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Social inequality and incidence of and survival from cancer in a population-based study in Denmark, 1994–2003: Background, aims, material and methods

Susanne Oksbjerg Dalton[a,*], *Marianne Steding-Jessen*[a], *Mette Gislum*[b], *Kirsten Frederiksen*[a], *Gerda Engholm*[b], *Joachim Schüz*[a]

[a]*Institute of Cancer Epidemiology, Danish Cancer Society, Strandboulevarden 49, DK-2100 Copenhagen Ø, Denmark*
[b]*Department of Cancer Prevention and Documentation, Danish Cancer Society, Strandboulevarden 49, DK-2100 Copenhagen Ø, Denmark*

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ABSTRACT

The purpose of this register-based study was to identify variations in cancer incidence and survival after cancer in Denmark on the basis of a range of socioeconomic, demographic and health-related indicators. The indicators were level of education, disposable income, affiliation to the work market, social class, housing tenure, size of dwelling, cohabitation status, type of district, ethnicity, Charlson comorbidity index, depression and schizophrenia measured at the individual level on an annual basis. The study population comprised all Danish residents born between 1925 and 1973 and aged ⩾30 years, who were followed up for cancer incidence in 1994–2003 and for survival in 1994–2006. The study was based on 3.22 million persons, yielding almost 26 million person-years and 147,973 cancers. In this paper, we provide a detailed description of the indicators and the statistical methods, and we discuss the strengths and limitations of our approach.

1. Introduction

Numerous studies have revealed consistent associations between social position and health; however, associations between markers of social position and the incidences of different cancers are much more heterogeneous. For instance, low social position, measured as educational level, occupational status or income, has been associated with increased risks for cancers of the cervix, head and neck, lung and stomach and lower risks for cancers of the breast, prostate and colon and malignant melanoma.[1–6] Although the available information is sparse, longitudinal data suggest that social class differences in the risks for some types of cancers are increasing with time.[1] Socioeconomic differences in cancer incidence can presumably be partly explained by known risk factors, such as smoking, occupational exposure, reproductive behaviour and biological agents (human papilloma virus, *Helicobacter pylori*, hepatitis B and C viruses), although only a limited number of epidemiological studies have addressed this hypothesis directly.[7–13]

Evidence for socioeconomic differences in survival has been found for many cancers and in many populations[14–16]: more socially disadvantaged patients have consistently poorer survival than those who are better off. The differences may be related to differences in the time of diagnosis, in the biological characteristics of the tumour, in the treatments given or in patient-specific factors, such as lifestyle or the presence of comorbid conditions. An extensive review of studies of socioeconomic differences in cancer survival published within the last decade (since 1995) concluded that

* *Corresponding author:* Tel.: +45 35257500; fax: +45 35257731.
E-mail address: sane@cancer.dk (S.O. Dalton).
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the explanatory power of stage at diagnosis is great but that this should not deflect attention from evidence for differences in treatment. Neither stage nor treatment can entirely explain the observed socioeconomic differences in cancer survival.[16]

1.1. The Danish welfare system

One of the basic principles of the Danish welfare system, often referred to as the Scandinavian welfare model, is that all citizens have equal rights to social security. Within the Danish welfare system, a number of services are freely available to citizens; for instance, health and education are free of charge (www.denmark.dk). The Danish welfare model is subsidised by the State, and, as a result, Denmark has one of the highest taxation levels in the world, and public expenditure accounts for 26% of the total gross domestic product. The social security system includes benefits for families with children and for young people, services for old-age pensioners and the disabled, and pensions. An exception is unemployment benefit, which is not covered by taxes alone but also through individual voluntary membership in an unemployment fund, usually aligned with a given union (www.denmark.dk).

Denmark has the largest workforce in Europe relative to its population. The high frequency of labour activity in Denmark is due in particular to the high proportion of women who are active in the labour market (approximately 70%); the respective proportion of men is 80% (www.denmark.dk). In a typical Danish family, both the husband and the wife work away from home. Agreements within the Danish labour market make it highly flexible with regard to working hours, overtime and hiring and firing of personnel. This also results in high mobility. In return for the high level of flexibility, Danish employees have relatively comprehensive social security, which is guaranteed by law in times of unemployment, illness or occupational injury (www.denmark.dk).

1.2. The Danish health-care system

Denmark has a tax-funded health-care system, which provides free access to general practice, outpatient and hospital care. The health-care system is organised into a primary sector of general practitioners and specialists, who are under contract with or paid by the national health insurance, and a secondary sector, which operates hospitals under the authority of the national regions or the Danish State. General practitioners play a pivotal role as gatekeepers to the rest of the health-care system, carrying out initial diagnostic investigations and making referrals to hospitals or outpatient clinics, as needed. Although there is free access to the primary and secondary health-care sector, dental care and prescription medications are only partly subsidised by the State (www.denmark.dk).

During the period of this study (1994–2006), cancer surgery was carried out at both general hospitals and oncological centres, and non-surgical cancer treatment was partially centralised at five regional radiotherapy and oncological centres.

1.3. The Danish way of life

The incidences of alcohol-related and smoking-related cancers, such as those of the lung, larynx and oesophagus, are higher in Denmark than in the other Nordic countries.[17] A Danish study on population mortality based on OECD data on 20 western countries found that in 1990–1999, the level of daily smoking amongst Danish men was the fourth highest (42%) and that amongst Danish women was the highest (36%).[18] Alcohol use was fifth highest in 15 western countries, with an average consumption of 10.3 l per inhabitant per year.[18] According to the WHO MONICA study, conducted in the first half of the 1990s, however, Danes had some of the lowest levels of overweight (41% of men and 26% of women) and obesity (13% of men and 12% of women) in the 10 western European countries surveyed.[18]

To varying degrees, differences in health in general and in cancer in particular by socioeconomic position can be explained by differences in health behaviour. Several studies have indicated that poorer health behaviour is concentrated in less advantaged groups,[19–21] and this might be exacerbated for behaviours like smoking, alcohol consumption and physical inactivity[21,22] all of which have been associated with both the incidence of and survival from certain cancers.

The conditions for carrying out population-based cancer research in Denmark and in the Nordic countries are much better than in the rest of the world. Each of the Nordic countries has a civil registration system with unique personal identification numbers, national population-based administrative registries such as national cancer registries, a uniform, free-of-charge health system and legislation that permits and supports registry-based research. In 1981, Denmark was the first country in the world to replace the questionnaire-based census usually made every 5 years by an annual register-based census.

