Original article

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Life expectancy and cancer survival in the EUROCARE-3 cancer registry areas

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Background: Mortality information is essential for estimating relative cancer survival (that excludes deaths from other causes). However, sufficiently detailed mortality data are not available for all areas covered by the cancer registries (CRs) participating in the EUROCARE-3 study.

Materials and methods: Mathematical methods were used to construct complete local mortality data (life tables) for each year of age (0–99), for each year (1978–2000) and by sex, from the incomplete life tables provided by CRs, presenting the results as life expectancy at birth (LE). Socio-economic data were obtained from the United Nations (UN) and Organisation for Economic Co-operation and Development (OECD).

Results: The time and regional trends in LE provided by our estimates are closely similar to those published by the UN at the country level. According to UN data, LE (men plus women) varied from 70 years in Estonia to almost 79 years in Sweden in the period 1995–1999. LE increased markedly over the 20-year study period in most countries except Estonia and Denmark. LE correlated directly with GDP, national expenditure on health and relative survival for all cancers combined. We found that within-country LE variation was large in some countries (particularly the UK). Sweden, Iceland, Switzerland, and parts of Spain and Italy had high LE; eastern European countries had low LE.

Conclusions: Detailed area-specific life tables are essential for reliable estimation of relative cancer survival and its comparison across populations, since LE varies markedly across Europe. Where not available, life tables can be constructed to the required level of detail using mathematical approaches.

Key words: cancer registries, cancer relative survival, Europe, life expectancy at birth

Introduction

Crude survival from a cancer is the cumulative probability of survival in a group of patients with the cancer at a given time after diagnosis; it considers deaths due to the cancer plus all other causes. *Cause-specific survival* is an assessment of survival that considers mortality due to the cancer only. Cause-specific survival is estimated by linking cancer registration files with death information and considering only deaths due to cancer. However, in many countries such linking is not possible due to confidentiality constraints; and where it is possible it is resource intensive and is often problematic because cause-of-death information is not sufficiently accurate. *Relative survival* methods have therefore been developed which estimate the survival of cancer patients relative to the life expectancy of the population [1].

Relative survival is the ratio of the observed survival probability in a group of patients to the general population survival probability expected in a similar group in the absence of cancer. Since mortality varies markedly with age, sex, over time and between populations [2], it is essential to account for all death risks not related to cancer in order to accurately estimate cancer relative survival and thereby render estimates comparable between different populations.

The EUROCARE project is a large-scale collaboration between European population-based cancer registries (CRs) whose purpose is to provide accurate estimates of the survival of cancer patients across Europe and to analyse and interpret survival differences [3]. In order to calculate relative survival, EUROCARE required general mortality data for all the populations covered by the participating CRs. All registries participating in EUROCARE-3 [3] were therefore asked to provide information on general mortality for their areas. The mortality data provided varied considerably in detail, and for many registry areas it was necessary to estimate general mortality rates from very limited data using mathematical interpolation and extrapolation procedures. The aim of these procedures was to produce ‘complete’ life tables for the populations covered, i.e. by each year of age (0–99), for men and for women, and for each year of the EUROCARE study period (1978–2000).

The first part of this article describes the general mortality data provided by the CRs, and the procedures used to calculate missing data for the different registry populations. The second part of this paper provides a general description of patterns and trends in life expectancy at birth (LE) (a measure directly derived from general

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Table 1. Truncated life table for men of the Province of Varese, Italy, 1995

Age *x*	D_x	P_x	m_x	q_x	p_x	l_x	d_x	L_x	T_x	e_x
0	13	3164	0.004109	0.004100	0.9959	100000	410	99794.99	7478626.59	74.79[a]
1	2	3549	0.000564	0.000563	0.999437	99590	56	99561.92	7378831.61	74.09
2	0	3642	0	0	1	99534	0	99533.86	7279269.69	73.13
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
49	11	5559	0.001979	0.001977	0.998023	93730	185	93637.79	2691025.54	28.71
50	20	4861	0.004114	0.004106	0.995894	93545	384	93353.10	2597387.75	27.77
51	25	4982	0.005018	0.005005	0.994995	93161	466	92927.89	2504034.65	26.88
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
98	7	11	0.636364	0.470787	0.529213	1092	514	835.26	1353.80	1.24
99	3	13	0.230769	0.206077	0.793923	578	119	518.55	518.55	0.90

x, Year of age; D_x, deaths from all causes for men in the Province of Varese in 1995; P_x, mid-year population of men of the Province of Varese in 1995; m_x, age-specific death rate ($m_x = D_x/P_x$); q_x, probability of dying between exact ages *x* and *x* + 1 ($q_x = 1 - e^{-mx}$); p_x, probability of surviving between exact ages *x* and *x* + 1 ($p_x = 1 - q_x$); l_x, number of people alive at exact age *x* (conventionally a life table is based on a cohort of 100 000 people alive at the beginning) ($l_x = l_{x-1} \cdot p_x$ and l_0 = 100 000); d_x, number of people (in the original cohort of 100 000) dying between ages *x* and *x* + 1 ($d_x = l_x - l_{x-1}$); L_x, number of person years lived between ages *x* and *x* + 1 [$L_x = (l_x + l_{x+1})/2$]; T_x, total number of person-years lived after exact age *x*, i.e. the L_x column cumulated from the bottom ($T_x = T_{x+1} + L_x$); e_x, expectation of life at age *x*, i.e. the average number of years a person aged *x* has still to live ($e_x = T_x/l_x$).
[a]Life expectancy at birth (e_0).

mortality data) in Europe with an indication of the relationship between LE and gross domestic product (GDP). These patterns serve as general health indicators against which cancer survival patterns should be considered. We also present an analysis of relationships between LE and cancer survival using the new EUROCARE-3 cancer survival data. In studies carried out on earlier EUROCARE data, we identified an important relation between relative cancer survival and LE: countries with high relative cancer survival also had high LE, while countries with low relative survival had low LE [2, 4].

Materials and methods

Mortality data, in the form of life tables, for all causes of death combined, were obtained from each participating CR. Table 1 shows an example of a CR life table. It refers to men in the Province of Varese, Italy, for 1995 and illustrates the relationship between mortality rates in the population (m_x), age-specific probabilities of survival (p_x) required for calculations of relative cancer survival and life expectancy at birth (e_0).

