Lung Cancer 63 (2009) 322–330

Contents lists available at ScienceDirect

Lung Cancer

journal homepage: www.elsevier.com/locate/lungcan

Socioeconomic inequalities in lung cancer mortality in 16 European populations

J.H.A. Van der Heyden[a,*,1], M.M. Schaap[b,1], A.E. Kunst[b,1], S. Esnaola[c,1], C. Borrell[d,e,f,1], B. Cox[a,1], M. Leinsalu[g,h,1], I. Stirbu[b,1], R. Kalediene[i,1], P. Deboosere[j,1], J.P. Mackenbach[b,1], H. Van Oyen[a,1]

[a] *Scientific Institute of Public Health, Belgium*
[b] *Department of Public Health, Erasmus MC, Rotterdam, Netherlands*
[c] *Department of Health of the Basque Country, Spain*
[d] *Agència de Salut Pública de Barcelona, Spain*
[e] *Universitat Pompeu Fabra, Barcelona, Spain*
[f] *CIBER de Epidemiología y Salud Pública (CIBERESP), Spain*
[g] *Stockholm Centre on Health of Societies in Transition at Södertörn University College, Huddinge, Sweden*
[h] *Department of Epidemiology and Biostatistics at the National Institute for Health Development, Tallinn, Estonia*
[i] *Faculty of Public Health Kaunas University of Medicine, Lithuania*
[j] *Interface Demography, Vrije Universiteit Brussel, Belgium*

ARTICLE INFO

Article history:
Received 28 February 2008
Received in revised form 2 June 2008
Accepted 7 June 2008

Keywords:
Lung cancer
Mortality
Socioeconomic
Education
Europe
Inequalities
Smoking

ABSTRACT

Objectives: This paper aims to describe socioeconomic inequalities in lung cancer mortality in Europe and to get further insight into socioeconomic inequalities in lung cancer mortality in different European populations by relating these to socioeconomic inequalities in overall mortality and smoking within the same or reference populations. Particular attention is paid to inequalities in Eastern European and Baltic countries.

Methods: Data were obtained from mortality registers, population censuses and health interview surveys in 16 European populations. Educational inequalities in lung cancer and total mortality were assessed by direct standardization and calculation of two indices of inequality: the Relative Index of Inequality (RII) and the Slope Index of Inequality (SII). SIIs were used to calculate the contribution of inequalities in lung cancer mortality to inequalities in total mortality. Indices of inequality in lung cancer mortality in the age group 40–59 years were compared with indices of inequalities in smoking taking into account a time lag of 20 years.

Results: The pattern of inequalities in Eastern European and Baltic countries is more or less similar as the one observed in the Northern countries. Among men educational inequalities are largest in the Eastern European and Baltic countries. Among women they are largest in Northern European countries. Whereas among Southern European women lung cancer mortality rates are still higher among the high educated, we observe a negative association between smoking and education among young female adults. The contribution of lung cancer mortality inequalities to total mortality inequalities is in most male populations more than 10%. Important smoking inequalities are observed among young adults in all populations. In Sweden, Hungary and the Czech Republic smoking inequalities among young adult women are larger than lung cancer mortality inequalities among women aged 20 years older.

Conclusions: Important socioeconomic inequalities exist in lung cancer mortality in Europe. They are consistent with the geographical spread of the smoking epidemic. In the next decades socioeconomic inequalities in lung cancer mortality are likely to persist and even increase among women. In Southern European countries we may expect a reversal from a positive to a negative association between socioeconomic status and lung cancer mortality. Continuous efforts are necessary to tackle socioeconomic inequalities in lung cancer mortality in all European countries.

* Corresponding author at: Scientific Institute of Public Health, Unit of Epidemiology, 14 Juliette Wytsmanstraat, B-1050 Brussels, Belgium. Tel.: +32 2 6425726; fax: +32 2 6425410.
E-mail address: jvanderheyden@iph.fgov.be (J.H.A. Van der Heyden).
[1] For the Eurothine consortium.

0169-5002/$ – see front matter © 2008 Elsevier Ireland Ltd. All rights reserved.
doi:10.1016/j.lungcan.2008.06.006

1. Introduction

Lung cancer in Europe is still the most common cancer related cause of death with an estimated 334,800 deaths (19.7% from total cancer mortality) in 2006 [1]. Even though lung cancer mortality in men has been declining since the late 1980s, female lung cancer mortality is still increasing in many European countries [2,3]. Trends also show important country variations [4].