1.4. Aim of the study

The purpose of this study was to describe variations in cancer risk and survival in Denmark on the basis of a range of socioeconomic, demographic and health-related indicators. All the indicators are measured at the individual level on an annual basis. Variations in cancer incidence and survival are reported on both a relative scale (i.e. ratios of rates) and an absolute scale (i.e. differences in rates) and thereby provide the answers to the following questions:

- What is the effect of indicators of social position on the incidence of cancer?
- To what extent do these socioeconomic indicators affect survival after cancer?
- Are some indicators of social position associated with a low incidence of cancer and good chances for survival after cancers at specific sites?
- Are there, conversely, indicators of social position that are markers for a high incidence of cancer and a worse prognosis?

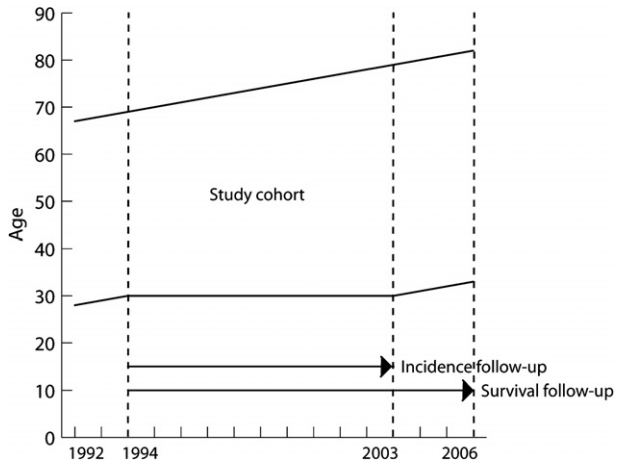

Fig. 1 – Definition of observation period by age and calendar time for analyses of cancer incidence (1994–2003) and survival (1994–2006) in the study population born 1925–1973 and entering the cohort at age 30 years, Denmark.

2. Materials and methods

2.1. *Study population*

Since 1968, all residents of Denmark have been registered in the Central Population Register and assigned a unique personal identification number that contains their date of birth and sex. Individual information is kept under this identification number in all Danish national registers, ensuring accurate linkage of information between registers. We extracted data on all 3,470,567 million persons who were born between 1925 and 1973 and who resided in Denmark in the period 1994–2003. All persons were followed up for the occurrence of cancer from age 30 or 1st January 1994, whichever occurred last, and until a diagnosis of cancer, emigration or 31st December 2003, whichever occurred first. The reasons for selecting this age group were that persons below the age of 30 might still be in the educational system and thus in the process of establishing their socioeconomic position, and that the socioeconomic position of persons at the higher age limit (69 years in 1994) is represented to only a limited extent in the data of Statistics Denmark. For instance, no data are available on the educational level of persons who were over 75 years of age in 1990. The definition of the observation period by age and calendar time for the analyses of incidence and survival in the study population is illustrated in Fig. 1.

2.2. *Information on vital status*

Dates of death, disappearance or emigration and the addresses of all persons were obtained from the files of the Central Population Registry through to 31st December 2006.

2.3. *Information on diagnosis of cancer*

By linkage with the files of the Danish Cancer Register, we obtained information on all incident cases of first primary cancer, excluding non-melanoma skin cancer, diagnosed in the study population between 1994 and 2003, the study period for cancer incidence. The Danish Cancer Register contains information on all persons in Denmark in whom cancer was diagnosed since 1943, including benign brain tumours and urinary bladder papillomas.[23] The tumours are classified in the register according to a modified Danish version of the *International Classification of Diseases*, 7th revision (ICD-7) and, from 1978, also according to ICD-O-1, with additional information on topography and morphology. For each cancer, the date of diagnosis and the cancer site were obtained. The following 11 major groups of cancer sites were defined according to the NORDCAN entities: mouth, pharynx and larynx; oesophagus, stomach and pancreas; colon and rectum; lung; breast; female genital organs; male genital organs; kidney and urinary bladder; skin; central nervous system; and non-Hodgkin lymphoma, Hodgkin lymphoma and leukaemias.[17] In the NORDCAN database, the national cancer codes are converted to a common international data format based on ICD-10 and grouped into 41 entities, which can be compared over time and between the Nordic countries. We excluded 97,407 persons with cancers diagnosed prior to 1994 (except non-melanoma skin cancer) and classified all persons with one of the selected cancers in the period 1994–2003 according to their first primary cancer.

2.4. *Information on socioeconomic and demographic factors*

Information on the socioeconomic characteristics of the study cohort was obtained by data linkage to the population-based Integrated Database for Labour Market Research in Statistics Denmark, which contains yearly data since 1980. The core variables in the database are derived by linkage with the Central Population Register, the taxation authorities, the Register for Education Statistics, the Register Relating to Unemployment and a register of all companies with more than one employee.[24] Datasets for research that are linked to census and other information at the individual level and are available with cryptified identification can be established and analysed at Statistics Denmark by special secured internet connections. For all persons in the study population, we obtained information at the individual level about a number of demographic and socioeconomic variables for each year of the study period. Further, we identified spouses, cohabiters and the number of children aged 0–17 years in the family at the end of each year of the study period to account for the changes in family structure and additional children born after first identification of the index persons. This allowed yearly updating of, for instance, the status of marriage or cohabitation for the study persons, the number of children (0–17 years of age) living at home and information on the income of all family members, in order to estimate family income. From the Building and Dwelling Register, which contains information on all address codes in Denmark,[25] we obtained information on size, type and tenure of dwellings.

