. These cancer sites and the magnitude of the attributable fractions are similar in men and in women; however, the number of prostate cancers, the most commonly diagnosed cancer among men that can be explained by the studied risk factors, is small (284 cases were attributable to the studied risk factors or 0.1% of the total cancers

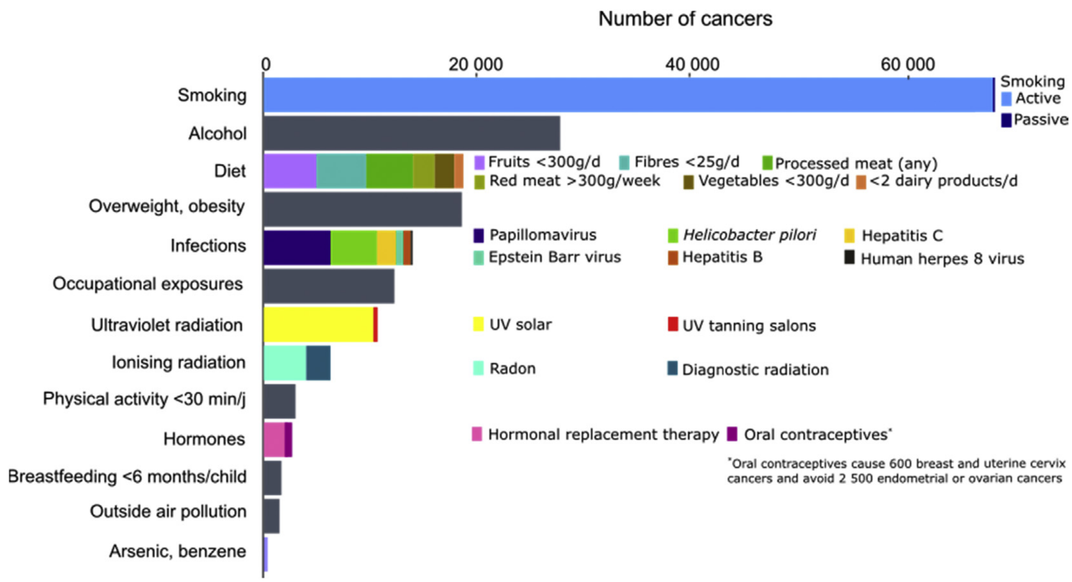

Fig. 1. Numbers and proportions of cancer cases attributable to lifestyle and environmental factors in France in 2015, both sexes combined.

diagnosed), while, for women, 36.8% of breast cancers (N = 20,000), the most commonly diagnosed cancer among women, could be attributed to the studied risk factors.

4. Discussion

Overall, 41% of all cancers among adults, 44% in men and 37% in women, in France in 2015 can be attributed to suboptimal lifestyle factors and exposures to environmental carcinogens. This represents 142,000 new cancer cases in France in 2015 that could potentially be avoided. Tobacco smoking remains the most important cause of cancer in France, followed by alcohol drinking, dietary factors and overweight or obesity. In total, these four risk factors contribute more than 90% of the total number of cancers attributable to the studied risk factors. Additionally, we observed an important contribution of infectious agents and occupational exposures, each contributing approximately 4% of the total number of new cancer cases. Furthermore, lung, breast and colorectal cancers contributed more than half (74,000 cases or 52%) of all avoidable cancer cases.

Our results are similar to those from the UK reported for the year 2015, where the total PAF was 38%, and from the US for the year 2014, where the PAF was 42% (Table 3), although the methods used were slightly different to those in this study. To some extent, our PAF estimates are also similar to those of the previous study in France in 2000 (total PAF: 35%) and to the Australian estimates in 2010 (PAF: 32%). The variation in the overall estimates are partly the result of differences in the number of risk factors included in the studies, e.g. only the most common occupational exposures were included in the previous French study, whereas occupational exposures were excluded in the Australian project [4,21,22]. As in all previous studies in high-income countries, we observed tobacco to be the leading cause of cancer. However, the second leading cause of cancer differed between countries, namely alcohol consumption in France, obesity and overweight in the US and the UK and UV exposure in Australia.