Some CRs cover an entire country; others only parts of a country [3]. Table 2 summarises the characteristics of the general mortality data provided by each CR and the estimations carried out for the purposes of EUROCARE-3. For each CR, the table gives the following information: country; age interval; maximum age; period (years) covered by the life tables; period (years) for which estimates were performed; and the procedures used for obtaining the estimates. The main problems with the submitted data, and the solutions adopted to overcome the problems, are summarised here.

Lack of data for some calendar years

We used the linear interpolation, or fraction method [2], to estimate the data for each missing year from data for the two nearest years. For example, if the death probabilities q_x at age *x* for the years 1979 and 1982 are known, the interpolated probabilities for the years 1980 and 1981 are given by
$q_x(1980) = 2/3\, q_x(1979) + 1/3\, q_x(1982)$,
and $q_x(1981) = 1/3\, q_x(1979) + 2/3\, q_x(1982)$.
If submitted data were grouped over several calendar years, the same method was used to estimate the death probability for each single year after first attributing the grouped data to the middle year of the interval. Missing data at either extreme of the study period (1978–2000) were taken to be those of the earliest and latest available life tables, respectively.

Missing data for the oldest population segment

The *adult age* method proposed by Elandt-Johnson and Johnson [5] was used to estimate death probabilities for very old people, when these were not available. This method assumes that mortality in old age follows the Gompertz distribution [5]. We calculated death probabilities up to 99 years of age. Although this approach is sufficiently accurate for estimating relative survival in the elderly, mortality rates calculated for the very oldest ages by this method have to be interpreted with particular caution.

Estimating complete life tables (single year age intervals) from 5-year age intervals

The *Elandt-Johnson* method [5] was used to obtain complete life tables from abridged life tables. This method is based on polynomial interpolations and employs different coefficients for children (0–9 years of age), and young people plus adults (10–74 years of age). The method assumes a Gompertz distribution [5] for ages ≥75 years.

Regional life tables available for a single (census) calendar year only

This was a problem with French CRs. Life tables for the registration area were available only for 1990, while complete life tables (for each calendar year) were only available on a national basis. In this case, the *Adaptive* method [6–7] was used for the period 1978–1995. This method, proposed by Ewbank [6], is

Table 2. Characteristics of submitted and estimated general mortality by registry

Registry	Country	Mortality data submitted			Data estimated by EUROCARE-3	
		Age interval, years	Maximum age, years	Period[a]	Period[a]	Method
Amsterdam[b]	NL	1	99	1978..2000		
Basel	CH	5	99	1981..1998	1978..1980	Fraction
					1981..1998	Elandt-Johnson
					1999..2000	Fraction
Pays Basque	E	1	100	1975–1976	1978..1980	Fraction
				1980–1981	1982..1985	Fraction
				1985–1986	1987..1990	Fraction
				1990–1991	1992..1995	Fraction
				1995–1996	1997..2000	Fraction
Bas Rhin	F	1	98	1986..1994	1978..1985	Adaptive
					1995..2000	Fraction
Calvados	F	1	98	1986..1994	1978..1985	Adaptive
					1995..2000	Fraction
Côte d’Or	F	1	98	1986..1994	1978..1985	Adaptive
					1995..2000	Fraction
Cracow	PL	1	100	1982..1996	1978..1981	Elandt-Johnson
					1982..1996	Exponential
					1997..2000	Fraction
Denmark[c]	DK	1	99	1978..1999	1978..1999	Exponential
					2000	Fraction
East Anglia[d]	UK	1	99	1971–1985, 1985–1995	1978..1995	Fraction
		5	85	1996..1999	1996..1999	Elandt-Johnson
					2000	Fraction
Eindhoven	NL	1	99	1976–1978, 1979–1981, 1982–1984, 1985–1987, 1988–1990, 1991–1993, 1994–1996, 1997–1999	1978..2000	Fraction
Estonia[c]	EST	1	110	1978..1999	2000	Fraction
Ferrara	I	1	99	1978..1997	1978..1997	Exponential
					1998..2000	Fraction
Finland	FIN	1	99	1976–1980, 1981–1985, 1986–1990, 1991–1995, 1996–1999	1978..2000	Fraction
Geneva	CH	5	99	1978..1999	1978..1999	Elandt-Johnson
					2000	Fraction
Genoa	I	1	99	1990..1999	1978..1989	
					2000	Fraction
Granada	E	1	99	1978..1998	1978..1998	Exponential
					1999..2000	Fraction
Iceland[c]	ICE	1	99	1995..1999	1978..1994	
					2000	Fraction
Isère	F	1	98	1986..1994	1978..1985	Adaptive
					1995..2000	Fraction
Latina	I	1	99	1978..1997	1978..1997	Exponential
					1998..2000	Fraction
Macerata	I	1	99	1978..1997	1978..1997	Exponential
					1998..2000	Fraction

Table 2. (*Continued*)

Registry	Country	Mortality data submitted			Data estimated by EUROCARE-3	
		Age interval, years	Maximum age, years	Period[a]	Period[a]	Method
Mallorca	E	1	90	1994..1996	1978..1993	Fraction
					1994..1996	Adult age
					1997..2000	Fraction
Malta[c]	MLT	1	85	1978..1997	1978..1997	Adult age and exponential
					1998..2000	Fraction
Mersey[e]	UK	1	99	1971–1985, 1985–1995	1978..1995	Fraction
		5	85	1996..1999	1996..1999	Elandt-Johnson
					2000	Fraction
Modena	I	1	99	1978..1997	1978..1997	Exponential
					1998..2000	Fraction
Munich[f]	D	1	90	1980..1997	1978..1979	Fraction
					1980..1997	Adult age
						Fraction
Murcia[g]	E	5	75	1989..1998	1989..1998	Elandt-Johnson and adult age
					1999..2000	Fraction
Navarra	E	1	99	1978..1999	1978..1999	Exponential
					2000	Fraction
Norway[c]	N	1	99	1953..1997	1998..2000	Fraction
Oxford[d]	UK	1	99	1971–1985, 1985–1995	1978..1995	Fraction
		5	85	1996..1999	1996..1999	Elandt-Johnson
					2000	Fraction
Parma	I	1	99	1978..1997	1978..1997	Exponential
					1998..2000	Fraction
Portugal[h]	P	1	99	1991, 1996	1992..1995	Fraction
					1997..2000	Fraction
Ragusa	I	1	99	1978..1997	1978..1997	Exponential
					1998..2000	Fraction
Romagna	I	1	99	1978..1997	1978..1997	Exponential
					1998..2000	Fraction
Saarland	D	1	Deaths: 99	1978..1997	1978..1997	Exponential
			Popul: 85		1998..2000	Fraction
Sassari	I	1	99	1978..1997	1978..1997	Exponential
					1998..2000	Fraction
Scotland[c]	UK	1	90	1995..1999	1978..1994	
					1995..1999	Adult age
					2000	Fraction
Slovakia[c]	SK	1	99	1992..1998	1978..1991	
					1999..2000	Fraction
Slovenia[c]	SLO	5	85	1990–1992, 1992–1993,	1978..1989	
		1	101	1993–1994, 1993–1995,	1990..1998	Elandt-Johnson
				1995–1996, 1996–1997,	1999..2000	Fraction
				1997–1998, 1998–1999		
South West	UK	1	99	1971–1985, 1985–1995	1978..1995	Fraction
		5	85	1996..1999	1996..1999	Elandt-Johnson
					2000	Fraction

