BMJ Open

Trends in cancer incidence and survival in the Augsburg study region—results from the Augsburg cancer registry

Nina Grundmann ,[1,2] Christa Meisinger,[1,2] Martin Trepel,[3,4] Jacqueline Müller-Nordhorn,[5] Gerhard Schenkirsch,[4] Jakob Linseisen[1,2]

To cite: Grundmann N, Meisinger C, Trepel M, *et al*. Trends in cancer incidence and survival in the Augsburg study region—results from the Augsburg cancer registry. *BMJ Open* 2020;**10**:e036176. doi:10.1136/bmjopen-2019-036176

► Prepublication history and additional material for this paper are available online. To view these files, please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2019-036176).

Received 14 February 2020
Revised 19 May 2020
Accepted 29 June 2020

[1]Chair of Epidemiology, Ludwig-Maximilians-Universität München at UNIKA-T, Augsburg, Germany
[2]IRG Clinical Epidemiology, Helmholtz Zentrum München, Neuherberg, Germany
[3]Department of Internal Medicine II, University Medical Center of Augsburg, Augsburg, Germany
[4]Interdisciplinary Cancer Center, University Medical Center of Augsburg, Augsburg, Germany
[5]Bavarian Cancer Registry, Bavarian Health and Food Safety Authority, Nuremberg, Germany

Correspondence to
Nina Grundmann;
n.grundmann@unika-t.de

ABSTRACT

Objectives Knowledge about time trends of cancer incidence and cancer survival in a defined region is an essential prerequisite for the planning of regional healthcare infrastructure. The aim of the study was to provide population-based analyses of all common tumour sites to assess the cancer burden in the Augsburg study region.

Setting Total population of the study region of Augsburg (668 522 residents), Southern Germany.

Participants The data obtained from the Cancer Registry Augsburg comprised 37 487 incident cases of malignant tumours (19 313 men and 18 174 women) diagnosed between 2005 and 2016 in the Augsburg region's resident population.

Primary and secondary outcome measures We calculated sex-specific, age-standardised incidence rates and annual percent change to assess time trends. In men and in women, 3-year and 5-year relative survival was calculated and results were compared with the latest German estimates. Survival trends were presented for the most common cancers only.

Results Decreasing age-standardised incidence rates were observed for prostate cancer and for colorectal cancer in men. For oropharyngeal cancer, rates declined in men, but significantly increased in women. Incidence for female breast cancer remained stable. Five-year relative survival ranged between 6.4% (95% CI: 4.1% to 10.1%) for pancreatic cancer and 97.7% (95% CI: 96.0% to 99.4%) for prostate cancer in men and between 10.2% (95% CI: 7.1% to 14.6%) for pancreatic cancer and 96.6% (95% CI: 93.6% to 99.6%) for malignant melanoma in women. Trends in 3-year survival of the five most common tumour sites in men showed a significant increase for lung and oropharyngeal cancer. In women, continuously rising survival trends were observed for breast cancer.

Conclusions Survival of cancer patients in the Augsburg study region was largely concordant with the situation in Germany as a whole, while incidence showed slight deviations in some cancer sites. Regional evaluations on cancer survival are a valuable instrument for identifying deficits and determining advances in oncological health management.

Strengths and limitations of this study

- Cancer registry data can serve as an instrument for the evaluation of oncological healthcare. Analyses of regional data can help to identify areas and targets of priority assessing directly the needs of the resident population.
- This study presents population-based data on relative survival and trends in incidence of all common tumour sites for the Augsburg study region, a geographically defined area in which large epidemiological long-term cohorts are ongoing.
- The epidemiological Cancer Registry Augsburg provided data of all confirmed cancer cases of the catchment area of Augsburg and thus ensures high data quality.
- For some more rare entities, regional evaluations on cancer survival are facing low case numbers.

BACKGROUND

In Germany, approximately 600 000 people were diagnosed with cancer in 2018, and for almost 250 000 cancer patients, the disease was fatal.[1] Increasing age is associated with a higher risk of developing cancer.[2] Due to Germany's ageing population, a distinct increase in cancer prevalence is to be expected, along with a growing need for healthcare resources. To face this challenge, the National Cancer Plan was initiated in Germany in 2008 and implemented in 2011. The plan aimed to improve cancer screening and establish a comprehensive clinical cancer registration process. Regional evaluations on cancer incidence and survival are a valuable instrument for identifying deficits and determining advances in oncological healthcare.

For a long time, German estimations of cancer survival were based predominantly on data of the Cancer Registry Saarland.[3] The most recent studies on cancer survival in Germany analysed data of different cancer registries, but the survival data of Bavaria have not been included in comparative regional investigations so far.[4–9] Regional differences between the federal states were found for incidence and mortality, varying by sex and primary cancer site.[4] However,

there is a lack of region-specific investigations dealing with population-based cancer registry data. Focusing on the needs of all oncology patients, survival analysis in a geographically defined region can serve as an indicator for the effectiveness of oncological healthcare in the resident population.[3] The region of Augsburg, covering the city of Augsburg and the surrounding counties Augsburg and Aichach-Friedberg, comprises about 668 522 (2016) residents.[10] The Augsburg region is of special importance because its population is used in the recruitment of the large, epidemiological cohorts of the KORA and NAKO studies.[11]

In Bavaria, comprehensive coverage in the registry of cancer data has been carried out since 2002.[12] The Cancer Registry Augsburg records all kinds of incident malignant neoplasms and thus provides population-based data for the Augsburg region. To our knowledge, this is the first study concentrating on cancer registry data in the region of Augsburg. The aim of this study is to assess cancer burden in the Augsburg study region, providing population-based estimates of relative survival and trends in incidence of all common tumour sites to contribute to the planning of regional healthcare infrastructure.

METHODS

Cancer registry data

The Cancer Registry Augsburg is the official cancer registry of Swabia, recording population-based epidemiological data on a legal basis. As all practitioners and medical facilities report their cases to the Cancer Registry Augsburg, it provides the total number of incident neoplasms of the Augsburg region. Quality indicators for the most common cancer sites are listed in the online supplementary table 1. Registration exists for all kinds of malignant neoplasms as well as their non-invasive stages. The recorded data comprise information about personal and epidemiological features of the patient, that is, date of birth, sex, date of first diagnosis, the cancer diagnosis according to ICD-10 classification and potentially the date of death. The vital status of the patients recorded with a cancer diagnoses was updated regularly by means of death certificates. For the entire study period, death certificates were provided for all of Swabia from the local health authorities of the region. Linkage of data is performed by demographic data. In case of death, this information is registered with the local authority of the person's place of residence. The information on data of cancer patients treated in other regions are passed to the responsible regional cancer registry via the Confidentiality Office of the Bavarian Cancer Registry. For the present study, the original data set comprised 37 487 incident cases of malignant neoplasms, with exception of non-melanoma skin cancer, diagnosed between 2005 and 2016 in patients residing in the region of Augsburg.

Statistical analyses

The study aimed to analyse the occurrence and distribution of cancer diseases in the Augsburg region. Data were given separately for the city of Augsburg and both counties and were stratified according to sex and age groups (<15, 15–34, 35–44, 45–54, 55–64, 65–74, 75+). Ten-year intervals were used from the age of 35 years onwards considering that cancer risk increases with age. Sex-specific absolute and relative frequencies of the most common cancer localisations were calculated, including the entire study period to achieve more stable results. Age-standardised incidence rates were presented for the

Table 1 Malignant tumours in the resident population of the Augsburg study region (City of Augsburg, County of Augsburg and County of Aichach-Friedberg): incident cases of the years 2005–2016 by sex and age

Region of Augsburg	Total, n=37 487		City of Augsburg, n=17 044		County of Augsburg, n=14 382		County of Aichach-Friedberg, n=6061	
	n	%	n	%	n	%	n	%
Sex								
Male	19 313	51.5	8661	50.8	7527	52.3	3125	51.6
Female	18 174	48.5	8383	49.2	6855	47.7	2936	48.4
Age at first diagnosis								
<15	190	0.5	75	0.4	74	0.5	41	0.7
15–34	864	2.3	390	2.3	331	2.3	143	2.4
35–44	1671	4.5	709	4.2	646	4.5	316	5.2
45–54	4396	11.7	1798	10.6	1789	12.4	809	13.4
55–64	7717	20.6	3389	19.9	2999	20.9	1329	21.9
65–74	11 501	30.7	5227	30.7	4462	31.0	1812	29.9
75+	11 148	29.7	5456	32.0	4081	28.4	1611	26.6
DCO cases	527	1.4	146	1.0	171	1.2	192	3.2
Cases detected at autopsy	23	0.1	16	0.9	7	0.1	–	–

years 2005 to 2016 for men and for women, using 5-year age groups. The analysis was performed using the mean population per calendar year (calculated for each year by taking the average of the population on 31 December in the current and preceding year, as listed in the population tables of the city of Augsburg, the county of Augsburg and the county of Aichach-Friedberg) and rates were tabulated per 100 000 men and women per year.[13] The population tables were obtained from the Federal Statistical Office of Bavaria.[14] The old European standard population was used for direct standardisation of incidence rates.[15] Annual percent change (APC) was computed by linear regression of logarithmised incidence rates using the year of diagnosis as the independent variable (Joinpoint Regression Program, V.4.7.0.0, National Cancer Institute).[16] To describe the trend of incidence rates for the study period joinpoints were identified. APC and its CIs were determined for the interval between the defined trend-change points.