Despite substantial decreases in tobacco-related cancers such as lung cancer in many western and northern European countries, the observed decline of these cancers in France remains to be slow [23]. Tobacco smoking remains the most important risk factor in France, contributing to 20% of all cancers. The cancers observed today are the consequence of the past exposures, and although tobacco consumption has been decreasing among men, smoking among women has increased markedly in generations born between 1945 and 1965. The ageing of the 1965 cohort and the female generations that follow is expected to lead to an increase in the number of tobacco-attributable diseases until 2045 [24]. Australia—for which 13% of cancer cases are attributable to smoking in 2010—has pioneered many tobacco control programmes, and currently only 16% of adults smoke compared with 34% of adults in France [24]. In addition to smoking, nutritional factors, including alcohol, diet, obesity and physical inactivity contribute sizeably to the burden, with 18% of all cancers attributed to these factors in France in 2015. Alcohol consumption alone contributes to 8% of the total figure, compared with only 3% in Australia or 4% in the UK [25,26]. Similar to many high-income countries, alcohol consumption in France has declined markedly, yet it remains high, with an average adult consumption of 2.6 units (10 g of pure alcohol) per day,

Table 2
Numbers of cancer cases attributable to lifestyle and environmental risk factors in France in 2015, by sex and risk factor.

Risk factors	Males	Females	Total
Tobacco smoking	54,178	14,502	68,680
First-hand tobacco smoking	54,142	14,360	68,502
Second-hand smoking (at home)	36	142	178
Alcohol consumption	16,217	11,639	27,856
Nutrition	10,868	7913	18,781
Fruit intake < 300 g/day	3672	1277	4950
Fibre intake < 25 g/day	1095	3628	4723
Any intake of processed meat	2830	1550	4380
Red meat intake > 300 g/week	1386	645	2031
Vegetable intake < 300 g/day	1466	378	1844
Dairy intake < 2 portions[a]/day	419	434	853
Overweight and obesity	8032	10,606	18,639
Infectious agents	6886	7122	14,007
Human papillomavirus	1753	4516	6269
Helicobacter pylori	2554	1845	4400
Hepatitis C virus	1414	377	1791
Epstein-Barr virus	469	221	690
Hepatitis B virus	557	130	687
Kaposi's sarcoma–associated herpesvirus	139	32	170
Occupational exposures	10,814	1500	12,314
Ultraviolet exposure			
Solar exposure	5356	4984	10,340
Indoor tanning	89	293	382
Ionising radiations			
Radon	2864	1118	3982
Medical diagnostic	945	1366	2311
Exogenous hormones			
Hormonal replacement therapy	–	2206	2206
Oral contraceptives[b]	–	585	585
Moderate physical activity < 30 min/day	463	2510	2973
Breastfeeding < 6 months per child	–	1649	1649
Air pollution (ambient—PM2.5)	1055	412	1466
Exposure to arsenic in water and indoor benzene[c]	271	81	352
Total attributable cases	84,188	57,961	142,149

PM, particulate matter.
[a] One portion is 15 cL of milk, 30 g of cheese or 125 g of yogurt.
[b] Oral contraceptives also protect against cancers: In France in 2015, oral contraceptives prevented 1663 endometrial cancer cases (preventable fraction: 22.3%) and 796 ovarian cancer cases (preventable fraction: 17.0%).
[c] In the general population.

ranking France as the sixth highest alcohol consumers among the 34 Organisation for Economic Co-operation and Development (OECD) countries [27]. A recent French report highlighted that many effective strategies to control alcohol consumption, such as taxation based on the ethanol content, better public education and advertisement restrictions, still need to be reinforced or implemented [27]. Efforts to reduce the prevalence of a range of risk factors, including suboptimal dietary habits, overweight and obesity and physical inactivity, are less well developed than those on tobacco probably owing to a limited understanding as to what constitutes effective interventions for these risk factors. Generally, intervening at a community rather than the individual level, e.g. by changing environmental laws (e.g. to reduce air pollution or population exposure to chemical carcinogens) or instigating specific prevention policies, is the most effective means to influence population-level behaviour and impact in terms of reducing cancer incidence rates. Such cancer control measures should be implemented in combination with (early) education programmes to ensure healthier choices for all, especially for the future generations.