Some studies have assessed socioeconomic inequalities in overall mortality and cause-specific mortality in a range of European countries [5,6]. The relationship between lung cancer mortality and socioeconomic status has also been investigated in several individual countries, both in Europe [7–9] and elsewhere [10,11]. In most countries a low education was found to be an independent risk factor for lung cancer and/or lung cancer mortality. One study conducted a systematic analysis of variations between countries in the size and pattern of socioeconomic inequalities in lung cancer mortality, using data from 10 European populations, collected in the first half of the 1990s [12]. The study demonstrated consistently higher lung cancer mortality rates among the "lower" educated men and women in Northern and Western Europe and an inverse or less pronounced socioeconomic gradient in some Southern European populations.

As lung cancer continues to be an unabated pandemic, further research of inequalities in lung cancer mortality remains an important issue.

Even though previous cross-European studies have put into evidence an important north–south gradient in socioeconomic inequalities both in lung cancer mortality and smoking [12,13], and related this to the theory of the smoking epidemic [14], there is need to focus further on regional differences in lung cancer mortality inequalities in Europe by including also Eastern European and Baltic countries. One particular point of interest is to find out if the smoking epidemic in Eastern European countries spreads through populations in a similar way as is the case in other European countries. As studies on socioeconomic inequalities in smoking have now been published for over two decades and recommendations to tackle inequalities in smoking have been suggested [15], there is also need to verify if there are any indications that inequalities in lung cancer mortality in Europe will in the future decrease, or on the contrary, will continue to persist.

In this paper we present new European results on socioeconomic inequalities in lung cancer mortality, based on recent and extensive datasets, collected in 16 European populations. More specifically the objectives of the paper are: (1) to describe socioeconomic inequalities in lung cancer mortality in a wide range of European population groups, including Eastern and Central European countries; (2) to assess the contribution of lung cancer to inequalities in total mortality; (3) to get further insight into socioeconomic inequalities in lung cancer mortality in different European populations by relating these to socioeconomic inequalities in smoking practices within the same or reference populations.

Cigarette smoking is indeed the major cause of lung cancer, and most lung cancers have historically occurred among current cigarette smokers or recent quitters. As population patterns in smoking prevalence will continue to be the most powerful predictor of the future occurrence of lung cancer [16], smoking data could give clues about the future evolution of socioeconomic inequalities in lung cancer mortality. In some birth cohorts also other environmental and occupational factors may have contributed to the present international patterns of socioeconomic differences in lung cancer mortality. In such case the relation between lung cancer mortality inequalities and former smoking inequalities may be less clear-cut.

Knowledge on the contribution of lung cancer to inequalities in total mortality is important to identify populations in which a reduction of the inequalities in lung cancer mortality will also have a substantial impact on inequalities in total mortality. Previous research has shown that the contribution of lung cancer mortality to the difference between manual and non-manual classes in total mortality varies substantially from one country to another [17]. This study allowed us to investigate the impact of lung cancer mortality on the overall socioeconomic inequalities in mortality with another socioeconomic measure and in a larger number of countries.

The study was conducted in the framework of the EUROTHINE project[2] that aimed to help policy-makers at the European and national level to develop rational strategies for tackling socioeconomic inequalities in health. Global results of this project, based on international comparisons of socioeconomic inequalities in mortality and morbidity in many European countries, have been presented elsewhere [18].

2. Methods

2.1. Data

Data on lung cancer mortality, total mortality and socioeconomic status were available for 16 countries or regions, including 4 Eastern European and 2 Baltic countries. Table 1 describes the data sources and some characteristics of the data collection. Most data sources were situated at the national level, but also regional and big urban populations (Basque Country, Barcelona, Madrid, Turin) were included. The majority of networks provided longitudinal data. In Barcelona a record linkage was done between the mortality register and the census data [19]. A similar approach was used in Madrid and the Basque country. In those populations it was not possible to achieve a 100% linkage between the population and death registries. In Madrid, this was particularly a problem: ca. 30% of mortality records could not be linked. No variation in this percentage was found according to age, sex, or socioeconomic position, therefore, estimates of relative inequalities in mortality are not likely to be biased to an important extent. Absolute estimates for Madrid were corrected by using weighted numbers of death with a weighting factor equaling 1/0.7 = 1.428571. In the Czech Republic, Estonia, Hungary, Lithuania and Poland unlinked cross-sectional data were used.

In order to compare results on mortality from longitudinal and cross-sectional datasets for similar age groups we grouped the data according to the average age of death, also for countries with longitudinal data sets, even if in the latter case it would have been more logical to do this based on age cohorts. The analyses were restricted to age groups with an average age at death between 40 and 79 years.

The cause specific mortality that was considered was mortality due to cancer of trachea, bronchus and lung (ICD 10 codes C33–C34; C39–ICD 9 codes 162–163; 165). Socioeconomic status was assessed through educational level. The national categories of educational level were harmonized on the basis of the International Standard Classification of Education (ISCED) and regrouped in three categories (no, primary and lower secondary education: ISCED 1 + 2; upper secondary and post-secondary non-tertiary education: ISCED 3 + 4; tertiary education: ISCED 5 + 6). Even though separate information for ISCED 1 and ISCED 2 level was available for most countries, these categories were taken together, as the distinction between these two groups is not the same for many countries

[2] http://www.eurothine.org.