For the total study period, estimates of relative three3-year and 5-year survival were presented. Trend analysis of sex-specific, 3-year relative survival of the most common cancers was performed, summarising the year of first diagnosis into three time periods (2005/2007, 2008/2010 and 2011/2013). Cases detected by autopsy or death certificate only (DCO)were excluded from survival analysis.[17] We excluded patients aged under 15 years at first diagnosis as well due to considerable differing prognosis of children and adults.[17] Patients with multiple primary cancers, localised in different sites, were kept in the study.[18] Relative survival can be considered as the survival from cancer after adjusting for other causes of death and is defined as the ratio of the observed survival to the expected survival during a specified interval.[19] The expected survival time of age-matched and sex-matched individuals was calculated using life tables for the general German population applying the Ederer II method.[20] The Federal Office of Statistics ('Statistisches Bundesamt') provided population data corresponding to the study period.[21] All analyses were performed in SAS, V.9.4 and R, V.3.5.1.

Patient and public involvement

This research was done without direct patient or public involvement.

RESULTS

Most common cancer entities in the Augsburg region

Overall, malignancies were almost equally frequent in both sexes with a slight excess in men, and results were comparable for the city and both counties (table 1). Breast cancer was the most common malignant disease in women (32.3%) and the prostate was the leading cancer site (23.2%) in men (table 2). Colorectal cancer (CRC) was the second most common cancer in men (14.8%) as well as in women (12.5%), followed by malignancies of the lung in both sexes (males: 12.1%, females: 6.2%).

Table 2 Absolute and relative frequencies: incident malignant tumours of the years 2005–2016 in the Augsburg study region by sex and site (n=37 487)

	ICD-10	Men		Women	
Site		n	%	n	%
Lip/oral cavity/ pharynx	C00–C14	761	3.94	273	1.50
Oesophagus	C15	403	2.09	108	0.59
Stomach	C16	724	3.75	517	2.84
Colorectum	C18–C21	2862	14.82	2264	12.46
Liver	C22	539	2.79	160	0.88
Gallbladder/biliary tract	C23–C24	180	0.93	201	1.11
Pancreas	C25	627	3.25	619	3.41
Larynx	C32	247	1.28	32	0.18
Lung	C33–C34	2331	12.07	1128	6.21
Malignant melanoma of the skin	C43	984	5.10	878	4.83
Mesothelioma	C45	111	0.57	14	0.08
Soft tissue without mesothelioma	C46–C49	178	0.92	155	0.85
Breast	C50	38	0.20	5876	32.33
Vulva	C51			195	1.07
Cervix uteri	C53			373	2.05
Corpus uteri	C54–C55			1022	5.62
Ovary	C56			703	3.87
Prostate	C61	4475	23.17		
Testis	C62	334	1.73		
Kidney	C64	709	3.67	396	2.18
Urinary bladder	C67	657	3.40	244	1.34
Central nervous system	C70–C72	315	1.63	254	1.40
Thyroid	C73	224	1.16	547	3.01
CUP	C80	360	1.86	369	2.03
Hodgkin's lymphoma	C81	140	0.72	83	0.46
Non-Hodgkin's lymphoma	C82–C88	730	3.78	631	3.47
Multiple myeloma	C90	253	1.31	229	1.26
Leukaemia	C91–C95	628	3.25	455	2.50
Other localisations		503	2.60	448	2.46

CUP, cancer of unknown primary; ICD, International Classification of Diseases.

Sex-specific trends in incidence rates

During the study-period, age-standardised incidence rates (figure 1) in both sexes revealed a decline in CRC, which was more pronounced in men (APC=−3.7%) than in women (APC=−1.2%) (table 3). For carcinoma of the oral

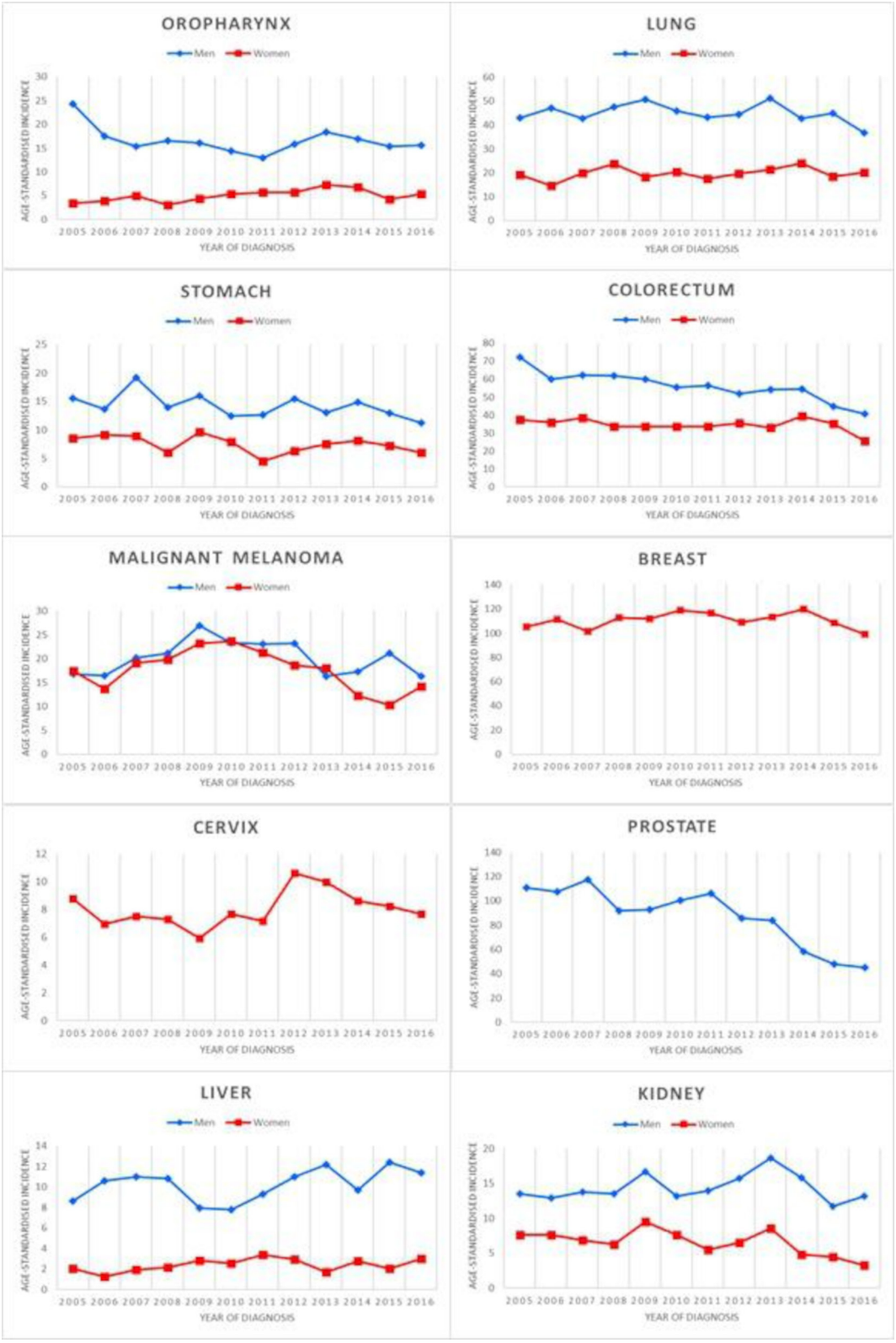

Figure 1 Age-standardised incidence of malignant tumours per 100 000 men or women in the Augsburg study region for selected sites.