Table 2. (*Continued*)

Registry	Country	Mortality data submitted			Data estimated by EUROCARE-3	
		Age interval, years	Maximum age, years	Period[a]	Period[a]	Method
Sweden[c]	S	1	99	1958..1999	2000	Fraction
Tarragona[i]	E	5	95	1985..1997	1985..1997	Elandt-Johnson
					1998..2000	Fraction
Thames[j]	UK	1	99	1971–1985, 1985–1995	1978..1995	Fraction
		5	85	1996..1999	1996..1999	Elandt-Johnson
					2000	Fraction
Trent	UK	1	99	1971–1985	1978..1995	Fraction
		5	85	1985–1995	1996..1999	Elandt-Johnson
				1996..1999	2000	Fraction
Turin	I	1	99	1978..1997	1978..1997	Exponential
					1998..2000	Fraction
Tuscany[k]	I	1	99	1978..1997	1978..1997	Exponential
					1998..2000	Fraction
Tyrol	A	5	90	1991..1999	1978..1990	
					1991..1999	Elandt-Johnson
					2000	Fraction
Varese	I	1	99	1978..1997	1978..1997	Exponential
					1998..2000	Fraction
Veneto	I	1	99	1978..1997	1978..1997	Exponential
					1998..2000	Fraction
Wales[c]	UK	1	99	1971–1985, 1985–1995	1978..1995	Fraction
		5	85	1996..1999	1996..1999	Elandt-Johnson
					2000	Fraction
Warsaw	PL	1	100	1986..2001	1978..1985	Elandt-Johnson
					1986..1997	Exponential
West Bohemia[l]	CZ	5	85	1978..1994	1978..1994	Elandt-Johnson
					1995..2000	Fraction
West Midlands	UK	1	99	1971–1985, 1985–1995	1978..1995	Fraction
		5	85	1996..1999	1996..1999	Elandt-Johnson
					2000	Fraction
Yorkshire	UK	1	99	1971–1985, 1985–1995	1978..1995	Fraction
		5	85	1996..1999	1996..1999	Elandt-Johnson
					2000	Fraction

[a]*'y1..y2'* means every year from *y1* to *y2* inclusive; *'y1–y2'* means that a single set of data for the period *y1–y2* was submitted.
[b]Life tables for the Netherlands used.
[c]National cancer registry (covering entire country).
[d]East Anglia and Oxford (UK) have the same life tables.
[e]Life tables of North Western (UK) used.
[f]Life tables for Germany used.
[g]Life tables start from 1989.
[h]Life tables start from 1991.
[i]Life tables start from 1985.
[j]Life tables for South-Thames (UK) used.
[k]Life tables for Florence (I) used.
[l]Life table data up to 1994, while life expectancy at birth information is up to 1999.
A, Austria; CZ, Czech Republic; DK, Denmark; UK for England, Scotland and Wales; EST, Estonia; FIN, Finland; F, France; D, Germany; ICE, Iceland; I, Italy; MLT, Malta; NL, Netherlands; N, Norway; P, Portugal; PL, Poland; SK, Slovakia; SLO, Slovenia; E, Spain; S, Sweden; CH, Switzerland.