We defined six socioeconomic indicators: level of education, disposable income, affiliation to the work market, social class, housing tenure and size of dwelling. We also defined three demographic indicators: cohabitation status, type of district and ethnicity (see Table 1 for definitions and categor-

Table 1 – Definitions and categorisation of socioeconomic, demographic and health-related indicators used in the study of social inequality of cancer incidence and survival in persons born between 1925 and 1973 and aged ⩾30 years, Denmark, 1994–2003

Variable, with categories	Definition of category
Socioeconomic indicators	
Highest attained education	
Basic school/high school	Basic school/high school education: 7–12 years of primary, secondary and grammar-school education
Vocational training	Vocational education: 10–12 years of education
Higher education	Higher education, ⩾13 years of education
Unknown	–
Disposable income	
Lowest (1st quartile)	Household income after taxation and interest per person, adjusted for number of persons in the household and deflated according to the 2000 value of the Danish crown (DKK) with the following formula from the Danish Ministry of Finance: deflated household income/(no. of persons in household$^{0.6}$). Persons with high negative income (⩽50,000 DKK per year) were excluded from all analyses (n = 56,814)
Middle (2nd–3rd quartile)	
Highest (4th quartile)	
Affiliation to the work market	
Working	Unemployed in November that year. Early retirement pension (formerly known as disability pension) is granted if a person is unable to work permanently due to mental or physical disability and this disability reduces the ability to work by at least 50%. Pensioners due to age (in Denmark in the study period, age 67) were categorised on the basis of their affiliation to the work market before their age-related retirement
Unemployed	
Early retirement pension	
Social class	
Creative core	Based on the theory of the creative class as an emerging social class,[33] subdivided into the creative core (e.g. researchers, designers, architects), creative professionals (e.g. managers, business and finance, lawyers, doctors) and bohemians (e.g. artists, models), the service class (e.g. nurses, hairdressers, caterers), the manual class (e.g. construction, transport, production workers) and the agricultural class (e.g. farmers, fishermen)
Creative professionals	
Bohemians	
Service class	
Manual class	
Agricultural class	
Unknown	
Housing tenure	
Owner-occupied	Unknown tenure includes sheltered housing, self-managed retirement units and institutions
Rental	
Unknown	
Size of dwelling (m^2)	
0–49	Not standardised for number of persons in the household
50–99	
100–149	
⩾150	
Demographic indicators	
Cohabitation status	
Married	In Denmark, over 20% of all couples living together in 2002 were unmarried (www.denmark.dk). These comprised in particular young couples without children, and a substantial proportion of these relationships are formalised by marriage when the couples have children. Cohabitation is defined as, in the absence of marriage, two persons of the opposite sex, over the age of 16 years, with a maximum age difference of 15 years living at the same address with no other adult in residence. This definition therefore excludes homosexual unmarried partners and partners with more than 15 years' difference in age. These categories, however, account for very few couples
Cohabiting	
Single	
Widow/widowed	
Divorced	
Degree of urbanisation	
Greater Copenhagen area	Grouped at level of the municipality. Provincial cities are those with >10,000 inhabitants; rural areas are rural municipalities with <10,000 inhabitants; peripheral rural areas are municipalities more than 40 km from a local centre with proper employment possibilities and no shared border with a municipality centre
Provincial cities	
Rural areas	
Peripheral rural areas	
Ethnicity	
Danish	Immigrants were defined as persons born outside Denmark to parents who were not Danish citizens or were born outside Denmark, and descendants are persons born in Denmark to parents neither of whom is a Danish citizen born in Denmark. Western countries were defined as the 13 Member States of the European Union (as of 31st December 2003), Andorra, Australia, Canada, Iceland, Liechtenstein, Monaco, New Zealand, Norway, San Marino, Switzerland, Vatican State and the United States and non-western countries comprised all other countries
Immigrants or descendants from western countries	
Immigrants or descendants from non-western countries	
Health-related indicators	
Charlson comorbidity index	
0	Grouped on the basis of the cumulated sum of scores of 0, 1 and ⩾2. This index provides an overall score for comorbidity based on a composite of values weighted by level of severity assigned to 19 selected conditions scored from 1 to 6.[34] As our analyses are based on first primary cancers only, no cancers are included in the index. Scores are summarised on the basis of information on hospitalisations from 1978 onwards. Score 1: myocardial infarct, congestive heart failure, peripheral vascular disease, cerebrovascular disease, dementia, chronic pulmonary disease, connective tissue disease, ulcer disease, mild liver disease, diabetes type 1 and diabetes type 2. Score 2: hemiplagia, moderate-to-severe renal disease, diabetes with end-organ damage type 1 or type 2. Score 3: moderate-to-severe liver disease. Score 6: AIDS
1	
⩾2	
Depression	
No	Ever or never hospitalised or outpatient contact for affective disorders, as defined by ICD-8 codes 296.09–99, 298.09–19, 300.19 and 300.4 and ICD-10 codes F30–39. Hospitalisations based on information from 1969 onwards
Yes	
Schizophrenia or other psychoses	
No	Ever or never hospitalised or outpatient contact for schizophrenia or other psychoses, as defined by ICD-8 code 295 and ICD-10 codes F20 and F25. Hospitalisations based on information from 1969 onwards
Yes	

Level of each indicator measured at the end of each calendar year.

isations). Because of missing variables in one or more of the socioeconomic indicators, or length of residence in Denmark less than 2 years in the study period, some 97,906 persons (2.8%) were excluded and a further 56,814 persons (1.6%) were excluded due to a high negative income (<50,000 DKK per year).

2.5. *Information on comorbid disorders*

By linking the personal identification number to the files of the Danish National Patient Register, we obtained full histories of diseases leading to hospitalisations from 1978 and, from 1995, outpatient visits by each cohort member through 2003. The information in the Register includes dates of admission and discharge and diagnoses coded according to Danish modified versions of the ICD-8 and, from 1994, ICD-10.[26]

The Psychiatric Case Register contains data on all admissions to Danish psychiatric inpatient facilities since 1969 and, since 1995, information from outpatient contacts[27] as well. There is no fee for psychiatric treatment in Denmark, and no private psychiatric facilities exist. The diagnostic system used during the study period was the ICD-8 up to 1993 and ICD-10 thereafter.

On the basis of information from these registers, we defined three health-related indicators to account for the presence of chronic somatic and psychiatric comorbidity: the Charlson comorbidity index, depression and schizophrenia or other psychoses (Table 1).

3. Statistical analyses

The results of the analyses for each cancer site are presented in two figures and two tables. We constructed a pre-defined set of analyses and used it for all the cancer sites investigated, so as to orient readers through the results sections and allow them to compare the effects of the socioeconomic, demographic and health-related indicators for each cancer site. All the analyses were conducted separately by sex.

3.1. *Analyses of cancer incidence*

We show incidence rates by age (5-year age groups) for the three educational levels, separately for men and women. In addition, incidence rates were standardised by age and period, with the distribution of the person-years accumulated by the total study population as the standard (Table 2).[28] Age was grouped into 5-year age groups (30–34, 35–39,..., 75–79), and period was grouped into two 5-year periods (1994–1998 and 1999–2003). Further, incidence rate differences were calculated. In order to avoid negative incidence rate differences, either higher education or basic schooling was used as the reference group.