cavity and the pharynx, the age-standardised incidence rates indicated a decline in men, but a clear increase in women (APC=4.5%). For lung cancer, rather stable age-standardised incidence rates were observed in men and women. Trend changing points were identified for malignant melanoma of the skin (online supplementary table 2). In both sexes, age-standardised incidence rates peaked in 2009 (men)/2010 (women), decreasing afterwards to less than the initial rate of the year 2005 (APC men= −5.5%; APC women= −11.3%). In women, rather

Table 3 Age-standardised incidence of malignant tumours in the Augsburg study region by sex and site—incident cases of the years 2005–2016

Site	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	APC (95% CI)
Men (n=19 313)													
Lip/oral cavity/ pharynx	24.3	17.6	15.4	16.5	16.1	14.4	13.0	15.9	18.4	16.9	15.4	15.7	–2.0 (–4.6 to 0.7)
Oesophagus	9.4	7.0	8.7	7.1	7.0	9.3	11.1	6.7	7.2	8.3	10.6	6.8	0.2 (–3.3 to 3.9)
Stomach	15.5	13.7	19.2	14.0	16.0	12.4	12.7	15.5	13.0	14.9	12.9	11.2	–2.3 (–4.6 to 0.1)
Colorectum	72.2	60.0	62.3	61.8	60.1	55.5	56.3	52.0	54.1	54.5	44.8	40.8	**–3.7 (–4.8 to –2.5)**
Liver	8.6	10.6	11.0	10.8	8.0	7.8	9.3	11.0	12.2	9.7	12.4	11.4	1.9 (–0.7 to 4.6)
Gallbladder/ biliary tract	2.9	3.6	2.8	2.2	2.7	2.5	2.8	4.3	4.4	2.7	5.5	3.5	4.8 (–0.1 to 9.8)
Pancreas	12.6	11.7	12.9	12.5	10.4	9.8	11.8	11.8	12.0	13.7	11.4	14.0	0.7 (–1.2 to 2.6)
Larynx	7.2	5.0	3.3	5.1	5.1	6.5	3.4	6.2	5.3	3.8	3.8	5.8	–1.7 (–6.1 to 2.8)
Lung	42.9	47.0	42.7	47.6	50.7	45.8	43.2	44.4	51.1	42.7	44.9	36.9	–0.7 (–2.4 to 0.9)
Malignant melanoma of the skin	16.8	16.5	20.2	21.2	26.9	23.4	23.0	23.2	16.4	17.3	21.2	16.3	–0.6 (–4.0 to 3.0)
Mesothelioma	1.0	3.1	2.4	0.8	2.3	1.6	1.7	2.3	2.8	1.7	1.5	2.1	–0.8 (–7.4 to 6.1)
Soft tissue	4.1	4.3	5.8	2.5	8.0	4.1	5.6	2.4	2.9	2.7	3.1	3.2	–4.6 (–12.1 to 3.4)
Breast	0.6	1.1	0.2	0.5	1.4	0.6	0.4	0.0	0.2	0.9	1.9	1.0	–
Prostate	110.7	107.4	117.3	92.1	92.9	100.3	105.9	85.7	83.7	58.4	47.8	45.1	**–6.7 (–9.7 to –3.7)**
Testis	6.1	7.0	9.1	9.5	11.4	9.8	10.2	7.8	9.3	9.2	7.8	7.3	0.1 (–3.4 to 3.8)
Kidney	13.5	13.0	13.8	13.6	16.7	13.2	13.9	15.7	18.7	15.8	11.7	13.2	0.6 (–2.0 to 3.4)
Urinary bladder	13.4	10.1	10.0	9.8	12.9	15.8	14.9	12.3	13.1	13.8	10.2	11.0	0.3 (–3 to 3.7)
Central nervous system	6.3	8.1	5.8	7.9	8.6	8.7	5.90	6.8	6.8	5.8	6.5	6.6	–1.2 (–4.1 to 1.7)
Thyroid	3.3	5.3	7.5	5.9	5.3	5.4	4.3	5.6	5.8	2.3	5.4	4.7	–1 .5 (–6.4 to 3.6)
CUP	7.7	8.8	7.8	5.9	7.8	7.1	8.0	7.1	5.6	4.7	5.4	7.7	–2.5 (–5.4 to 0.5)
Hodgkin's lymphoma	3.7	1.7	3.0	3.7	3.5	3.3	4.7	5.1	4.6	2.5	2.6	3.3	1.3 (–4.8 to 7.7)
Non-Hodgkins lymphoma	13.5	14.8	15.9	15.8	15.9	17.7	15.7	13.2	13.3	17.4	12.2	12.4	–1.0 (–3.4 to 1.4)
Multiple myeloma	3.5	7.1	3.9	3.5	7.1	6.8	5.5	6.0	3.6	4.3	3.8	4.0	1.9 (–8.1 to 13.0)
Leukaemia	10.8	13.3	17.3	11.7	18.6	12.5	12.8	11.4	16.0	12.4	11.6	8.5	–1.9 (–5.9 to 2.2)
Women (n=18 174)													
Lip/oral cavity/ pharynx	3.4	3.9	5.0	3.1	4.4	5.3	5.7	5.8	7.3	6.8	4.3	3.4	**4.5 (0.3 to 8.9)**
Oesophagus	1.4	1.3	1.3	2.5	1.2	1.2	1.5	2.1	2.6	2.5	1.6	1.4	3.6 (–2.2 to 9.7)
Stomach	8.5	9.1	8.9	6.1	9.6	8.0	4.5	6.3	7.6	8.1	7.3	8.5	–2.5 (–6.1 to 1.3)
Colorectum	37.4	35.9	38.5	33.7	33.7	33.6	33.4	35.6	32.8	39.4	35.3	37.4	–1.2 (–3.0 to 0.7)
Liver	2.1	1.3	1.9	2.1	2.8	2.6	3.4	3.0	1.7	2.8	2.0	2.1	3.0 (–1.8 to 8.1)
Gallbladder/ biliary tract	2.5	2.3	3.5	3.0	3.1	3.0	3.2	2.3	3.5	2.5	2.8	2.5	–0.4 (–3.4 to 2.6)
Pancreas	7.6	6.8	6.4	10.6	9.7	10.0	9.2	12.0	8.6	8.2	9.8	7.6	1.7 (–1.7 to 5.3)
Larynx	0.6	0.8	0.2	0.3	0.3	0.2	1.1	0.6	1.2	0.3	0.8	0.6	4.8 (–8.1 to 19.6)
Lung	19.3	14.7	20.0	23.7	18.2	20.5	17.5	19.6	21.4	23.9	18.5	19.3	1.0 (–1.4 to 3.5)
Malignant melanoma of the skin	17.4	13.7	19.2	19.9	23.2	23.6	21.3	18.7	18.1	12.2	10.3	14.2	–2.9 (–7.4 to 1.7)
Mesothelioma	0.4	0.0	0.3	0.3	0.2	0.0	0.3	0.0	0.4	0.3	0.0	0.6	–
Soft tissue	4.6	4.3	2.3	2.9	5.2	1.2	2.8	3.1	2.2	3.0	1.5	2.0	**–6.7 (–12.7 to –0.2)**