Table 3. Life expectancy at birth for men in EUROCARE-3 cancer registry areas

Cancer registry	Country	Life expectancy at birth, years			Rank (increasing order)			Quartile		
		1978	*1987*	*1997*	*1978*	*1987*	*1997*	*1978*	*1987*	*1997*
Estonia	EST	64.59	66.37	64.69	1	1	1	1	1	1
Slovakia	SK	66.99	67.12	68.80	3	2	2	1	1	1
West Bohemia	CZ	66.53	67.37	70.04	2	3	3	1	1	1
Warsaw	PL	67.70	68.21	70.43	6	4	4	1	1	1
Cracow	PL	67.70	68.24	70.74	6	5	5	1	1	1
Slovenia	SLO	67.52	68.58	71.09	5	6	6	1	1	1
Portugal[a]	P	–	–	71.54	–	–	7	–	–	1
Scotland	UK	67.94	70.47	72.53	9	8	8	1	1	1
Finland	FIN	68.45	70.59	73.15	10	9	9	1	1	1
Saarland	D	67.42	70.87	73.31	4	10	10	1	1	1
Mersey	UK	69.69	71.55	73.39	16	13	11	2	1	1
Denmark	DK	71.40	71.84	73.51	35	15	12	3	2	1
Bas Rhin	F	69.55	71.19	73.63	14	11	13	2	1	1
Calvados	F	69.73	71.36	73.86	17	12	14	2	1	2
Yorkshire	UK	70.00	71.83	74.14	20	14	15	2	1	2
Mallorca	E	69.47	72.07	74.15	13	16	16	1	2	2
Granada	E	71.12	72.93	74.16	30	33	17	3	3	2
Basque Country	E	70.13	72.44	74.16	21	21	18	2	2	2
Wales	UK	70.32	72.40	74.20	23	19	19	2	2	2
Munich	D	69.99	72.07	74.25	19	17	20	2	2	2
Eindhoven	NL	71.20	72.79	74.30	32	29	21	3	3	2
West Midlands	UK	70.47	72.36	74.49	25	18	22	2	2	2
Ferrara	I	70.20	72.48	74.49	22	22	23	2	2	2
Murcia[b]	E	–	–	74.50	–	–	24	–	–	2
Trent	UK	70.75	72.61	74.78	28	23	25	3	2	2
Malta	MLT	68.76	72.70	74.87	11	26	26	1	2	2
Genoa	I	70.74	72.78	75.02	27	27	27	3	2	3
Isère	F	71.16	72.78	75.21	31	28	28	3	3	3
Varese	I	69.94	72.70	75.34	18	25	29	2	2	3
Côte d’Or	F	71.28	72.88	75.38	33	30	30	3	3	3
Norway	N	72.28	72.91	75.43	44	32	31	4	3	3
Veneto	I	69.33	72.43	75.46	12	20	32	1	2	3
Sassari	I	71.38	73.36	75.46	34	36	33	3	3	3
Amsterdam	NL	72.60	73.91	75.50	48	41	34	4	4	3
Parma	I	70.73	72.91	75.55	26	31	35	2	3	3
Tyrol	A	72.20	74.32	75.55	40	43	36	4	4	3
Thames	UK	71.79	73.55	75.65	38	38	37	3	3	3
Latina	I	71.48	73.47	75.70	37	37	38	3	3	3
Modena	I	71.05	73.34	75.74	29	35	39	3	3	3
Turin	I	69.64	72.95	75.79	15	34	40	2	3	4
Navarra	E	71.46	74.48	75.95	36	45	41	3	4	4
South West	UK	71.98	73.90	76.08	39	40	42	4	4	4
Ragusa	I	72.63	74.62	76.20	49	49	43	4	4	4
Iceland	ICE	73.22	74.92	76.28	52	52	44	4	4	4
East Anglia	UK	72.26	74.06	76.35	42	42	45	4	4	4
Basel	CH	73.02	73.85	76.36	51	39	46	4	3	4
Tarragona[c]	E	–	74.85	76.54	–	51	47	–	4	4
Romagna	I	72.24	74.41	76.66	41	44	48	4	4	4
Tuscany	I	72.35	74.57	77.06	45	46	49	4	4	4
Geneva	CH	72.56	74.69	77.07	46	50	50	4	4	4
Macerata	I	72.28	74.59	77.07	43	48	51	4	4	4
Sweden	S	72.97	74.59	77.19	50	47	52	4	4	4

[a]Mortality data not available before 1991. In 1978 and 1987 we assumed that the Portuguese CR areas had the same rank as in 1997.
[b]Mortality data not available before 1989. In 1978 and 1987 we assumed that the Murcia CR area had the same rank as in 1997.
[c]Mortality data not available before 1985. In 1978 we assumed that Tarragona CR area had the same rank as in 1997.
A, Austria; CZ, Czech Republic; DK, Denmark; UK for England, Scotland and Wales; EST, Estonia; FIN, Finland; F, France; D, Germany; ICE, Iceland; I, Italy; MLT, Malta; NL, Netherlands; N, Norway; P, Portugal; PL, Poland; SK, Slovakia; SLO, Slovenia; E, Spain; S, Sweden; CH, Switzerland.

Table 4. Life expectancy at birth for women in EUROCARE-3 cancer registry areas

Cancer registry	Country	Life expectancy at birth, years			Rank (increasing order)			Quartile		
		1978	1987	1997	1978	1987	1997	1978	1987	1997
Estonia	EST	74.50	75.12	75.97	4	2	1	1	1	1
West Bohemia	CZ	73.50	74.46	76.63	2	1	2	1	1	1
Slovakia	SK	74.73	75.50	76.75	5	3	3	1	1	1
Cracow	PL	75.24	75.64	77.25	8	4	4	1	1	1
Warsaw	PL	75.24	75.85	77.71	8	5	5	1	1	1
Scotland	UK	74.02	76.51	77.90	3	7	6	1	1	1
Denmark	DK	77.40	77.63	78.51	25	12	7	2	1	1
Mersey	UK	75.58	77.04	78.62	11	9	8	1	1	1
Slovenia	SLO	75.06	76.41	78.74	7	6	9	1	1	1
Portugal[a]	P	–	–	78.79	–	–	10	–	–	1
Yorkshire	UK	75.80	77.22	79.13	12	11	11	1	1	1
Wales	UK	75.95	77.88	79.33	13	15	12	1	2	1
Saarland	D	74.74	77.85	79.43	6	14	13	1	1	1
Trent	UK	76.50	77.92	79.47	18	16	14	2	2	2
Malta	MLT	73.04	76.92	79.52	1	8	15	1	1	2
West Midlands	UK	76.31	77.74	79.59	14	13	16	2	1	2
Eindhoven	NL	77.70	79.03	80.08	35	24	17	3	2	2
Thames	UK	77.49	78.90	80.20	29	20	18	3	2	2
Munich	D	76.63	78.54	80.31	19	18	19	2	2	2
East Anglia	UK	77.60	78.93	80.39	32	21	20	3	2	2
Finland	FIN	77.23	78.69	80.49	21	19	21	2	2	2
South West	UK	77.53	79.12	80.61	31	25	22	3	2	2
Murcia[b]	E	–	–	80.67	–	–	23	–	–	2
Granada	E	76.81	78.96	80.77	20	22	24	2	2	2
Ragusa	I	76.42	78.24	80.93	17	17	25	2	2	2
Norway	N	78.68	79.60	80.98	42	29	26	4	3	2
Amsterdam	NL	79.10	80.42	80.99	49	41	27	4	4	3
Bas Rhin	F	77.34	79.37	81.36	22	27	28	2	2	3
Tyrol	A	78.27	81.02	81.36	40	51	29	4	4	3
Iceland	ICE	79.09	79.88	81.43	48	35	30	4	3	3
Genoa	I	77.35	79.64	81.84	24	30	31	2	3	3
Ferrara	I	77.47	79.79	81.86	27	34	32	3	3	3
Latina	I	77.47	79.67	81.92	28	31	33	3	3	3
Sassari	I	77.46	79.68	81.92	26	32	34	2	3	3
Mallorca	E	76.33	79.43	81.94	15	28	35	2	3	3
Tarragona[c]	E	–	80.44	82.04	–	–	36	–	–	3
Turin	I	76.34	79.33	82.05	16	26	37	2	2	3
Modena	I	77.83	80.17	82.14	37	38	38	3	3	3
Basel	CH	79.53	80.51	82.18	52	44	39	4	4	3
Varese	I	77.61	79.78	82.20	33	33	40	3	3	4
Sweden	S	79.18	80.51	82.21	50	43	41	4	4	4
Veneto	I	77.64	80.00	82.36	34	37	42	3	3	4
Basque Country	E	77.50	79.98	82.38	30	36	43	3	3	4
Romagna	I	78.70	80.65	82.59	43	45	44	4	4	4
Calvados	F	78.54	80.38	82.59	41	40	45	4	4	4
Parma	I	78.16	80.17	82.59	39	39	46	3	3	4
Tuscany	I	78.79	80.85	82.68	45	49	47	4	4	4
Macerata	I	78.76	80.81	82.68	44	48	48	4	4	4
Isère	F	78.81	80.69	82.85	46	46	49	4	4	4
Côte d’Or	F	79.02	80.92	83.06	47	50	50	4	4	4
Geneva	CH	79.42	81.08	83.07	51	52	51	4	4	4
Navarra	E	78.04	80.76	83.07	38	47	52	3	4	4