Table 1
Data sources in the populations understudy

Population	Type of mortality data	Follow-up period	Person years at risk	Data sources used for comparison with socioeconomic inequalities on smoking	Year(s) of survey(s)	Sample size
North						
Finland	Longitudinal	1990–2000	27,550,171	Finbalt Health Monitor	94/98/00/02/04	20,371
Sweden	Longitudinal	1991–2000	48,340,986	Swedish Survey of Living Conditions	00/01	11,484
Norway	Longitudinal	1990–2000	22,262,277	Norwegian Survey of Living Conditions	02	6,820
Denmark	Longitudinal	1996–2000	15,354,602	Danish Health and Morbidity Survey	00	16,690
Continental						
Belgium	Longitudinal	1991–1995	27,635,206	Health Interview Survey	97/01	18,481
Switzerland	Longitudinal	1990–2000	30,728,441	Not available	–	
South Turin	Longitudinal	1991–2001	5,287,281	Health and health care utilization survey Italy	99/00	118,245
Basque Country	Longitudinal	1996–2001	6,457,258	Basque Health Interview Survey	97/02	12,443
Barcelona	Longitudinal	1992–2001	8,915,780	Health Interview Survey Barcelona	00	10,045
Madrid	Longitudinal	1996–1997	4,664,793	National Health Survey	01	20,748
East						
Slovenia	Longitudinal	1991–2000	10,325,538	Not available		
Hungary	CS unlinked	1999–2002	24,953,908	National Health Interview Survey	00/03	10,532
Czech Rep.	CS unlinked	1999–2003	30,308,765	Sample Survey of the Health Status of the Czech Pop.	02	2,476
Poland	CS unlinked	2001–2003	65,844,117	Not available	–	
Baltic						
Lithuania	CS unlinked	2000–2002	6,189,927	Finbalt Health Monitor	94/98/00/02/04	11,647
Estonia	CS unlinked	1998–2002	4,141,440	Health Behaviour among Estonian Adult Population	02/04	4,376

and may be especially problematic in the unlinked cross-sectional studies because of the numerator/denominator bias. Information on the educational distribution in the populations, including the percentage of missing data is provided in Table 2.

For 11 populations, including 4 Eastern European countries, survey data were available with information on smoking status. For Turin and Madrid no health interview data were available but we used national health interview surveys from Italy and Spain instead.

As indicators for smoking were used 'being a current regular or occasional smoker' and 'having ever smoked.'

2.2. Analysis

In the first step we calculated for each population age standardized lung cancer mortality rates by level of education. This was done by direct standardization using the European standard population as reference. Standardized rates were calculated stratified by sex for the complete age group under study and for 4 subgroups: 40–49 years, 50–59 years, 60–69 years and 70–79 years.

In the second step we computed the Relative Index of Inequality (RII) for lung cancer mortality, which is a regression-based measure

Table 2
Distribution of populations by level of education[a]

	Mortality data				Survey data			
	% low	% middle	% high	% missing	% low	% average	% high	% missing
North								
Finland	51.0	28.7	20.3	0.0	23.4	56.3	18.8	1.6
Sweden	36.1	37.9	16.2	9.8	26.4	46.2	27.3	0.1
Norway	34.0	45.7	18.0	2.3	17.0	54.9	25.2	2.9
Denmark	49.8	31.9	18.3	0.0	25.8	53.6	18.4	2.2
Continental								
Belgium	61.3	18.7	14.1	6.0	39.5	28.9	28.0	3.6
Switzerland	32.1	52.8	14.6	0.6				
South								
Turin/Italy	72.8	18.9	8.3	0.0	63.5	30.1	6.4	0.0
Basque C.	69.8	16.0	12.7	1.5	53.0	25.0	22.0	0.1
Madrid/Spain	64.6	16.5	15.6	3.3	66.9	19.7	13.2	0.2
Barcelona	70.1	13.9	15.3	0.7	53.0	25.0	22.0	0.1
East								
Slovenia	47.5	40.7	10.4	1.3				
Hungary	64.3	23.3	12.4	0.0	57.4	28.9	13.4	0.3
Czech Rep.	62.8	26.7	10.5	0.0	56.6	31.1	12.4	0.0
Poland	55.8	31.2	11.0	2.0				
Baltic								
Lithuania	30.6	52.8	16.1	0.5	39.9	40.5	18.2	1.4
Estonia	29.4	51.6	16.6	2.3	47.6	34.3	17.5	0.6

[a] Three levels are distinguished: low = no, primary and lower secondary education (ISCED 1 + 2); middle = upper secondary and post-secondary non-tertiary education (ISCED 3 + 4); high = tertiary education (ISCED 5 + 6).