Continued

Table 3 Continued

Site	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	APC (95% CI)
Breast	105.3	111.5	101.2	112.9	111.9	118.8	116.4	108.9	113.5	119.7	108.5	99.0	0.1 (–1.1 to 1.2)
Vulva	2.2	2.2	3.3	2.5	3.0	3.8	3.5	4.2	2.6	2.9	2.0	2.8	0.5 (–4.1 to 5.3)
Cervix uteri	8.8	7.0	7.5	7.3	5.9	7.7	7.2	10.6	10.0	8.6	8.2	7.7	1.5 (–1.5 to 4.6)
Corpus uteri	15.9	17.4	21.5	15.6	20.1	16.2	15.8	18.3	17.7	17.7	19.9	17.9	0.4 (–1.6 to 2.4)
Ovary	10.3	15.1	14.3	12.6	13.7	15.1	10.2	9.1	12.6	13.4	11.7	9.0	–2.1 (–5.2 to 1.1)
Kidney	7.6	7.7	6.8	6.3	9.5	7.6	5.5	6.6	8.5	4.8	4.50	3.3	**–4.7 (–8.9 to –0.2)**
Urinary bladder	2.9	3.5	4.1	4.6	2.8	3.7	3.6	2.9	4.9	3.1	2.7	2.7	–1.4 (–5.4 to 2.8)
Central nervous system	5.4	3.3	5.9	4.3	4.2	6.7	7.6	3.4	6.4	4.6	3.7	5.5	0.2 (–5.1 to 5.8)
Thyroid	12.2	12.6	15.5	12.8	12.2	12.3	11.4	14.9	9.1	13.1	10.9	11.2	–1.5 (–3.9 to 1.0)
CUP	5.6	6.6	6.7	6.8	4.8	3.1	6.7	3.5	6.2	3.1	5.5	4.4	–3.2 (–7.8 to 1.5)
Hodgkin's lymphoma	1.5	2.0	1.5	4.0	1.5	1.2	1.1	1.2	0.7	3.2	3.1	2.8	2.9 (–6.2 to 13.0)
Non-Hodgkin's lymphoma	13.7	11.3	10.0	15.1	9.9	12.0	11.5	11.2	9.1	10.7	7.1	7.7	**–4.0 (–6.9 to –1.0)**
Multiple myeloma	3.7	4.7	3.7	5.2	3.6	4.6	2.4	3.2	3.1	3.7	2.1	2.5	**–4.8 (–8.5 to –0.9)**
Leukaemia	8.1	8.4	9.4	8.3	11.4	9.3	7.6	7.0	9.0	8.4	5.1	6.1	–3.1 (–6.4 to 0.3)

Incidence rate per 100 000 men and women; age-standardisation by the use of 'old European standard population'.
All significant results are given in bold format.
APC, annual percent change.

stable age-standardised incidence rates could be observed for breast cancer (APC=0.1%). The data revealed a distinct decline in prostate cancer since 2012 regarding the crude (online supplementary table 3) and age-standardised incidence rates (2012–2016: APC=–18.0%). Sex-specific crude mortality rates corresponding to the study period were presented in online supplementary table 4.

Sex-specific relative cancer survival

The 5-year relative survival turned out to be highest for prostate cancer (97.7%) and for testicular cancer (97.2%) (table 4). A favourable prognosis was observed for melanoma of the skin with a 5-year relative survival of 95.3% in men and 96.6% in women. For carcinoma of the breast, survival estimates in women reached 88.6% (figure 2). With 5-year survival rates of 18.1% in men and 20.8% in women, the prognosis for patients with lung cancer was still quite poor. Five-year survival was the worst for carcinoma of the pancreas with rates of 6.4% in males and 10.2% in females. Survival was almost equally as poor for carcinoma of the liver, with 5-year rates of 14.1% for men and 19.8% for women. Only slight sex differences in the 5-year relative survival could be observed for CRC, with rates of 69.3% in men and 70.4% in women.

For the majority of the presented cancer sites, no significant change was observed in the 3-year relative survival rates over the study period (table 5). In men, lung and oropharyngeal cancer showed an increase in 3-year relative survival rates between 2005/2007 and 2011/2013 (figure 3). In women, rising 3-year relative survival rates were found for breast cancer and for carcinoma of the ovary.

DISCUSSION

The present study outlines trends in cancer incidence and survival in the population of the Augsburg region. Regarding the most frequent cancer entities specifically, in men incidence rates for CRC and prostate cancer decreased, while the rates for lung cancer remained relatively stable during the period of 2005 to 2016. After a peak in 2009/2010, incidence rates for malignant melanoma declined in both sexes. In women, the incidence rates for oropharyngeal cancer increased, and the rates for lung and for breast cancer remained rather stable. Trends in 3-year survival of the most common tumour sites in men showed an increase in lung cancer and carcinoma of the oral cavity and the pharynx. In women, rising trends in survival were observed for breast cancer and for ovarian cancer.

Observing three time-periods from 2005/2007 to 2011/2013, the Augsburg data suggest an increase in breast cancer survival. The 5-year relative survival reached 88.6% in females, approximately coinciding with the latest average German rates (87%[22]). During the study period, age-standardised incidence rates for breast cancer remained rather stable. More effective treatment methods, and early detection of tumours,[23] were the main reasons for the decrease of mortality regarding this tumour site.[24] Considerably higher survival is seen in patients with early-stage, compared with advanced-stage breast cancers.[23 25] To diagnose breast cancer at an early stage, a systematic mammography screening programme (MSP) has been implemented into routine medical care

Table 4 Malignant tumour 3-year and 5-year relative survival and its 95% CI in the Augsburg study region by sex and site—incident cases of the years 2005–2011 (n=21 493)

	Men		Women	
Site (ICD-10)	3-year RES (95% CI)	5-year RES (95% CI)	3-year RES (95% CI)	5-year RES (95% CI)
Lip/oral cavity/pharynx (C00–C14)	49.6 (44.8 to 54.9)	43.2 (38.4 to 48.7)	66.5 (58.4 to 75.8)	61.0 (52.3 to 71.2)
Oesophagus (C15)	30.3 (24.7 to 37.3)	25.7 (20.2 to 32.7)	37.6 (25.8 to 54.8)	23.9 (14.0 to 40.8)
Stomach (C16)	44.3 (39.2 to 50.0)	41.4 (36.0 to 47.5)	47.1 (41.1 to 54.0)	43.4 (37.0 to 50.8)
Colorectum (C18–C21)	74.6 (72.2 to 77.2)	69.3 (66.5 to 72.3)	73.4 (70.6 to 76.4)	70.4 (67.2 to 73.7)
Liver (C22)	18.9 (14.4 to 24.8)	14.1 (10.0 to 19.7)	28.5 (19.7 to 41.3)	19.8 (12.2 to 32.1)
Gallbladder/biliary tract (C23–C24)	33.8 (24.3 to 47.2)	24.5 (15.7 to 38.4)	20.5 (14.0 to 30.0)	16.4 (10.5 to 25.7)
Pancreas (C25)	9.8 (6.9 to 13.8)	6.4 (4.1 to 10.1)	11.9 (8.6 to 16.4)	10.2 (7.1 to 14.6)
Larynx (C32)	72.2 (64.3 to 81.1)	65.0 (56.3 to 75.1)	47.6 (28.1 to 80.7)	49.0 (28.9 to 83.0)
Lung (C33–C34)	21.0 (18.7 to 23.5)	18.1 (15.9 to 20.6)	27.1 (23.6 to 31.0)	20.8 (17.6 to 24.5)
Malignant melanoma of the skin (C43)	95.6 (92.8 to 98.5)	95.3 (91.8 to 99.0)	98.1 (95.9 to 100.4)	96.6 (93.6 to 99.6)
Mesothelioma (C45)	24.3 (15.0 to 39.3)	18.0 (9.7 to 33.3)	30.2 (11.1 to 82.3)	32.4 (11.9 to 88.3)
Soft tissue without mesothelioma (C46–C49)	67.6 (58.4 to 78.2)	69.8 (60.0 to 81.3)	69.5 (60.2 to 80.2)	63.0 (53.1 to 74.8)
Breast (C50)	69.0 (49.6 to 95.8)	61.0 (40.6 to 91.8)	91.7 (90.4 to 92.9)	88.6 (87.1 to 90.1)
Vulva (C51)			67.8 (58.3 to 78.8)	62.6 (52.3 to 74.8)
Cervix uteri (C53)			71.4 (65.0 to 78.3)	67.2 (60.5 to 74.7)
Corpus uteri (C54–C55)			85.4 (81.9 to 89.1)	82.5 (78.4 to 86.8)
Ovary (C56)			48.0 (43.2 to 53.3)	40.2 (35.5 to 45.6)
Prostate (C61)	96.5 (95.1 to 97.9)	97.7 (96.0 to 99.4)		
Testis (C62)	97.4 (94.8 to 100.0)	97.2 (94.5 to 100.0)		
Kidney (C64)	81.9 (77.1 to 87.0)	79.8 (74.3 to 85.7)	76.6 (70.6 to 83.1)	76.2 (69.6 to 83.4)
Urinary bladder (C67)	61.3 (55.6 to 67.5)	58.1 (51.8 to 65.1)	48.4 (40.1 to 58.4)	48.4 (39.6 to 59.3)
Central nervous system (C70–C72)	29.2 (23.1 to 37.0)	24.2 (18.5 to 31.7)	33.3 (26.2 to 42.3)	28.1 (21.4 to 36.9)
Thyroid (C73)	96.5 (91.5 to 101.8)	95.1 (89.2 to 101.5)	95.3 (92.5 to 98.2)	95.9 (92.9 to 99.0)
CUP (C80)	18.8 (13.9 to 25.3)	16.0 (11.3 to 22.6)	17.6 (12.8 to 24.1)	15.8 (11.0 to 22.7)
Hodgkin's lymphoma (C81)	89.2 (81.6 to 98.0)	87.6 (78.8 to 97.4)	92.3 (84.0 to 101.4)	94.2 (85.7 to 103.6)
Non-Hodgkin's lymphoma (C82–C88)	75.5 (70.8 to 80.5)	73.2 (68.0 to 78.8)	75.3 (70.5 to 80.5)	74.6 (69.3 to 80.3)
Multiple myeloma (C90)	59.5 (51.4 to 68.8)	53.0 (44.5 to 63.2)	58.7 (50.6 to 68.1)	47.5 (39.2 to 57.7)
Leukaemia (C91–C95)	70.3 (64.8 to 76.3)	67.2 (61.2 to 73.9)	65.8 (59.7 to 72.6)	62.5 (55.9 to 69.7)