[a]Mortality data not available before 1991. In 1978 and 1987 we assumed that Portugal CR areas had the same position as in 1997.
[b]Mortality data not available before 1989. In 1978 and 1987 we assumed that the Murcia CR area had the same position as in 1997.
[c]Mortality data not available before 1985. In 1978 we assumed that Tarragona CR area had the same position as in 1997.
A, Austria; CZ, Czech Republic; DK, Denmark; UK for England, Scotland and Wales; EST, Estonia; FIN, Finland; F, France; D, Germany; ICE, Iceland; I, Italy; MLT, Malta; NL, Netherlands; N, Norway; P, Portugal; PL, Poland; SK, Slovakia; SLO, Slovenia; E, Spain; S, Sweden; CH, Switzerland.

an extension of Brass' logit method [8]. It allowed us to estimate the complete life tables for each French registry area and for each year by rescaling the corresponding national life tables according to local mortality in the year 1990.

Calculating death probabilities

Sometimes, CRs submitted mortality rates instead of death probabilities. In such cases a standard *Exponential* method [9] was used to calculate death probabilities from the mortality rates. This method assumes that survival time is exponential, and that in any one time interval the death rate is constant. If the probability is ${}_tq_x$, and the mortality rate ${}_tm_x$ for an interval of t units of time, the relationship is

$$ {}_tq_x = 1 - e^{-{}_tm_x * t} $$

Results

Tables 3 and 4 show LE in 1978, 1987 and 1997 for men and women, respectively, for all registry areas, as determined from submitted or estimated mortality data. These tables rank registry areas (lowest first) according to LE for 1997.

For men, LE ranged from 64.6 to 73.2 years in 1978, and from 64.7 to 77.2 years in 1997. At both ends of the study period, Estonia had the lowest LE. In 1978, Iceland had the highest LE and in 1997, Sweden had the highest LE. The largest increases in LE (>6 years) were in Turin, Veneto (Italy) and Malta (see quartile column, Table 3). The eastern European countries (Estonia, Slovakia, Czech Republic, Poland and Slovenia) consistently had the lowest LEs; Portugal, Scotland, Finland, Denmark and parts of England also had low LEs. Iceland, Sweden and parts of England, Italy, Spain and Switzerland had consistently high LEs. Registry areas in the UK were characterised by marked variation in LE: in 1997, LE was low (72.5 years) in Scotland but high (>76 years) in the South West and East Anglia (England) CR areas.

For women (Table 4), LE ranged from 73.0 years in Malta to 79.5 years in Basel, Switzerland in 1978, and from 76.0 years in Estonia to 83.1 years in Navarra, Spain in 1997. The overall pattern for women was similar to that for men (except that LEs were higher for women), with lowest LEs again in the eastern European countries, Portugal, Scotland and Denmark (but not Finland) and parts of England. LE was consistently high in Sweden (but not Iceland) and parts of France, Italy, Spain and Switzerland (but not England).

Figures 1 and 2 show LE trends over the 20 years of the study period. The median LE is shown together with that for the CR area that, for each year, had the highest, third highest, third lowest and lowest values. These figures illustrate the considerable variation in the lowest LE for both men and women. They also show that the median curves are much closer to the higher curve than the lower one. The differences between the third highest and third lowest curves are wider in 2000 than in 1978 for both men and women. For men, the difference widened from 6.0 to 8.0 years, and for women from 5.2 to 6.3 years. Generally, LEs increased modestly over the study period in countries or areas that had low LE in 1978. For men (Figure 1 and Table 3), LEs increased by ≤3 years (compared with a median increase of about 3.7 years) in Estonia, Slovakia, Czech Republic, Poland and Denmark. Iceland (which had the highest LE in 1978) and areas of The Netherlands also had

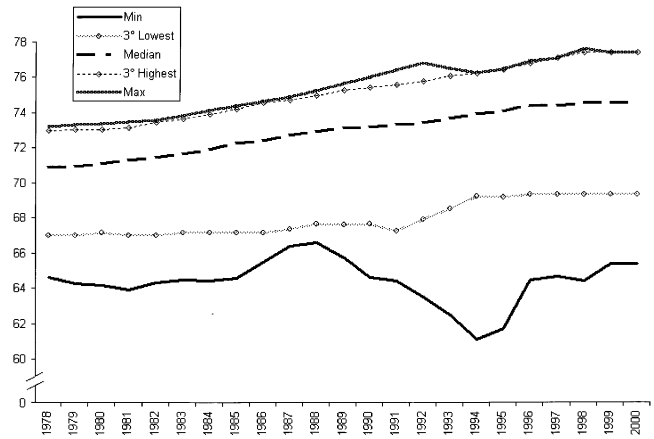

Figure 1. Trends in life expectancy at birth for men. The median life expectancy at birth is shown together with that for the cancer registry area that, for each year, had the highest, third highest, third lowest and lowest values.