We used log–linear Poisson regression models to estimate incidence rate ratios, with 95% confidence intervals between the levels of each factor, where one (usually the level with most cases) was chosen as the reference level, first adjusted for period (in 5-year periods) and age (modelled as age and age^2 in years) (model 1), and secondly by additionally adjusting for education and disposable income (model 2).

Table 2 – Weights (%)[a] used to standardise incidence rates by age and period

Age group (years)	Weight[b] (%)	
	1994–1998	1999–2003
30–34	6.5	6.2
35–39	6.6	7.1
40–44	6.6	6.5
45–49	7.0	6.4
50–54	6.7	6.7
55–59	5.1	6.4
60–64	4.4	4.7
65–69	3.9	3.9
70–74	1.2	3.3
75–79	–	0.9

a Based on distribution of person-years in the study population: persons born 1925–1973 who entered the cohort at age 30 years and were followed-up for cancer in the period 1994–2003.
b Although exact weights were used in the calculations, the weights shown here do not sum up to 100% due to rounding.

The models for the incidence rate, λ, were

$$\text{model 1: } C_{apf} \sim \text{Poisson}(\lambda_{apf} \cdot P_{apf})$$
$$\log(\lambda_{apf}) = \beta_1 a + \beta_2 a^2 + \beta_p + \gamma_f$$

$$\text{model 2: } C_{apeif} \sim \text{Poisson}(\lambda_{apeif} \cdot P_{apeif})$$
$$\log(\lambda_{apeif}) = \beta_1 a + \beta_2 a^2 + \beta_p + \beta_e + \beta_i + \gamma_f$$

where C_{apf} and C_{apeif} are the number of observed incident cancer cases occurring in the respective group, defined by a as the age in years from 30 to 79; p as the period in two groups: 1994–1998 and 1999–2003; e as the level of education, as defined in Table 1; i as the disposable income, as defined in Table 1; f as the respective socioeconomic, demographic or health-related indicator, as defined in Table 1; and f is measured at age $a - 2$ years; and P_{apf} and P_{apeif} are the number of person-years experienced in the respective group.

All estimates of incidence rate ratios for the different socioeconomic, demographic and health-related indicators, such as education and disposable income, are for Danes only and not for immigrants and their descendants (see Table 1), except in the analysis of ethnicity. We used exposure status 2 years before the year of observation for all factors except age and period in order to avoid misclassification due to, e.g. a change in socioeconomic position or health status because of the presence of a yet undiagnosed cancer. For affiliation to the work market for persons who had retired due to their age, however, we used the latest recorded occupation. Owing to the absence of information on the occupations before retirement of the eldest persons in the cohort, follow-up for the analyses of affiliation to the work market ended at age 69 years for the whole study period.

3.2. *Analyses of relative survival*

We calculated a cumulative relative survival up to 5 years for first incident cancers between 1994 and 2003, with follow-up for deaths through 2006. Patients in whom a cancer was

Table 3 – Descriptive characteristics at entry, person-years at risk and numbers of first primary cancers (excluding non-melanoma skin cancer) diagnosed, by socioeconomic, demographic and health-related variables, in Danish persons born between 1925 and 1973 and aged ⩾30 years, Denmark, 1994–2003

	Men (n = 1,628,651)						Women (n = 1,589,789)					
	n	%	Person-years	%	No. of cancers	%	n	%	Person-years	%	No. of cancers	%
Period												
1994–1998	1,333,158	88	6,060,351	48	28,076	42	1,308,326	89	5,996,555	48	33,186	44
1999–2003	180,248	12	6,580,237	52	38,976	58	172,390	11	6,557,785	52	42,299	56
Age (years)												
30–39	657,230	43	3,408,105	27	2801	4	633,490	42	3,308,944	26	4229	6
40–49	364,700	24	3,396,521	27	6164	9	351,979	24	3,307,048	26	11,275	15
50–59	286,137	19	3,176,082	25	16,505	24	279,010	19	3,087,436	25	21,559	28
60–69	205,068	14	2,053,610	16	27,431	41	216,003	15	2,136,756	17	26,543	35
70–79	271	0	516,269	5	14,151	21	234	0	714,154	6	11,879	16
Level of education												
Basic or high school	543,965	36	4,448,551	35	29,059	43	661,487	45	5,534,594	44	40,190	53
Vocational education	643,582	43	5,418,238	43	26,541	40	479,130	32	4,106,362	33	22,142	29
Higher education	302,149	20	2,582,524	20	10,322	15	323,605	22	2,780,522	22	12,308	16
Unknown	23,710	2	191,275	2	1130	2	16,494	1	132,863	1	845	1
Disposable income[a]												
Lowest (1st quartile)	360,971	24	2,962,751	23	23,004	34	355,594	24	2,983,594	24	22,371	30
Middle (2nd–3rd quartile)	778,773	51	6,429,082	51	29,573	44	757,644	51	6,367,489	51	34,874	46
Highest (4th quartile)	373,662	25	3,248,755	26	14,475	22	367,478	25	3,203,258	26	18,240	24
Affiliation to work market[b]												
Working	1,231,074	81	9,909,249	82	35,310	67	1,063,545	71	8,627,396	73	38,057	60
Unemployed or other	173,717	11	1,239,072	10	7627	14	265,660	18	1,918,043	16	11,802	19
Early retirement pensioner	69,374	5	673,214	6	6761	13	118,964	8	1,085,637	9	11,007	17
Unknown	38 970	3	212,783	2	3203	6	32,313	2	209,110	2	2740	4
Social class[c]												
Creative core	99,958	7	830,808	7	3215	5	39,719	3	331,193	3	1292	2
Creative professional	217,087	14	1,968,723	16	9861	15	131,241	9	1,212,634	10	6298	8
Bohemian	8511	1	72,864	1	346	1	4666	0	40,735	0	177	0
Service	424,575	28	3,199,067	25	15,817	24	917,809	62	7,671,044	61	41,838	55
Manual	547,380	36	5,007,904	40	28,717	43	118,826	8	1 082 376	9	6 561	9
Agricultural	77,182	5	578,951	5	3143	5	23,991	2	188 389	2	1 182	2
Unknown	138,713	9	982,271	8	5953	9	244,464	17		16		24
Housing tenure												
Owner-occupied	978,070	65	8,718,191	69	43,301	65	934,617	63	8,316,808	66	46,946	62
Rental	501,993	33	3,696,092	29	22,837	34	521,809	35	4,073,951	32	27,713	37
Unknown	33,343	2	226,305	2	914	1	24,290	2	163,582	1	826	1
Size of dwelling (m^2)												
0–49	78,570	5	500,560	4	2565	4	38,656	3	221,698	2	1163	2
50–99	528,740	35	3,968,748	31	24,975	37	541,560	37	4,306,231	34	30,477	40
100–149	575,927	38	5,021,007	40	25,031	37	580,328	39	5,009,685	40	27,787	37
⩾150	330,69	22	3,150,273	25	14,481	22	320,172	21	3,016,727	24	16,058	21
Cohabiting status												
Married	831,313	55	7,910,078	63	46,431	69	894,335	61	8,059,620	64	47,584	63
Cohabiting	268,739	18	1,703,090	13	4865	7	235,594	16	1,474,562	12	5174	7
Single	314,342	21	1,985,768	16	6001	9	185,800	12	1,169,479	9	4608	6
Widow/widower	14,156	1	192,126	2	3088	5	54,293	4	719,873	6	9575	13
Divorced	84,856	6	849,527	7	6667	10	110,694	8	1,130,807	9	8544	11
Type of district												
Capital area	490,041	32	3,931,822	31	22,105	33	489,495	33	4,007,869	32	25,147	33
Provincial cities	775,476	51	6,509,107	51	33,518	50	757,436	51	6,459,225	51	38,449	51
Rural areas	174,129	12	1,544,830	12	7744	12	164,340	11	1,465,080	12	8132	11
Peripheral rural areas[d]	73,760	5	654,829	5	3685	5	69,445	5	622,166	5	3757	5
Ethnicity												
Danish	1,513,406	93	12,640,588	94	67,052	96	1,480,716	93	12,554,341	94	75,485	96
Immigrants or descendants from western countries	41,891	3	279,627	2	1321	2	39,570	2	290,255	2	1783	2
Immigrants or descendants from non-western countries	73,354	4	489,364	4	1139	2	69,503	4	441,942	3	1193	2
Charlson comorbidity index[e]												
None	1,403,753	93	11,276,270	89	50,453	75	1,396,404	94	11,439,920	91	63,403	84
1	79,167	5	941,110	7	10,632	16	56,876	4	726,536	6	7524	10
⩾2	30,486	2	423,208	3	5967	9	27,436	2	387,884	3	4558	6
Depression[f]												
No	1,498,502	99	12,479,028	99	65,723	98	1,454,934	98	12,270,673	98	72,911	97
Yes	14,904	1	161,559	1	1329	2	25,782	2	283,667	2	2574	3
Schizophrenia or other psychoses[f]												
No	1,498,422	99	12,501,192	99	66,424	99	1,466,776	99	12,414,122	99	74,482	99
Yes	14,984	1	139,396	1	628	1	13,940	1	140,218	1	1003	1