In our study, infections were found to be the fifth leading cause of cancer in France, with the human papillomavirus (HPV), *Helicobacter pylori* and hepatitis C virus being the three major contributors to the PAF for infection. The HPV vaccination coverage of 15% (in 2015) is low among girls aged 16 years, despite the national recommendation of HPV vaccination in 2007 [28]. In addition to the ongoing implementation of organised screening, increased coverage of HPV vaccination could potentially reduce the future burden of cervical cancer and other HPV-related cancers in the future. Moreover, improved management and prevention of *H. Pylori* and hepatitis C virus infections may decrease the risk of cancers related to these infectious agents.

We estimated that occupational exposures were the sixth leading cause of cancer in France in 2015, taking into account the cumulative exposures, i.e. going further back in time than exposures received one decade ago, as was the case for the other studied risk factors. Many safety measures have been put in place in the last decades, leading to a decreased exposure to many occupational carcinogens [29]. The cancers in 2015 are the consequences of exposures to occupational carcinogens that date back as far as the 1950s, at a time when exposures were generally much greater than they are now. As regulations regarding some major carcinogens were only implemented in the 1990s—the total ban of asbestos in France was only implemented in 1997 [30]—we can expect a decrease in cancers attributable to such carcinogens further in the future.

OCs increase the risk of breast and cervical cancers, but they also decrease the risk of cancers of the ovary and endometrium, with preventive fractions of 22% and 17%, respectively, larger than the negative impact of breast and cervical cancer (cancer-specific PAF: 0.8% and 4.5%, respectively). The use of OCs is high in France as it is in other European populations [31], with the marked decline in ovarian cancers in many high-income countries linked to an increasing uptake from the 1970s [31]. The prevalence of users among women aged 15–49 years has recently decreased in France, however, from 50% in 2010 to 41% in 2013 [32], likely the result of several factors. These include the reported increase in the risk of deep venous thrombosis associated with OC use, as well as concomitant changes in the types of OCs used and the proportion of users and ex-users over time subsequent to stopping the use. These changes may impact the future risk of OC-related cancers among women [33] and should be taken into account in future studies.

Table 3
Population attributable fraction (%) estimates for France (2015), Australia (2010), the United Kingdom (2015) and the United States (2014).