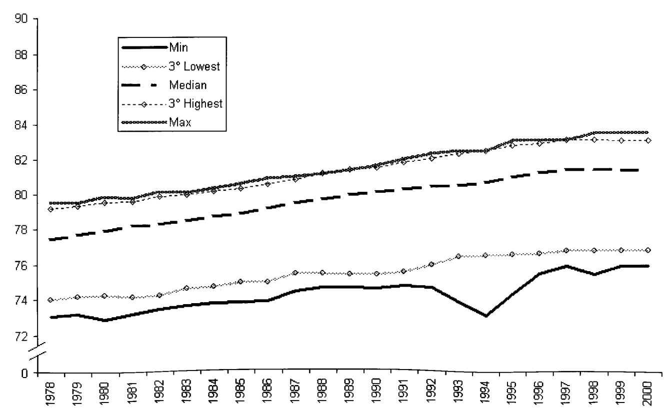

Figure 2. Trends in life expectancy at birth for women. The median life expectancy at birth is shown together with that for the cancer registry area that, for each year, had the highest, third highest, third lowest and lowest values.

only small increases. In contrast, LE increases were of the order of 4 or 5 years in almost all the areas which had higher LEs in 1978 (Table 3).

LE changes with time for women were similar to those in men. The eastern European countries (except Slovenia) all had small increases (around 2 years) in LE over the study period; other countries with small increases (around 3 years) were Denmark, Iceland and Norway, parts of England, and parts of The Netherlands. Again, the greatest increases in LE in women were observed in areas which had the highest LEs in 1978: 5.6 years in Mallorca, 5.7 years in Turin and 6.5 years in Malta (quartiles column, Table 4).

Figure 3 shows United Nations (UN) estimates of LE from 1975 to 1999 [10] for countries participating in EUROCARE-3. These figures are presented as 5-year averages to average out random variation. The countries are grouped by colours representing

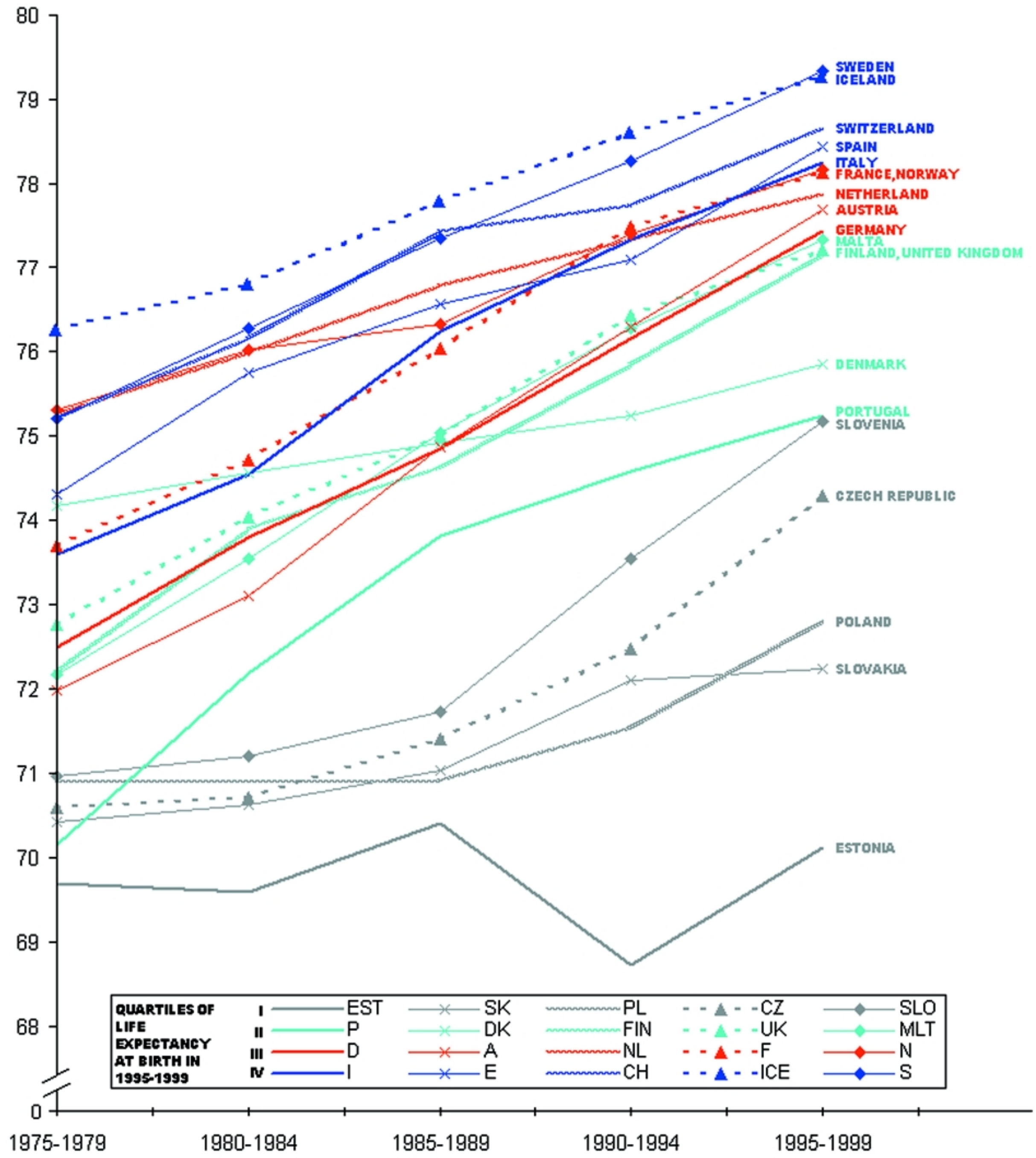

Figure 3. Trends in life expectancy in selected EUROCARE-3 countries. Men and women combined, 1975–1999. Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat (2003). World Population Prospects: The 2002 Revision [10]. A, Austria; CZ, Czech Republic; DK, Denmark; UK for England, Scotland and Wales; EST, Estonia; FIN, Finland; F, France; D, Germany; ICE, Iceland; I, Italy; MLT, Malta; NL, Netherlands; N, Norway; P, Portugal; PL, Poland; SK, Slovakia; SLO, Slovenia; E, Spain; S, Sweden; CH, Switzerland.