For all indicators other than ethnicity, numbers exclude immigrants and descendants.

a Household income after taxation and interest adjusted for the number of persons in household. Categorised on the basis of sex-specific distributions of household disposable income per person.

b For age-pensioners, the work market affiliation prior to pension date was assigned to each person, and follow-up ended at age 69.

c Based on theory of creative class[33]: the creative core (e.g. researchers, designers, architects), creative professionals (e.g. managers, business and finance, lawyers, doctors), bohemians (e.g. artists, models), the service class (e.g. nurses, hairdressers, caterers), the manual class (e.g. construction, transport or production workers) and the agricultural class (e.g. farmers, fishermen).

d Defined as being more than 40 km from a local centre with proper employment possibilities and no border with a municipal centre.

e Presence of disorders as defined in the Charlson comorbidity index was defined as in- or outpatient contact with one of the diagnoses listed in Table 1 between 1978 and 2 years before the cancer diagnosis. Grouped according to the accumulated sum of scores.

f Presence of psychiatric disorders was defined as in- or outpatient contact with one of the diagnoses from 1969.

detected incidentally at autopsy or from a death certificate only (DCO) were excluded from the analyses (1118 (0.75%)). The total number of cases of cancer was thus 146,864.

Cumulative relative survival, $R(t)$, is the ratio of the observed proportion of survivors between diagnosis and follow-up time t, $S(t)$, and the proportion that would have been expected had they had the mortality rates of the study population, $S^*(t)$[29]

$$R_{a,f}(t) = S_{a,f}(t)/S^*_{a,f}(t),$$

where a is age, grouped as 30–49, 50–59, 60–69 and 70–79 years, and f is the respective socioeconomic, demographic or health-related indicator as defined in Table 1, measured at age −2 years.

$S(t)$ was estimated by the actuarial method and $S^*(t)$ was estimated by the Ederer II method in the SAS macro developed by Dickman.[29] The cumulative relative survival is obtained by modelling the observed mortality rate $\lambda(t)$ for the cancer patients as the sum of the population mortality rate $\lambda^*(t)$ plus an excess mortality rate $\nu(t)$, which is interpreted as the mortality rate due to cancer:

$$\lambda_{af}(t) = \lambda^*_{af}(t) + \nu_{af}(t).$$

The rates are assumed to be constant in the follow-up intervals 0–0.5, 0.5–1, 1–2, 2–3, 3–4 and 4–5 years.

To avoid attributing to the cancer socioeconomic differences in mortality from causes other than cancer, we calculated mortality rates excess to the population mortality by each level of each socioeconomic, demographic or health-related indicator, as well as the usual stratification by age, period and sex. The indicator level used was thus the status 2 years before the year of cancer diagnosis. The background mortality rates were calculated for the age groups 30–34 and 35–39 and subsequently in 1-year age groups from age 40 to 81 years, and for the periods 1994–1997, 1998–2002 and 2003–2006. To estimate the 1- and 5-year cumulative relative survival, we used the above-mentioned SAS macro for the intervals 0–1 and 0–5 years.[29] For each cancer site, the relative survival estimates and the excess mortality rates were standardised for age, with the age distribution (age groups 30–49, 50–59, 60–69 and 70–79 years) at the time of diagnosis as the standard.