Exposures	France, 2015[a]			Australia, 2010[b]			United Kingdom, 2015[b]			United States, 2014[a]		
	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
Tobacco smoking	28.5	9.3	19.8	15.8	10.1	13.4	17.7	12.4	15.1	24.0	14.8	19.4
Alcohol consumption	8.5	7.5	8.0	3.0	2.4	2.8	3.1	3.5	3.3	4.8	6.4	5.6
Dietary factors[c]												
Insufficient fibre	0.6	2.3	1.4	2.3	2.1	2.2	3.1	3.4	3.3	0.9	1.0	0.9
Insufficient fruit	1.9	0.8	1.4	1.5	1.2	1.3	n/a	n/a	n/a	2.2	1.5	1.9
Insufficient non-starchy vegetables	0.8	0.2	0.5	0.3	0.2	0.3						
Dairy	0.2	0.3	0.2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Red and processed meat	2.2	1.4	1.9	2.7	1.6	2.2	2.1	0.9	1.5	1.7	0.8	1.3
Insufficient calcium	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.4	0.5	0.4
Overweight and obesity	4.2	6.8	5.4	2.5	4.5	3.4	5.2	7.5	6.3	4.8	10.9	7.8
Infectious agents	3.6	4.6	4.0	2.4	3.7	2.9	3.1	4.2	3.6	3.3	3.3	3.3
Occupational exposures	5.7	1.0	3.6	n/a	n/a	n/a	5.0	2.5	3.8	n/a	n/a	n/a
Ultraviolet exposure												
Sun exposure	2.8	3.2	3.0	7.1	5.0	6.2	3.8	3.7	3.8	5.8	3.7	4.7
Indoor tanning	<0.1	0.2	0.1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Ionising radiation												
Radon	1.5	0.7	1.2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Diagnostic radiation	0.5	0.9	0.7	n/a	n/a	n/a	1.7	2.1	1.9	n/a	n/a	n/a
Exogenous hormones												
Hormone replacement therapy	–	1.4	0.6	–	1.1	0.3	–	0.8	0.4	n/a	n/a	n/a
Hormone-based contraceptives	–	0.4	0.2	–	0.3	0.1	–	0.5	0.2	n/a	n/a	n/a
Insufficient physical activity	0.2	1.6	0.9	0.5	2.9	1.6	0.5	0.5	0.5	1.5	4.4	2.9
Insufficient breastfeeding	–	1.1	0.5	–	0.5	0.2	–	1.5	0.7	n/a	n/a	n/a
Ambient air pollution	0.6	0.3	0.4	n/a	n/a	n/a	1.0	1.0	1.0	n/a	n/a	n/a
Chemical exposure[d]	0.1	0.1	0.1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

[a] Among adults aged 30 years and older.
[b] Among people of all ages.
[c] Reference limits differ slightly by country.
[d] Arsenic and benzene only.

The reported estimates are largely based on population representative data and relative risks from meta-analyses which are a major strength of this study. In addition, the PAF for each risk factor was estimated following the established methods and advice from a multidisciplinary team of experts (see the list of experts in the Acknowledgements). However, there are also limitations to our study. The data sources, availability of data and the methods used all differed for each risk factor under study, and therefore, the risk factor–specific PAF should be interpreted with caution in light of the data sources, risk factor–specific misclassifications of exposure and assumptions used for the analysis (Table 1). For instance, in the estimation of the PAF for occupational exposures, a binary prevalence of those exposed versus non-exposed was used. Studies have shown that cancer risk markedly increases with increasing exposure or age at exposure, and thus, the PAF related to occupational carcinogens may be underestimated or overestimated depending on the distribution of exposures to these factors. Furthermore, for most risk factors (e.g. diet and the body mass index), the measurement of exposure was cross-sectional because lifetime exposure and/or corresponding risk data were not available. For alcohol consumption, breastfeeding, occupational exposures and radiation, the PAFs were estimated, taking into account the cumulative exposure. While for factors such as ionising radiation and tobacco smoking we were able to obtain risk estimates based on cohort studies, in the case of other risk factors (including several chemicals in occupational settings), we had to use risk estimates based on case-control studies. In the latter instances, the reported odds ratios are assumed to approximate the relative risks which may have led to a slight overestimation of the risk and the number of attributable cancers [34,35].

Another assumption was the duration of latency between exposure to a carcinogen and the development of cancer. For most factors, the average latency duration is unknown, and following other publications, 10-year latency was generally assumed [36]. This might be too short considering the long process of carcinogenesis, and thus, when there was strong evidence of a different latency time, this was used. As mentioned, we assumed an impact for up to 50 years after occupational exposures, given studies have clearly shown substantially longer latency time [30]. On the other hand, the mean effect of exogenous hormones on cancer risk can be observed within a year after exposure, and, accordingly, this was the lag time used here [37]. For OCs, while studies have also shown the importance of time since stopping the use, this could not be taken into account in our analysis. Hence, given a large decrease in OC use in France, the negative impact of OCs on breast and cervical cancer