APC, annual percent change; RES, relative survival (%).

in Germany in 2005.[25] The programme targets all women aged between 50 and 69 years and biannually invites them to mammography screening.[25] In 2009, comprehensive coverage of the MSP was achieved in the Augsburg region, but incidence rates have not reflected the effects of the MSP observed in Germany as a whole so far. However, a detailed investigation of incidence rates of UICC (Union Internationale Contre le Cancer) stages might give further insights regarding the impact of the MSP on the disease course of breast cancer. Incidence rates of breast cancer showed a slightly decreasing trend in women aged 50–69, mainly caused by the decline in rates of regional cancers (figure 4). However, localised cancers did not clearly increase with introduction of the MSP in the target group. Enhanced by increasing the use of imaging techniques during the past decade, opportunistic screening might have had an impact on these findings as well.

Major risk factors for breast cancer relate to fertility and childbearing, for example, parity and breastfeeding

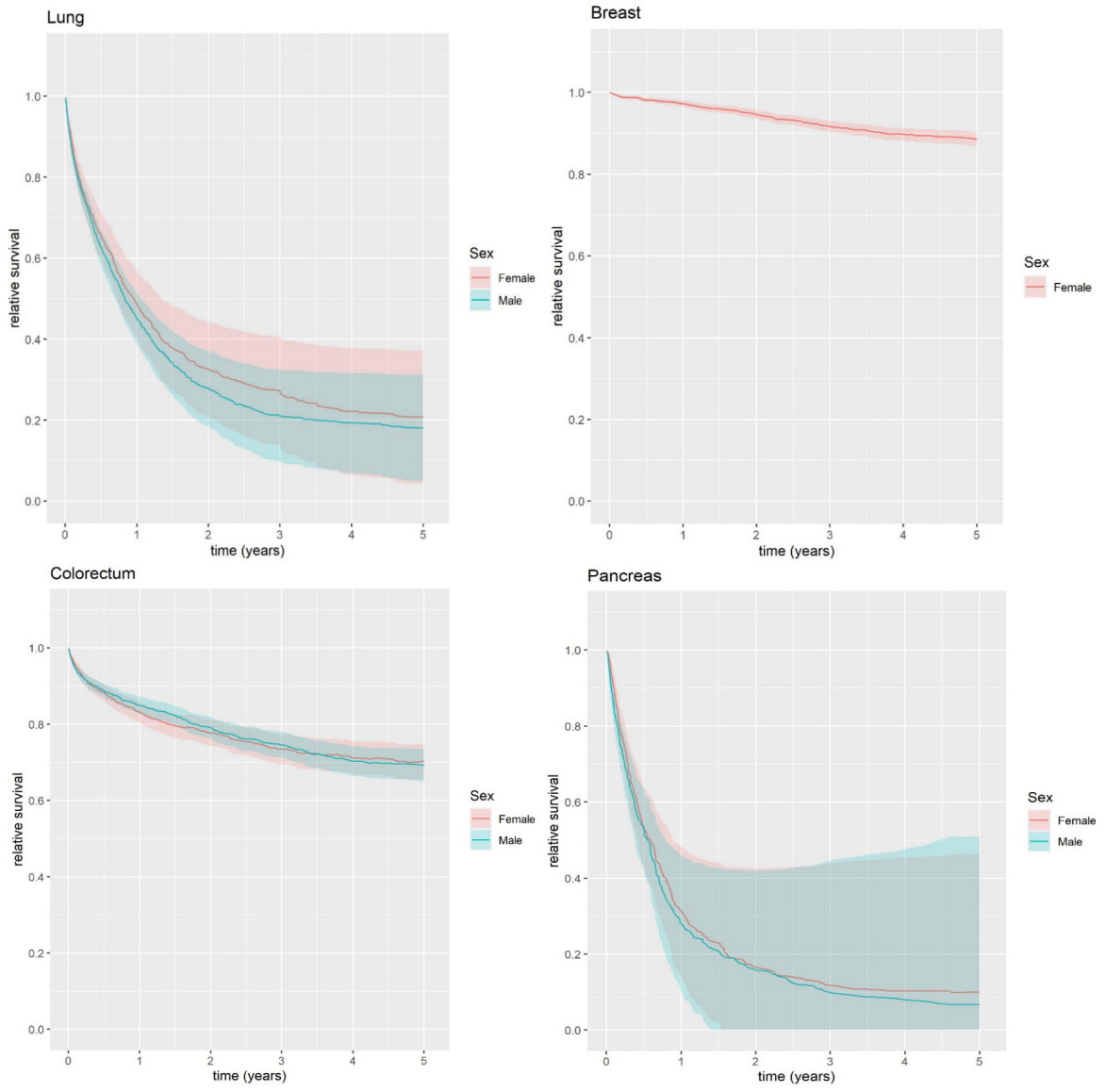

Figure 2 Malignant tumours 3-year and 5-year relative survival in the Augsburg study region for selected sites

duration,[26 27] and the utilisation of hormone replacement therapy.[28] None of these factors may have changed distinctly during the study period. Common life-style factors, for example, high level of alcohol consumption, obesity and physical inactivity increase the risk for the occurrence of breast cancer as well.[27] In the Augsburg region, between 1999 and 2001, 35.6% of the population aged 25–74 years were found to have a high alcohol intake.[29] Rising trends in the prevalence of obesity were observed between 1989 and 2001, though the prevalence for physical activity increased distinctly in the same time.[29]

For carcinoma of the cervix, no clear time trend of age-standardised incidence was seen in the Augsburg region, but rates have remained stable in Germany for the last 15 years.[22] Five-year relative survival in the Augsburg region (67.2%) was as high as in the whole of Germany (67%[22]). As human papilloma virus (HPV) is a main risk factor, early HPV vaccination is recommended by the Standing Committee on Vaccination (STIKO) for girls since 2007 and for boys since 2018.[30] In 2015, lowest rates in HPV vaccination in 17-year old girls within Germany were seen in Bavaria (34.2%).[31] Screening for cervical cancer is part of the German national statutory cancer screening programme and is performed by Pap smear test once a year for women aged 20 years and above. No systematic screening programme was implemented in the study period, but started in 2020.

Lung cancer incidence was approximately twice as high in men compared with women, and was distinctly higher than the average German rates.[22] Five-year relative survival reached 18.1% in men and 20.8% in women in the Augsburg region, which is comparable to the latest Germany-wide rates of 15% in men and 21% in women.[22] Overall, flat survival trends were recorded worldwide for lung cancer between 1995 and 2014, but Germany was among the 21 countries in which survival increased by 5%–10%.[32] In the region of Augsburg, an increase in 3-year relative survival between 2005/2007

Table 5 Malignant tumours 3-year relative survival and its 95% CI in the Augsburg study region in three time periods (2005/2007, 2008/2010 and 2011/2013) by sex and site—incident cancer cases of the years 2005–2013