Excess mortality has often been found to be inhomogeneous over time since diagnosis, especially in the first year.[29] We evaluated excess mortality according to educational level, by estimating and plotting the relative survival curves up to 5 years and the excess mortality rates in the follow-up intervals after diagnosis (0–0.5, 0,5–1, 1–2, 2–3, 3–4 and 4–5 years). If a difference between educational levels is seen in the curves of relative survival up to 5 years, the excess mortality rates can show whether the difference between levels is greater in some follow-up intervals than in others. Calculation of the cumulative 5-year relative survival during one interval or as a product of that in different follow-up intervals provides slightly different estimates, as can seen by comparing the figures and tables for survival by educational level.

Table 4 – Number of cancers by site diagnosed in the study population of Danish persons born between 1925 and 1973 and aged ⩾30 years and the total number of cancers diagnosed in Denmark, 1994–2003

Cancer site (ICD 10)	Men			Women		
	Denmark	Study population		Denmark	Study population	
	n	*n*	% of total	*n*	*n*	% of total
Mouth and pharynx (C03–06, C46.2, C09–14)	2780	2173	78	1285	811	63
Larynx (C32)	2028	1446	71	450	315	70
Oesophagus (C15)	2585	1600	62	1016	475	47
Stomach (C16)	3300	1834	56	1963	839	43
Pancreas (C25)	3352	1948	58	3690	1709	46
Colon (C18)	9856	5125	52	11,305	4833	43
Rectum (C19–21)	7619	4406	58	6133	3005	49
Lung (C33–34)	20,451	12,061	59	14,957	9431	63
Breast (C50)	–	–		35,821	25,417	71
Cervix C53)	–	–		4314	3007	70
Uterus (C54)	–	–		6120	3826	63
Ovary (C56, C57.0–4)	–	–		5969	3855	65
Prostate (C61)	18,406	8279	44	–		
Testis (C62)	2814	1770	63	–		
Kidney (C64)	3034	1901	63	2055	1040	51
Bladder (C65–68, D09, D41.4)	13,128	7078	54	4835	2393	49
Malignant melanoma (C43)	4482	3208	72	5603	3752	67
Brain/central nervous system (C70–72, D32–33, D42–43)	4179	2669	64	4794	2953	62
Non-Hodgkin lymphoma (C82–85, C96)	4022	2519	63	3548	1997	56
Hodgkin lymphoma (C81)	724	396	55	510	240	47
Leukaemias (C91–95)	4055	2113	52	3185	1373	43
All other cancers[a]	15,878[b]	8986	57	15,522	7190	46
All cancers	122,693	69,512	57	133,075	78,461	59

a Excluding non-melanoma skin cancer.
b Including male breast cancer.

4. Overall description of the study population

The study is based on 3,218,440 persons and 25,764,811 person-years of follow-up for cancer (Table 3). A total of 147,973 cancers were diagnosed, representing 57% of all cancers diagnosed in Denmark during the period (Tables 3 and 4). Because of the age range of the cohort, about one-fourth (27%) of the person-years were accumulated in the lowest age group (30–39 years), which had about 5% of all cancer cases observed, whilst 5% of the persons-years were accumulated in the age group 70–79 years, in which 18% of all cancer cases were observed (Table 3). Immigrants or their descendants accounted for 6% of the person-years, which were excluded from the analyses of all indicators other than ethnicity. Thus, most of the analyses were based on 25,194,929 person-years and on 132,895 incident cancer cases.

Men and women with basic or high-school education accumulated 35% and 44% person-years, respectively, and about one-fifth of the person-years were for men and women with higher education. The vast majority was employed (82% of person-years in men and 73% in women); however, the distribution by social class differed between men and women. In men, about 24% of person-years were accumulated in the creative class (creative core, creative professionals, 'bohemians'), 25% in the service class, 40% in the manual class and 5% in the agricultural class, whereas the respective proportions in women were 13%, 61%, 9% and 2%, respectively. About two-thirds lived in owned housing, and less than 4% of the person-years were accumulated by persons living in the smallest dwellings. About three-fourths of the participants were married or cohabiting. About one-half of the person-years were for persons living in provincial cities, one-third in capital areas and about 15% in rural areas, with 5% in peripheral rural areas. Men with somatic comorbidity accounted for 10% of person-years and women for 9%, and men with psychiatric comorbidity for 2% and women for 3%.

The numbers of cancer cases by site observed in the cohort and the total number diagnosed in Denmark throughout the study period are shown in Table 4. Because of differences in incidence patterns by age and sex, the proportions of all cancers included in the study ranged from 43% for leukaemias in women to 78% for mouth and pharynx cancer in men.

The regression models for cancer incidence were adjusted for educational level and income. Fig. 2 shows that in both sexes, educational level was correlated to some extent with disposable income throughout the age range included in the study. Disposable income increased during the study period, the increase being greater in the high than in the low income