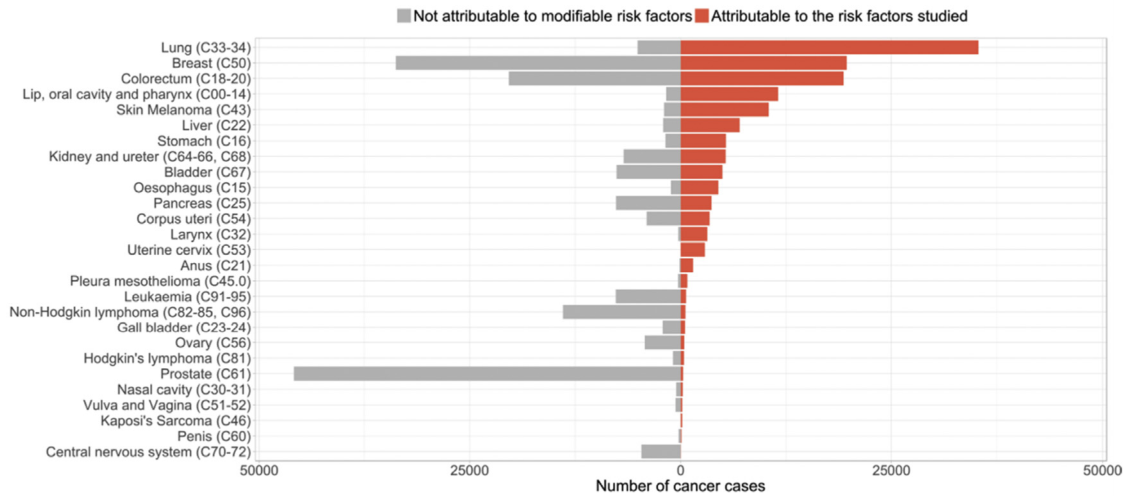

Fig. 2. Numbers of cancers attributable and not attributable to the studied risk factors in France in 2015, both sexes combined.

may be slightly underestimated. Finally, the estimation of total PAF assumed that the risk factors were independent of each other. Some of the risk factors considered in this study are not independent, for instance, tobacco smoking and alcohol drinking. Indeed, studies have shown that the risk of head and neck cancer related to smoking is strongly modified by alcohol drinking [38]. In this study, the combined effect of smoking and alcohol did not take into account this interaction owing to a lack of data on long-term smoking and alcohol drinking. In the future, the impact of such associations on the total PAF should be assessed.

5. Conclusion

On the basis of available knowledge and data, we estimate that 41% of all cancers among adults in France could potentially be avoided by eliminating exposure to lifestyle and environmental risk factors, i.e. 142,000 new cancer cases, thereby preventing a large health, economic and social burden [39,40]. In future studies, estimating attributable fractions based on evidence of effective control strategies can provide additional insights when planning cancer control policies, especially those related to tobacco smoking, alcohol use and obesity [41,42]. Studies in France have demonstrated persisting social inequalities with regard to the distribution of cancer risk factors [28] and have also shown their contribution to the cancer burden [43]. In addition to differences by socio-economic groups, differences in exposures to risk factors and hence the cancer burden in France also vary largely by the region, i.e. the differences in excess burden of skin melanoma (related to UV) [44] or lung cancer related to radon [45]. Cancer prevention programmes in France could have a substantial impact on reducing cancer cases, with an even larger effect among the disadvantaged groups. Despite substantial efforts to provide a comprehensive overview of the PAF, we were limited in our attempts to find data on population exposures to many environmental carcinogens and also their risk estimates.

Clearly with two-fifths of cancers in France today attributable to preventable risk factors, common strategies to education and to cancer prevention are warranted. Reducing smoking and alcohol consumption and adopting a healthier diet and ideal body weight remain important targets to reduce the increasing number of new cancer patients in France in the decades to follow. Continued monitoring of the major risk factors and the resulting cancer burden must continue to monitor the progress and realign cancer control planning accordingly.

Conflict of interest statement

None.

Role of the funding source

The French National Cancer Institute who funded this project had no role in the design of this study, its execution, analyses, interpretation of the data nor the decision to submit the results.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ejca.2018.09.009.

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