quartiles of the LE distribution in the period 1995–1999. All five eastern European countries were in the lowest quartile (grey); the LE of Estonia did not increase over the period, while the LEs of the other four eastern European countries changed little up to 1985–1989 and by 1.5–2.5 years thereafter. Countries in the second lowest quartile are represented in turquoise. Among these, the LE of Portugal increased—mostly in the earlier part of the period—by about 5 years. In the same group, the LEs for Malta, Finland and the UK increased by similar amounts as Portugal, while the LE increase for Denmark was the smallest of all countries except Estonia. LEs for countries in the second highest quartile (red) were in the narrow range 77 to 78 years in the period 1995–1999, while in 1975–1979 the range was much wider. LEs in Austria and Germany increased by around 5 years from the

72 years of 1975–1979. Among the countries with the highest LEs (blue), those for Iceland, Sweden and Switzerland were consistently high throughout the period, while that for Italy and Spain increased most (>4 years).

Relationships between LE and major economic indicators are shown in Table 5 and Figure 4. GDP, total national expenditure on health (TNEH) and total public expenditure on health (TPEH) were estimated at the country level after cost-of-living adjustments [13–15]. Overall LE were strongly and significantly correlated with GDP (Pearson $r = 0.85$, $P < 0.001$), and with both TNEH ($r = 0.83$, $P < 0.001$) and TPEH ($r = 0.82$, $P < 0.001$) (Table 5). LE increased directly with GDP for the eastern European countries (Figure 4). In contrast, Malta and Spain had high LEs in relation to their GDP, while the relationship between LE and GDP for countries with GDPs over 20 000 $PPP was weak (right hand side of Figure 4). In this group, Denmark had a lower LE than expected.

Table 5 shows median values of macro-economic indicators for country groups defined by quartiles of the LE distribution taken from OECD and UN publications. All three indicators were low for countries belonging to the lowest LE quartile. The median GDP and TPEH presented an increasing trend through all the quartiles of LE.

We analysed the relation of our own LE data to 5-year relative survival [12] for selected cancers. Table 6 shows median 5-year relative survival for these cancers by country groups defined by quartiles of LE distribution. For all the cancer sites considered, the lowest relative survival was in the lowest LE quartile. The correlation between LE and survival was not particularly strong for lung cancer ($r = 0.38$, $P < 0.01$) or Hodgkin's disease ($r = 0.40$; $P < 0.01$), and non-existent for pancreatic cancer ($r = 0.02$, $P = 0.92$). In contrast, the correlation was strong for colorectal cancer ($r = 0.71$; $P < 0.001$) and all cancers combined ($r = 0.71$, $P < 0.001$).

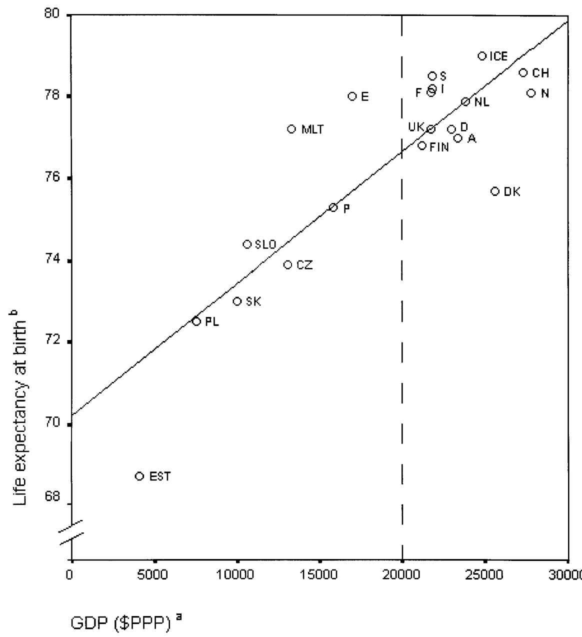

Figure 4. Life expectancy at birth and gross domestic product (GDP) by country, 1997. [a]Gross domestic product from OECD Health Data 2002 [13] and from Human Development Report 1999 [11] for Malta, Estonia and Slovenia. $PPP, parity purchasing power per capita (US$). [b]Life expectancy at birth (male plus female) (years) from Human Development Report 1999 [11]. A, Austria; CZ, Czech Republic; DK, Denmark; UK for England, Scotland and Wales; EST, Estonia; FIN, Finland; F, France; D, Germany; ICE, Iceland; I, Italy; MLT, Malta; NL, The Netherlands; N, Norway; P, Portugal; PL, Poland; SK, Slovakia; SLO, Slovenia; E, Spain; S, Sweden; CH, Switzerland.

Discussion

EUROCARE-3 is a large study designed to reliably compare population-based cancer survival across different countries and areas of Europe. Life tables are essential for estimating relative survival, the indicator used to compare cancer survival, correcting mortality due to causes other than the considered cancer. We systematically constructed life tables for each CR area, applying various approaches to estimate complete mortality data (and hence life expectancy at birth) from the often incomplete data provided by the CRs.

The general time and regional trends in LE provided by our estimates (Figures 1 and 2) are closely similar to those published by the UN at the country level (Figure 3). In particular, the eastern European countries had low LE, while Iceland, Italy, Spain, Sweden and Switzerland had high LE. During the 20-year EUROCARE study period, LEs increased considerably in most European countries except those in eastern Europe and Denmark (Tables 3 and 4). For the eastern European countries, the stasis may be related to the rapid social and economic changes that occurred following the dissolution of the USSR. However, it is not clear why LE in Denmark did not increase as much as in other western European countries. Our analysis uncovered a wide range in LE across European countries (Figure 3), and also considerable within-country variation in some cases (Tables 3 and 4; Figures 1 and 2). In particular, there was wide variation in LE across the seven CR areas of England, Wales and Scotland (Tables 3 and 4). This finding indicates that, in order to produce accurate relative survival figures, it is necessary to work with accurate local life tables. In fact, if not accounted for by use of local area-specific LE data, large differences in general mortality can severely confound comparisons of relative survival [2].