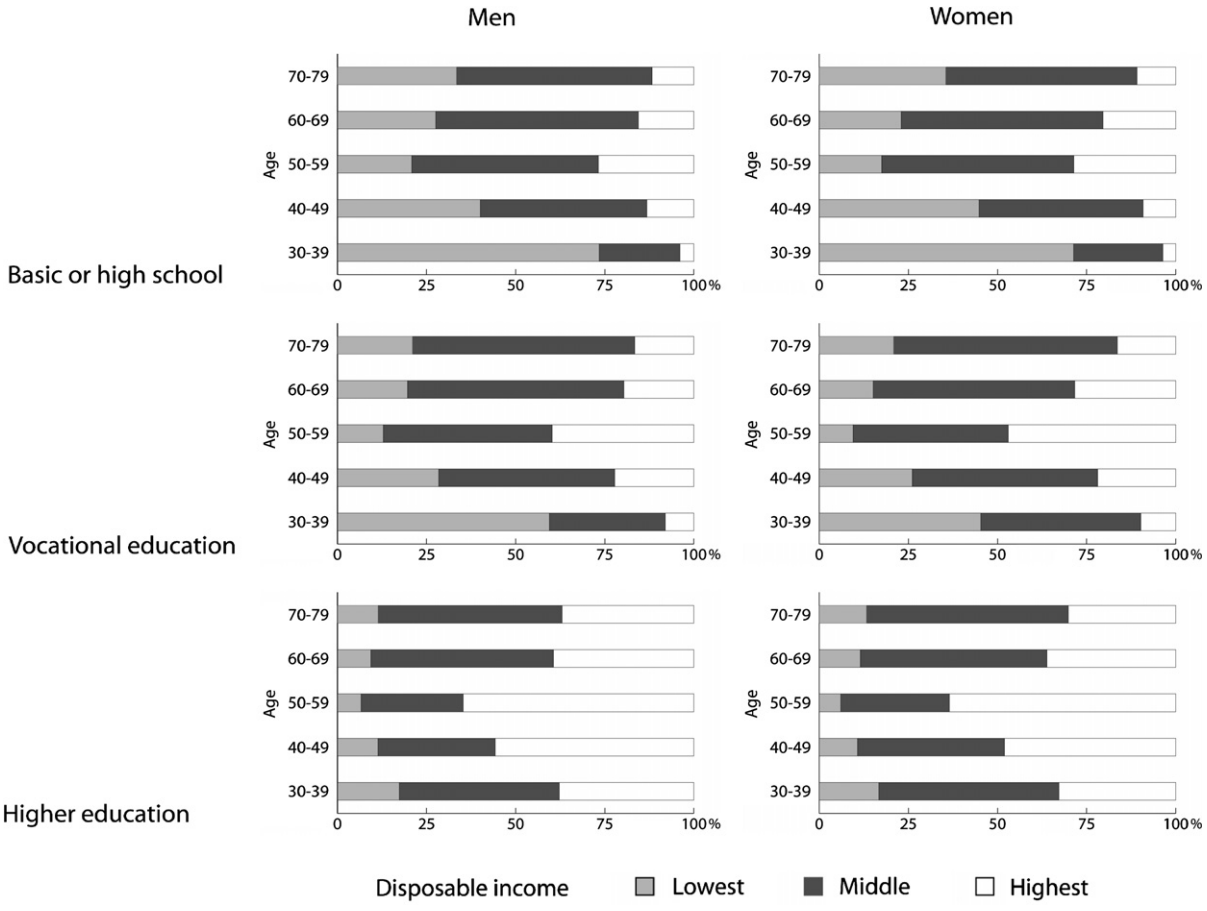

Fig. 2 – Disposable income by age, sex and educational level in 1999 for the study population born between 1925 and 1973 and entering the cohort at age 30 years, Denmark. Disposable income is income after taxation and interest adjusted for the number of persons in the household and deflated according to the 2000 value of the Danish crown (DKK) categorised into low (1st quartile), middle (2nd–3rd quartile) and high (4th quartile) income.

Table 5 – Disposable income (DKK) in 25% and 75% fraction levels by study year in the population of Danish persons born between1925 and 1973 and aged ⩾30 years, 1994–2006

Year	Men		Women	
	25%	75%	25%	75%
1994	104,235	159,337	100,181	155,086
1995	104,876	161,430	100,847	157,260
1996	109,314	167,692	104,378	163,155
1997	110,562	170,431	105,192	165,662
1998	111,598	174,019	106,047	169,075
1999	111,562	175,216	105,783	170,046
2000	113,708	180,668	107,616	175,067
2001	114,929	183,394	108,625	177,627
2002	110,701	176,791	105,006	170,911
2003	111,365	179,230	105,745	173,317
2004	123,243	202,252	117,002	197,017
2005	123,312	203,677	116,817	198,140
2006	126,782	213,058	119,524	206,776

Household income after taxation and interest per person adjusted for the number of persons in the household and deflated according to the 2000 value of the Danish crown (DKK) by the following formula: deflated household income/(no.of persons in household$^{0.6}$). Persons with a yearly income ⩽50,000 DKK excluded. In 2002, the taxation system in Denmark changed, resulting in a slight reduction in fraction levels between 2001 and 2002.

group. Throughout the study period, disposable income was lower for women than men (Table 5).

Fig. 3 illustrates the observed and the expected age-standardised survival in the study population by sex and educational level, with the age distribution of all cancers. Although the differences in survival between the groups were small, there was stepwise better observed and expected survival with increasing length of education for both men and women. The variation in expected survival tended to be smaller in women than men for all indicators (data not shown). The differences in expected survival with all health-related indicators were larger than for the other indicators. Further, early retirement pensioners had much lower expected survival, reflecting the fact that many of these persons suffer from chronic disorders that prevent them from holding a job. Differences in type of district and ethnicity had little effect on expected survival (data not shown).

5. Comments

For our descriptive study of social inequality in cancer incidence and survival, we established a population-based nationwide cohort, which ensured optimal use of the data available in statistical registers based on the administrative data in Denmark to achieve the largest possible number of cases. The age range was limited, the upper age limit increasing with time due to the increasing availability of data. Although the size of the population ensures sufficient statistical power to address the question of social inequality for cancers at most sites, one disadvantage of the construction of the cohort is that it is difficult to compare incidence rates and cumulative relative survival proportion ratios derived directly from cancer register data. The comparability of the overall figures with those based on cancer register data was not, however, the aim of the project, which was to address the question of social gradients and to identify vulnerable groups.

We designed a joint analytical strategy for the chosen cancer sites which encompassed both the indicators investigated and how they were categorised. This strategy allows comparison across cancer sites. The common analytical strategy might not, however, have been the most appropriate model for detecting the most vulnerable group for a specific cancer.

Because annually updated data were available, we categorised persons by indicator status 2 years before the observation time. It would have been better to categorise them by the status of the indicator more than 2 years before the

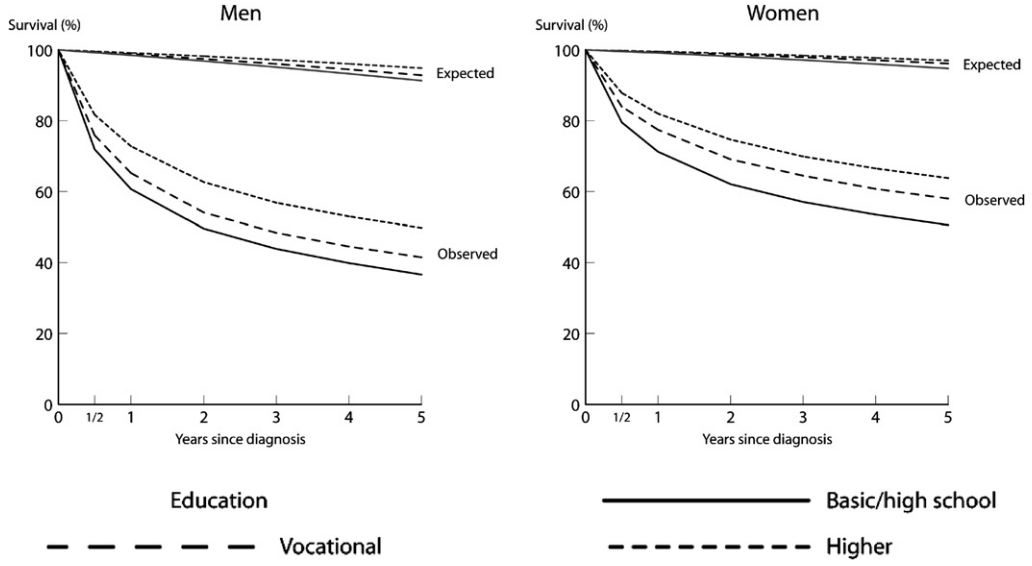

Fig. 3 – Observed and expected age-standardised survival according to age distribution of all cancers in the study population, born between 1925 and 1973 and entering the cohort at age 30 years, Denmark, 1994–2006, by sex and educational level.