	2005–2007	2008–2010	2011–2013
Site (ICD-10)	3-year RES (95% CI)	3-year RES (95% CI)	3-year RES (95% CI)
Men (n=14 538)	**n=4660**	**n=4890**	**n=4988**
Lip/oral cavity/pharynx (C00–C14)	45.9 (39.2 to 53.8)	53.5 (46.2 to 61.8)	61.6 (54.5 to 69.8)
Oesophagus (C15)	25.2 (17.4 to 36.4)	30.9 (22.6 to 42.4)	38.0 (29.2 to 49.4)
Stomach (C16)	48.8 (41.2 to 57.9)	36.9 (29.9 to 45.7)	44.7 (37.4 to 53.5)
Colorectum (C18–C21)	74.7 (71.0 to 78.5)	74.5 (70.7 to 78.5)	76.6 (72.8 to 80.6)
Liver (C22)	20.2 (13.7 to 29.8)	16.8 (10.7 to 26.1)	24.8 (18.2 to 34.0)
Pancreas (C25)	9.0 (5.2 to 15.6)	10.0 (5.9 to 17.0)	14.9 (9.9 to 22.2)
Lung (C33–C34)	19.4 (16.0 to 23.5)	22.8 (19.4 to 26.7)	27.1 (23.6 to 31.3)
Malignant melanoma of the skin (C43)	94.1 (89.1 to 99.4)	96.9 (93.1 to 100.8)	99.2 (95.2 to 103.3)
Prostate (C61)	98.1 (96.3 to 100.0)	94.2 (91.9 to 96.6)	98.0 (95.9 to 100.2)
Testis (C62)	97.3 (93.6 to 101.2)	97.9 (94.5 to 101.5)	97.2 (93.4 to 101.2)
Kidney (C64)	82.0 (74.8 to 90.0)	80.0 (72.8 to 88.0)	77.9 (71.2 to 85.2)
Urinary bladder (C67)	60.0 (51.1 to 70.5)	60.1 (51.7 to 69.8)	73.9 (66.2 to 82.5)
Central nervous system (C70–C72)	38.2 (28.1 to 52.0)	22.5 (15.0 to 33.6)	20.0 (12.6 to 31.7)
CUP (C80)	13.3 (7.8 to 22.7)	22.0 (14.3 to 33.9)	23.4 (15.8 to 34.7)
Non-Hodgkin's lymphoma (C82–C88)	71.9 (64.5 to 80.2)	79.2 (72.6 to 86.3)	77.9 (70.9 to 85.7)
Leukaemia (C91–C95)	68.5 (59.9 to 78.3)	69.9 (61.8 to 79.0)	67.0 (59.2 to 75.8)
Women (n=13 342)	**n=4160**	**n=4571**	**n=4611**
Lip/oral cavity/pharynx (C00–C14)	60.4 (47.7 to 76.4)	67.1 (55.0 to 81.9)	83.0 (73.5 to 93.7)
Stomach (C16)	46.7 (38.3 to 57.1)	42.4 (34.0 to 53.0)	55.2 (45.2 to 67.3)
Colorectum (C18–C21)	73.0 (68.8 to 77.5)	74.1 (69.8 to 78.7)	77.6 (73.4 to 82.0)
Pancreas (C25)	10.0 (5.5 to 18.3)	12.1 (7.8 to 18.9)	11.5 (7.4 to 17.8)
Lung (C33–C34)	26.9 (21.6 to 33.5)	29.1 (24.2 to 35.1)	25.7 (20.9 to 31.7)
Malignant melanoma of the skin (C43)	99.5 (96.2 to 102.8)	97.4 (94.1 to 100.7)	97.1 (93.3 to 101.0)
Breast (C50)	89.9 (87.9 to 92.0)	92.7 (91.0 to 94.6)	95.0 (93.3 to 96.7)
Cervix uteri (C53)	72.1 (62.9 to 82.6)	72.2 (62.8 to 83.1)	77.3 (69.3 to 86.3)
Corpus uteri (C54–C55)	82.7 (77.3 to 88.5)	87.3 (82.1 to 92.8)	88.4 (83.4 to 93.6)
Ovary (C56)	41.7 (34.9 to 49.9)	52.4 (45.3 to 60.6)	66.3 (58.6 to 75.0)
Kidney (C64)	82.8 (74.3 to 92.2)	73.8 (64.8 to 84.0)	75.9 (66.8 to 86.2)
Central nervous system (C70–C72)	39.1 (27.9 to 54.8)	28.0 (18.6 to 42.1)	27.4 (18.8 to 40.1)
Thyroid (C73)	94.5 (90.3 to 99.0)	96.4 (92.0 to 101.0)	98.6 (95.3 to 102.0)
CUP (C80)	20.0 (13.1 to 30.6)	16.0 (9.4 to 27.3)	17.4 (10.7 to 28.4)
Non-Hodgkin's lymphoma (C82–C88)	74.9 (67.4 to 83.4)	76.4 (69.5 to 84.1)	75.0 (67.7 to 83.2)
Leukaemia (C91–C95)	64.8 (55.6 to 75.5)	69.2 (60.4 to 79.3)	58.0 (48.0 to 70.0)

RES, relative survival (%)

and 2011/2013 could be found in men, but not in women. The nationwide trend in age-standardised lung cancer incidence and mortality have shown a differential development in men and women since the 1990s, with continuously rising rates in females and declining rates in males.[2 22] Tobacco smoking is the main risk factor for lung cancer,[33] and thus, diverging time trends of smoking habits in both sexes are assumed to be causal for this development.[34] Considering demographic trends, the rise of tobacco-associated raw mortality is likely to continue, and this process is estimated to persist longer in females than in males.[35 36] In the MONICA/KORA Augsburg-based surveys, the age-standardised prevalence of smoking in the Augsburg region was found to remain rather stable over the study period 1989–2001, with prevalence reaching 26.3% for current and 31.0% for former smokers in the resident population between 25 and 74 years of age.[29]

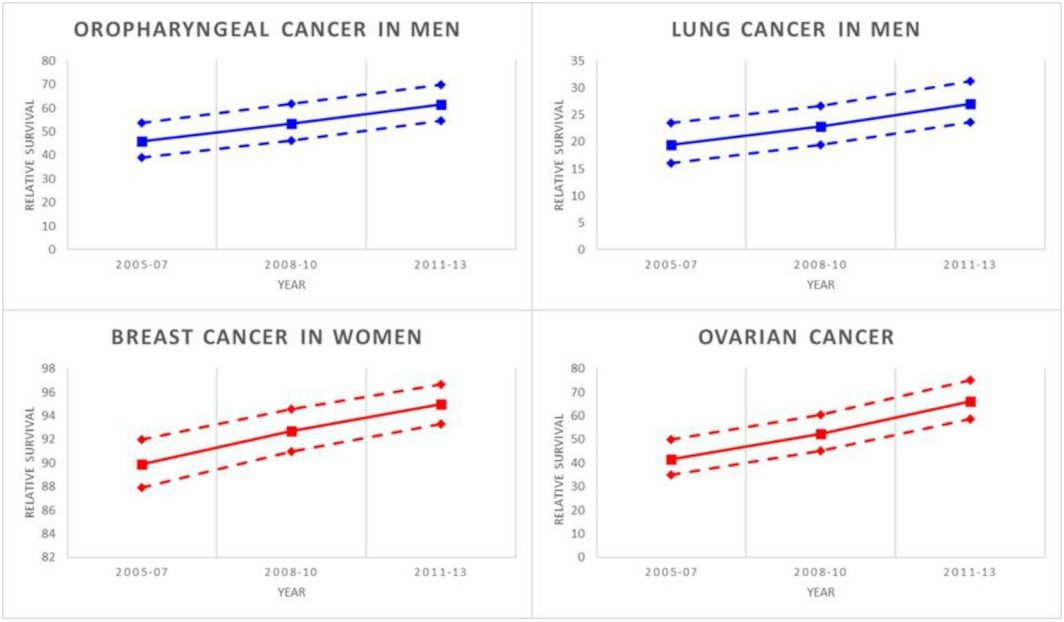

Figure 3 Trend in 3-year relative survival and its 95% CI (dashed lines) in the Augsburg study region for selected sites with significant changes over time.

Oropharyngeal cancers are heterogeneous in respect to localisation and morphology. This is reflected in a differing susceptibility to risk factors. Major risk factors are either tobacco smoking combined with high alcohol intake, which together have a synergistic effect, or HPV infection.[22] Cancer of the oral cavity, the tongue and the pharynx, which are particularly susceptible to smoking and alcohol intake, are more likely to be found in men.[22] In contrast, women are more often affected by cancer of the oropharynx, which are more likely to be caused by HPV infection.[22] Oropharyngeal cancers have a better prognosis as they respond well to radiotherapy and chemotherapy.[37] Correspondingly, the 5-year relative survival of women in the Augsburg region (61.0%) exceeded that of men (43.2%). Survival in women was comparable to the latest national estimates (63%[22]), whereas rates in men ranked below the national average (47%[22]). Trends in 3-year survival between 2005/2007 and 2011/2013 showed a significant increase in oropharyngeal cancer only in males. The age-standardised incidence rates for oropharyngeal cancer decreased in men, but increased in women, which might be due to the change in smoking behaviour already mentioned above.