We found that LE was strongly associated with GDP (Figure 4), TPEH and TNEH (Table 5). However, detailed examination of the data revealed a complicated pattern and that, among the richest countries, relations between LE and both GDP and TPEH were no longer straightforward, suggesting the need for further investigation.

We also found that LE was strongly associated with 5-year relative survival for all cancers combined (Table 6). However, for lung cancer, Hodgkin's disease and pancreatic cancer, the relationship between LE and survival was weak or non-existent (Table 6). This could reflect differences in treating these cancers, which may not be closely related to economic development or general health expenditure. Almost all patients with pancreatic cancer, for instance, die quickly from their disease, and between-country survival differences, often due to differences in the accuracy of diagnosis or follow-up, are small and not related to LE.

Table 5. Life expectancy at birth in 1997 and median values (range) of macro-economic indicators

Quartile	Country	Life expectancy, 1997[a]	Median value per quartile ($PPP), 1997		
			GDP[b]	TNEH[c]	TPEH[d]
			r = 0.85 (P <0.001)	r = 0.83 (P <0.001)	r = 0.82 (P <0.001)
I	Estonia	68.7	10 281	677	639
	Poland	72.5	(4062–15 814)	(243–1360)	(207–881)
	Slovakia	73.0			
	Czech Republic	73.9			
	Slovenia	74.4			
	Portugal	75.3			
II	Denmark	75.7	22 408	1873	1328
	Finland	76.8	(13 316–25 610)	(1481–2465)	(1180–1856)
	Austria	77.0			
	Malta	77.2			
	United Kingdom	77.2			
	Germany	77.2			
III	The Netherlands	77.9	22 822	2002	1443
	Spain	78.0	(17 026–27 759)	(1294–2193)	(920–1849)
	France	78.1			
	Norway	78.1			
IV	Italy	78.2	23 360	1879	1530
	Sweden	78.5	(21 852–27 317)	(1684–2841)	(1216–1664)
	Switzerland	78.6			
	Iceland	79.0			

[a]Life expectancy at birth (male plus female) (years) from Human Development Report 1999 [11].
[b]GDP from OECD Health Data 2002 [13] and Human Development Report 1999 [11] (for Malta, Estonia and Slovenia).
[c]TNEH from OECD Health Data 2002 [13] and Human Development Report 2002 [14] (for Estonia and Slovenia; data for Malta not available).
[d]TPEH from OECD Health Data 2002 [13] and Human Development Report 2000 [15] (for Estonia and Slovenia; data for Malta not available).
GDP, gross domestic product; $PPP, parity purchasing power per capita (US$); TNEH, total national expenditure on health; TPEH, total public expenditure on health.

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Table 6. Life expectancy at birth (in quartiles) and relative survival (maximum and minimum values in parenthesis) for selected cancers from EUROCARE-3. *R* correlation coefficient between life expectancy and relative survival

Quartile	Cancer registry[a]	Country	Life expectancy 1997[b]	Five-year relative survival[c], men and women combined				
				All cancers combined $r = 0.71$ ($P <0.001$)	Colorectal cancer $r = 0.71$ ($P <0.001$)	Hodgkin's disease $r = 0.40$ ($P <0.01$)	Pancreatic cancer $r = 0.02$ ($P = 0.92$)	Lung cancer $r = 0.38$ ($P <0.01$)
I	Estonia	EST	70.74	39.2	37.8	74.9	3.3	8.0
	Slovakia	SK	72.85	(30.0–51.1)	(25.1–53.1)	(62.0–85.3)	(1.9–6.4)	(6.2–12.3)
	West Bohemia	CZ	73.41					
	Cracow	PL	74.16					
	Warsaw	PL	74.34					
	Slovenia	SLO	75.03					
	Scotland	UK	75.31					
	Denmark	DK	76.05					
	Mersey	UK	76.09					
	Saarland	D	76.50					
	Yorkshire	UK	76.69					
II	Wales	UK	76.84	49.1	52.7	81.1	4.3	9.4
	Finland	FIN	76.94	(37.8–53.8)	(39.1–60.3)	(70.5–88.4)	(1.9–8.7)	(5.9–15.7)
	West Midlands	UK	77.07					
	Eindhoven	NL	77.16					
	Trent	UK	77.16					
	Bas Rhin	F	77.60					
	Thames	UK	78.02					
	Mallorca	E	78.11					
	Norway	N	78.23					
	Amsterdam	NL	78.29					
	Ferrara	I	78.33					
III	Basque Country	E	78.34	47.3	51.3	80.1	4.2	10.0
	Calvados	F	78.36	(40.5–58.6)	(41.9–60.4)	(68.6–87.9)	(1.0–11.7)	(5.4–17.0)
	East Anglia	UK	78.39					
	Oxford	UK	78.39					
	South West	UK	78.41					
	Tyrol	A	78.54					
	Ragusa	I	78.62					
	Genoa	I	78.62					
	Sassari	I	78.73					
	Iceland	ICE	78.83					
	Latina	I	78.85					
	Varese	I	78.89					
IV	Modena	I	79.03	48.4	51.4	79.7	4.3	10.8
	Veneto	I	79.03	(45.4–54.3)	(49.6–57.7)	(62.3–90.0)	(2.7–5.6)	(7.8–14.4)
	Turin	I	79.05					
	Parma	I	79.19					
	Tarragona	E	79.31					
	Navarra	E	79.53					
	Romagna	I	79.71					
	Sweden	S	79.72					
	Macerata	I	79.96					
	Tuscany	I	79.99					
	Geneva	CH	80.23					

[a]Because of missing data for one or more cancer sites, cancer registries of Basel (CH), Côte d'Or (F), Granada (E), Isère (F), Malta (MLT), Munich (D), Murcia (E) and Portugal (PT) are not included.
[b]Life expectancy at birth (men and women combined).
[c]Median of the distribution of the 5-year cancer relative survival in each quartile of the distribution of life expectancy at birth (minimum and maximum value in parentheses).
A, Austria; CZ, Czech Republic; DK, Denmark; UK for England, Scotland and Wales; EST, Estonia; FIN, Finland; F, France; D, Germany; ICE, Iceland; I, Italy; NL, Netherlands; N, Norway; PL, Poland; SK, Slovakia; SLO, Slovenia; E, Spain; S, Sweden; CH, Switzerland.

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