observation time, as effects on, e.g. cancer risk might have a longer time lag. This was not possible in our data. Our approach, however, has the advantage of allowing for changes in the indicators on a yearly basis and is thus better than point-in-time census data, which are often used for such analyses. Further, the 2-year time lag ensures minimal misclassification of persons in respect of socioeconomic or health status due to the presence of an undiagnosed cancer.

With regard to ethnicity, we categorised the population into Danes, immigrants and descendants from western countries and immigrants and descendants from non-western countries (see Table 1). The last group is very broad, consisting of people from four continents with different cultural, social and health-related behaviour; hence, the results should be interpreted with caution. Depending on the age at immigration and the country of origin, information is missing and the comparability of the social indicators with the Danish system is an issue for this group. Migrant studies, with finer subdivisions into more homogeneous groups, are more appropriate for investigating cancer incidence and survival in this context, but this again was not in the scope of the present project. We therefore restricted our analyses for all indicators except ethnicity to the group of Danes, to achieve the most clear-cut definition of a target group for investigating social inequality.

We defined a variety of indicators of socioeconomic position, not as exchangeable indicators of the same underlying concept, but rather to acknowledge their actions in causal chains: education determines occupation, which affects income, which determines housing, and so on. We did, however, choose education and disposable income as core variables, and these indicators were included in the models of incidence rate ratios; we also used level of education to illustrate the social distribution of the incidence rates by age, incidence rate differences and relative survival and excess mortality plotted over time since diagnosis.

Formal education is usually completed in young adulthood, and therefore captures the long-term influences of early-life circumstances on adult health and the influence of adult resources (for example employment status) on health. Further, the knowledge and skills attained through education can affect people's cognitive functioning and make them more receptive to health education messages and more capable of communicating with and accessing the appropriate health services.[30] The meaning of 'educational level' varies, however, for different birth cohorts, and there have been considerable changes, e.g. in educational opportunities for women during the last part of the 20th century.

The other core variable we chose is disposable income, which is defined as household income after taxation and interest, adjusted for the number of persons in the household. Disposable income is preferable to, for instance gross income, which is used in many studies, because it reflects what individuals can actually spend. Income is hypothesised to influence health mainly by a direct effect on material resources, and the proposed mechanisms include greater access to better-quality resources, such as food and housing, and better access to services that may improve health directly (health services, leisure activities) or indirectly (e.g. education).[30]

We also chose to include in the analysis demographic and health-related indicators. It might be argued that some of these, such as somatic and psychiatric comorbidity, are mediators of social inequality. We included these indicators in our descriptive analyses, however, to provide as broad a picture of the social distribution of cancer as possible, as some of the groups defined by these indicators, such as those with comorbidity, represent disadvantaged minorities or vulnerable groups with major health problems and thus differ from the rest of the population. This type of social inequality, in which a specific problem is associated with a minority, has been called a 'gap', in contrast to the social gradient, in which a health problem increases with lower socioeconomic position.[31]

Estimation of relative survival is used to eliminate the effects of competing causes of mortality in the absence of information on the cause of death, thereby circumventing problems of inaccuracy or lack of death certificates. Expected survival is usually estimated from population mortality, stratified by age, sex and calendar time. As studies have shown that mortality from all causes is higher in groups of lower socioeconomic status,[32] relative survival ratios, in which expected survival is based on mortality in an entire population according to age, sex and calendar time, tend to provide overestimates of social differences in the survival of cancer patients. The relative survival ratios for lower socioeconomic groups would be underestimated because these groups have higher mortality from all causes than the general population, whilst the relative survival ratios for higher social classes would be overestimated due to the attribution of socioeconomic differences in, e.g. mortality from cardiovascular disease to the cancer.[32]

The cumulative relative survival function $R(t)$ is calculated as the ratio of the observed to the expected proportions of survival and could in rare situations exceed 100% and increase with length of follow-up. It is used to represent the proportion of cancer patients alive t years after diagnosis when the cancer in question is the only cause of death. The validity of this interpretation depends on the accuracy of the estimate of expected survival and on the independence between mortality from conditions other than cancer and from cancer. The relative survival method thus does not solve all the problems associated with competing causes of mortality, and the results must be interpreted with caution. Smokers who die from smoking-associated cancers, for instance, have increased mortality from nearly all causes. Information on smoking was not available at the individual level in our study, which might have affected the comparisons between socioeconomic groups, with more appropriate adjustment for smoking-related mortality in lower socioeconomic groups, which include a larger proportion of smokers than higher socioeconomic groups. Use of level-specific population mortality in estimating expected survival reduced this problem.

Despite the limitations of descriptive studies discussed above, the study is a comprehensive investigation of possible associations between socioeconomic, demographic and health-related indicators and cancer incidence and survival. The approach has several strengths. The study is population-based and includes all persons in a certain age range living in Denmark, with valid, complete information on the

indicators. All the indicators were updated annually, which is rarely done in such investigations. We had access to a variety of indicators, so that we obtained a broader picture than with the commonly used indicators of social position, including identification of vulnerable groups which may be only subgroups in a large socioeconomic category. We also used new concepts for categorising socioeconomic position, such as that developed by Florida[33] to describe modern changes in the organisation of the work market. The putatively vulnerable groups were early retirement pensioners, persons living in peripheral rural areas, persons living in small housing and persons with somatic and psychiatric disorders. Addition of such indicators to the usual social gradients provides a more complete picture of cancer incidence and survival patterns.

Conflict of interest statement

None declared.

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