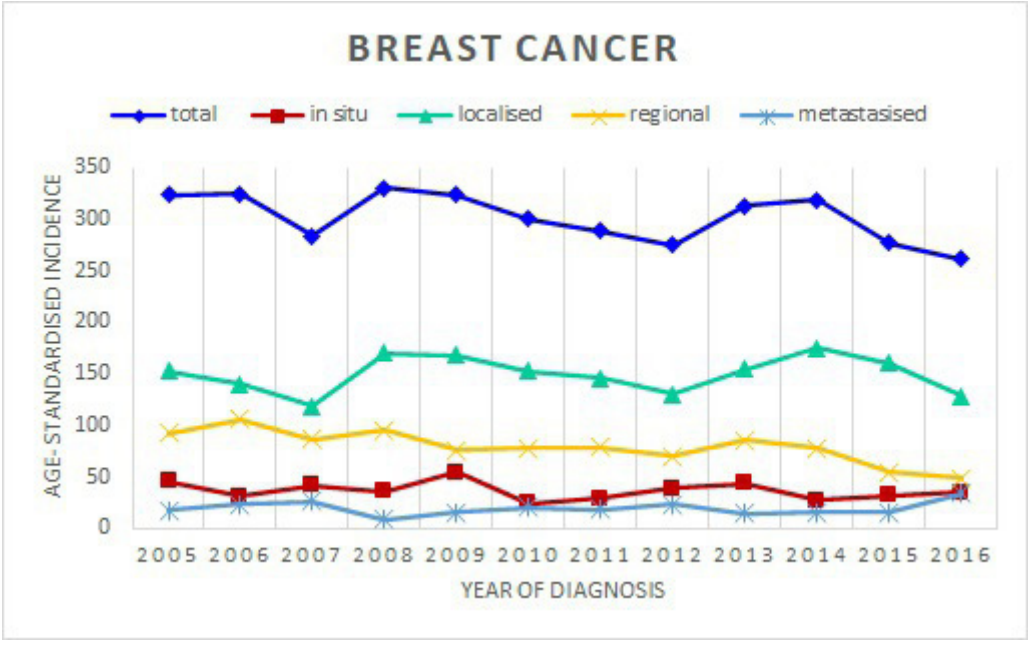

Figure 4 Breast cancer incidence, total and by stage, in women aged 50–69 years in the Augsburg study region between 2005 and 2016, age-standardised rate per 100 000 women.

The trends of incidence, mortality and survival during the study period suggest a reduced burden of CRC in the Augsburg region. The relative survival (69.3% in men and to 70.4% in women) exceeded the average German rates (62% in men, 63% in women (without C21)[22]). A decline of age-standardised incidence rates for CRC was observed in both sexes during the study period, though more pronounced in men than women. During the same time-period, CRC mortality decreased markedly only in males, which mainly relates to decreased mortality due to colon cancer (online supplementary table 4A). For Germany, a decrease in age-standardised incidence rates was reported as well, starting in 2003 and becoming stronger in the last years, being accompanied by markedly falling age-standardised mortality rates in both sexes.[28] The incidence of CRC in Germany is clearly higher in men than in women.[38] Improved survival and decreased mortality are mainly due to advances in treatment,[38 39] as well as earlier detection of the disease,[40] which can be achieved by CRC screening via occult blood test in stool and/or colonoscopy. Falling incidence rates may relate to a lower prevalence of risk factors and among others are attributable to the decline in smoking.[28 41] Screening via colonoscopy in particular is likely to have contributed to the decrease of CRC incidence as precancerous lesions are already removed during the intervention. This has an impact on both the incidence and mortality of CRC and in consequence plays an important role in the prevention of CRC.[28] CRC screening via colonoscopy became part of the German national statutory cancer screening programme in 2002 and was offered to men and women age 55 and above through the end of the study period. However, there was no national, systematic screening programme for CRC in Germany during this time.

Age-standardised incidence rates for prostate cancer have declined markedly since 2011 in the region of Augsburg as well as in Germany, after steadily increasing over a long period of time.[22] The decrease of prostate-specific antigen-based screening is assumed to be the cause of the decline in prostate cancer incidence rates,[42] which had in the past led to the detection of many latent cancers, and through a shift of the time point of diagnosis, to artificially high survival rates.[43] This might be true for the Augsburg region as well, as 5-year relative survival has increased to 97.7%, exceeding the latest national average for Germany (89%[22]). While the age-standardised incidence rates in the region of Augsburg (105.9/100 000) were still comparable to the average German rates in 2011 (113.4/100 000[22]), they progressively deviated afterwards, until in 2016 a striking divergence could be observed (Germany: 91.6/100 000;[22] Augsburg: 45.1/100 000).

There are some limitations of the present study. First, the data do not encompass the all DCO cases. In consequence, a minor deviation of incidence rates might be possible. However, the proportion of DCO cases from all incident cancer cases in the Augsburg region was less than 10% from 2007 onwards.[12] Second, until 1 April 2017, reporting of incident cases was not compulsory. However, the Cancer Registry Augsburg was already a clinical and epidemiological registry leading up to that time, and provided data on all clinically confirmed cancer cases in the catchment area of Augsburg. Reliability strongly depends on the validity of information received by death certificates. Incomplete mortality registration unavoidably leads to the overestimation of survival rates. The major strength of this study is that it provides population-based analyses focusing on a geographically defined region and the needs of its resident population. Survival can serve as an instrument to evaluate the efficiency of oncological healthcare in respect to the availability of preventive and therapeutic options.[3] Cancer registries can be used as an evidence base for cancer control, helping to identify targets of priority, allocate required resources and evaluate the effect of the measures performed.[44]

CONCLUSION

In general, cancer incidence and survival in the Augsburg region were comparable to the national average in Germany. For the majority of the cancer sites included in this analysis, no significant change in relative survival was observed during the study period. Tumour stage at diagnosis still is the key issue to address. Efforts should be taken to enhance the participation in screening programmes in the Augsburg region. Sex differences seem to have diminished, for example, in lung cancer and carcinoma of the oral cavity and the pharynx, likely due to adaption of lifestyle and associated risk factors. This emphasises the importance of modifiable risk factors such as tobacco smoking and alcohol intake, and should be considered in the future planning of prevention programmes. Additionally, adolescent girls and boys should be encouraged to adhere to the recommended HPV vaccination schedule. The leading key issues for the allocation of healthcare resources in the Augsburg region remain the most common tumour sites. Though facing low numbers of cases for some entities, regional analyses are a valuable instrument to evaluate the efficiency of oncological healthcare at the local level.

Acknowledgements We thank Ms Christina König (University Medical Center of Augsburg, Department of Cancer Data Management, Interdisciplinary Cancer Center, Augsburg) for her great support in data preparation.

Contributors All authors were actively involved in the planning of the study. NG, CM and JL contributed substantially to the conception and design of the study. GS and MT were in charge of the acquisition of data. NG analysed and interpreted the data with feedback from JL, JM-N and CM. NG drafted and revised the manuscript based on comments, which were provided by all authors. JL, JM-N, MT, GS and CM revised the article critically for important intellectual content. All authors approved the final version of the manuscript to be published.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting or dissemination plans of this research.

Patient consent for publication Not required.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement No data are available.

ORCID iD
Nina Grundmann http://orcid.org/0000-0002-5715-2406

REFERENCES

1 International Agency for Research on Cancer. Germany, source: Globocan, 2018. Available: https://gco.iarc.fr/today/data/factsheets/populations/276-germany-fact-sheets.pdf [Accessed 01 Aug 2019].
2 Haberland J, Bertz J, Wolf U, *et al*. German cancer statistics 2004. *BMC Cancer* 2010;10:52.
3 Nennecke A, Brenner H, Eberle A, *et al*. [Cancer survival analysis in Germany--heading towards representative and comparable findings]. *Gesundheitswesen* 2010;72:692–9.
4 Geiss K, Meyer M. Regional comparison of cancer incidence, mortality, and survival on the level of federal states in Germany using funnel plots. *Eur J Cancer Prev* 2019;28:234–42.
5 Jansen L, Castro FA, Gondos A, *et al*. Recent cancer survival in Germany: an analysis of common and less common cancers. *Int J Cancer* 2015;136:2649–58.
6 Nennecke A, Geiss K, Hentschel S, *et al*. Survival of cancer patients in urban and rural areas of Germany--a comparison. *Cancer Epidemiol* 2014;38:259–65.
7 Hiripi E, Gondos A, Emrich K, *et al*. Survival from common and rare cancers in Germany in the early 21st century. *Ann Oncol* 2012;23:472–9.
8 De Angelis R, Sant M, Coleman MP, *et al*. Cancer survival in Europe 1999-2007 by country and age: results of EUROCARE--5-a population-based study. *Lancet Oncol* 2014;15:23–34.
9 Rossi S, Baili P, Capocaccia R, *et al*. The EUROCARE-5 study on cancer survival in Europe 1999-2007: database, quality checks and statistical analysis methods. *Eur J Cancer* 2015;51:2104–19.
10 Bayerisches Landesamt für Statistik. GENESIS-Online Datenbank: Bevölkerungsstand. Available: https://www.statistikdaten.bayern.de/genesis/online/data?operation=abruftabelleAbrufen&selectionname=12411-007s&levelindex=1&levelid=1554800297044&index=13; [Accessed 06 Apr 2019].
11 Meisinger C, Peters A, Linseisen J. [From the MONICA-project via KORA to the NAKO-study: Practical Utility of Epidemiological Studies in Augsburg Region]. *Gesundheitswesen* 2016;78:84–90.
12 Bayerisches Krebsregister. Datenbankabfrage: region Schwaben: Augsburg, Stadt; Augsburg; Aichach-Friedberg; diagnose (ICD-10) Alle bösartigen (C00-C97), 2019. Available: https://www.krebsregister-bayern.de/lgl_abfrage_d.php [Accessed 10 Jun 2019].
13 Silva dosS I. *Cancer epidemiology: principles and methods*. Geneva: World Health Organization, 1999.
14 Bayerisches Landesamt für Statistik. Fortschreibung des Bevölkerungsstandes, 2019. Available: https://www.statistikdaten.bayern.de/genesis/online/data?operation=abruftabelleAbrufen&selectionname=12411-007s&levelindex=1&levelid=1556097832727&index=21, [Accessed 24 Apr 2019].
15 Gesundheitsberichterstattung des Bundes. Im Informationssystem Der GBE Zur Altersstandardisierung benutzte Standardbevölkerungen. Gliederungsmerkmale: alter, Geschlecht, Standardbevölkerung, 2019. Available: http://www.gbe-bund.de/oowa921-install/servlet/oowa/aw92/dboowasys921.xwdevkit/xwd_init?gbe.isgbetol/xs_start_neu/&p_aid=3&p_aid=19650715&nummer=1000&p_sprache=D&p_indsp=-&p_aid=19130962 [Accessed 28 May 2019].
16 National Cancer Institute. *Joinpoint regression program*. Version 4.7.0.0, 2019. https://surveillance.cancer.gov/joinpoint
17 Nennecke A, Barnes B, Brenner H, *et al*. [Data quality or differences in oncological care? - standards of reporting for cancer survival analyses based on registry data]. *Gesundheitswesen* 2013;75:94–8.
18 Brenner H, Hakulinen T. Patients with previous cancer should not be excluded in international comparative cancer survival studies. *Int J Cancer* 2007;121:2274–8.
19 Ederer F, Axtell LM, Cutler SJ. The relative survival rate: a statistical methodology. *Natl Cancer Inst Monogr* 1961;6:101–21.
20 Ederer and Heise. *Instructions to IBM 650 programmers in processing survival computations*. National Cancer Institute, 1959.
21 Statistisches Bundesamt. Sterbetafel, 2019. Available: https://www-genesis.destatis.de/genesis/online/data;sid=20A19B2E8DB32176 8571842EE457DB94.GO_2_2?operation=abruftabelleAbrufen&selectionname=12621-0001&levelindex=0&levelid=1559045500487&index=1
22 Robert Koch-Institut, Zentrum für Krebsregisterdaten und Gesellschaft. *Der epidemiologischen Krebsregister in Deutschland e.V. (Hrsg.). Krebs in Deutschland für 2015/16*. 12. Ausgabe. Berlin, 2019.
23 Sant M, Allemani C, Capocaccia R, *et al*. Stage at diagnosis is a key explanation of differences in breast cancer survival across Europe. *Int J Cancer* 2003;106:416–22.
24 Becker N, Altenburg H-P, Stegmaier C, *et al*. Report on trends of incidence (1970–2002) of and mortality (1952–2002) from cancer in Germany. *J Cancer Res Clin Oncol* 2006;133:23–35.
25 Simbrich A, Wellmann I, Heidrich J, *et al*. Trends in advanced breast cancer incidence rates after implementation of a mammography screening program in a German population. *Cancer Epidemiol* 2016;44:44–51.
26 Hermon C, Beral V. Breast cancer mortality rates are levelling off or beginning to decline in many Western countries: analysis of time trends, age-cohort and age-period models of breast cancer mortality in 20 countries. *Br J Cancer* 1996;73:955–60.
27 Clarke CA, Purdie DM, Glaser SL. Population attributable risk of breast cancer in white women associated with immediately modifiable risk factors. *BMC Cancer* 2006;6:170.
28 Brenner H, Schrotz-King P, Holleczek B, *et al*. Declining bowel cancer incidence and mortality in Germany. *Dtsch Arztebl Int* 2016;113:101–6.
29 Thiele I, Linseisen J, Heier M, *et al*. Time trends in stroke incidence and in prevalence of risk factors in southern Germany, 1989 to 2008/09. *Sci Rep* 2018;8:11981.
30 Takla A, Wiese-Posselt M, Harder T, *et al*. Background paper for the recommendation of HPV vaccination for boys in Germany. *Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz* 2018;61:1170–86.
31 Robert Koch-Institut. Aktuelles aus der KV-Impfsurveillance - Impfquoten ausgewählter Schutzimpfungen in Deutshland, 2018. Available: https://www.rki.de/DE/Content/Infekt/EpidBull/Archiv/2018/Ausgaben/01_18.pdf?__blob=publicationFile; [Accessed 13 May 2020].
32 Allemani C, Matsuda T, Di Carlo V, *et al*. Global surveillance of trends in cancer survival 2000-14 (CONCORD-3): analysis of individual records for 37 513 025 patients diagnosed with one of 18 cancers from 322 population-based registries in 71 countries. *Lancet* 2018;391:1023–75.
33 Eberle A, Jansen L, Castro F, *et al*. Lung cancer survival in Germany: a population-based analysis of 132,612 lung cancer patients. *Lung Cancer* 2015;90:528–33.
34 Twardella D, Geiss K, Radespiel-Tröger M, *et al*. [Trends in incidence of lung cancer according to histological subtype among men and women in Germany : Analysis of cancer registry data with the application of multiple imputation techniques]. *Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz* 2018;61:20–31.
35 Zeiher J, Finger JD, Kuntz B, *et al*. [Trends in smoking among adults in Germany : Evidence from seven population-based health surveys from 1991-2015]. *Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz* 2018;61:1365–76.
36 Mons U, Brenner H. Demographic ageing and the evolution of smoking-attributable mortality: the example of Germany. *Tob Control* 2017;26:455–7.
37 Wienecke A, Kraywinkel K. Epidemiology of head and neck cancer in Germany. *Onkologe* 2019;25:190–200.
38 Brenner H, Kloor M, Pox CP. Colorectal cancer. *Lancet* 2014;383:1490–502.
39 Ahmed S, Johnson K, Ahmed O, *et al*. Advances in the management of colorectal cancer: from biology to treatment. *Int J Colorectal Dis* 2014;29:1031–42.
40 Brenner H, Bouvier AM, Foschi R, *et al*. Progress in colorectal cancer survival in Europe from the late 1980s to the early 21st century: the EUROCARE study. *Int J Cancer* 2012;131:1649–58.
41 Liang PS, Chen T-Y, Giovannucci E. Cigarette smoking and colorectal cancer incidence and mortality: systematic review and meta-analysis. *Int J Cancer* 2009;124:2406–15.
42 Hermann S, Kraywinkel K. Epidemiology of prostate cancer in Germany. *Onkologe* 2019;25:294–303.
43 Karim-Kos HE, de Vries E, Soerjomataram I, *et al*. Recent trends of cancer in Europe: a combined approach of incidence, survival and mortality for 17 cancer sites since the 1990s. *Eur J Cancer* 2008;44:1345–89.
44 Ferlay J, Colombet M, Soerjomataram I, *et al*. Cancer incidence and mortality patterns in Europe: estimates for 40 countries and 25 major cancers in 2018. *Eur J Cancer* 2018;103:356–87.