that looks at the systematic association between mortality and relative socioeconomic position across all educational groups [20,21]. This index is calculated as the ratio of the mortality of the most disadvantaged ($x = 0$) to the most advantaged ($x = 1$). It should be noted that the values $x = 0$ and 1 do not correspond to the lowest and highest categories but to the extremes of these categories, based on a rank measure of education, where the rank is calculated as the mean proportion of the population having a higher level of education. They thus represent extreme, possibly hypothetical, subgroups [22]. If the index is 2 then the mortality rate of the most disadvantaged is 2 times as high as that of the most advantaged. An RII of 1 indicates that there is no inequality. An RII below 1 indicates that a higher mortality is found among the most advantaged.

Age standardized and gender specific RIIs were computed for all ages (40–79 years) together and for the four age groups separately.

RIIs for smoking calculated as prevalence rate ratios were obtained from a regression using a log-link function and assuming binominal distribution of the smoking variable.

For each population we compared RIIs for lung cancer mortality in the age group 40–59 years with RIIs for smoking in the age group 20–39 years. Assuming a time lag of 20 years it was estimated that the latter would give an indication on future inequalities of lung cancer mortality.

The RIIs were calculated with the GENMOD procedure of SAS v9.1 applying age adjusted Poisson models in case of lung cancer mortality and binomial models in case of smoking.

Both for total mortality and lung cancer mortality we computed the Slope Index of Inequality (SII), which measures the absolute rate difference between the lower and the higher end of the educational hierarchy. As the SII is a measure of absolute inequalities it is sensitive to the average level of health in the population. If the mortality rate is low, the SII will be low as well, even if the RII is substantial. A negative SII corresponds with a higher mortality among the higher educated. The SII permits a decomposition of inequalities in total mortality into inequalities in cause specific mortality.

The SII for total and lung cancer mortality can be estimated with the formula $\mathrm{SII} = 2\mathrm{MR}(\mathrm{RII} - 1)/(\mathrm{RII} + 1)$ [23] where MR is the age adjusted overall mortality rate. By dividing the SII for lung cancer mortality by the SII for total mortality we obtained the contribution of inequalities in lung cancer mortality to inequalities in total mortality.

3. Results

In the 16 studied populations the age adjusted lung cancer mortality rates in the age group 40–79 years ranged from 65.8/100,000 person years in Sweden to 252.4/100,000 person years in Hungary among men, and from 11.9/100,000 person years in Madrid to 76.4/100,000 person years in Denmark among women.

Table 3 presents age adjusted lung cancer mortality rates by level of education for men and women in different age groups. Among men we observed a sharp increase in lung cancer mortality with a decreasing educational level. The largest socioeconomic differences were found in the younger age groups. In the Southern European populations the socioeconomic gradient was smaller or even absent, e.g. in the age group between 40 and 49 years in the Basque Country.

Among women gradients in lung cancer mortality rates as a function of educational attainment varied more between the regions. In the Northern European and Continental populations we observed in all age groups a similar pattern as among men: the lower the educational level, the higher the lung cancer mortality rate and this for all age groups. In the Southern European populations higher mortality rates were found among the highest educated. The pattern among women in the Eastern European countries was remarkable: while we observed higher mortality rates among the low educated in the youngest age group, this relationship gradually inversed with increasing age. In the highest age group higher mortality rates were observed in the highest educated group. This phenomenon was most pronounced in Hungary, but also observed in Poland and Slovenia.

The observed patterns are confirmed in Table 4 in which RIIs and 95% confidence intervals are presented by country, sex and age group. In all populations, except in the Southern European populations RIIs among men were all significantly higher than 1 and decreased with increasing age. Large inequalities were observed among men aged 40–59 years in Eastern European and Baltic countries. Among the male population in Southern European populations' inequalities were small or non-existent in all age groups.

Inequalities among women were generally smaller than among men in all age groups. In the Southern European populations most RIIs were significantly lower than 1.

The contribution of lung cancer mortality to the total mortality in the population 40–79 years is presented in Fig. 1. Among men the contribution of inequalities in lung cancer mortality to inequalities in total mortality was largest in Belgium and Turin. Among women this percentage was largest in Denmark and Norway. Only in the latter populations lung cancer mortality contributed substantially to the inequalities in total mortality. In the other female populations the contribution of lung cancer mortality was marginal, or even negative, indicating that lung cancer mortality rates were higher among the high educated, while an inverse relationship was found for total mortality.

In Fig. 2 we present for each population RIIs for lung cancer mortality for persons between 40 and 59 years in relation to RIIs for current smoking and ever smoking for persons between 20 and 39 years. The assumption is made that the latter gives us an indication of possible lung cancer mortality inequalities among persons aged 40–59 years within 20 years.

It is striking that in some countries, like Sweden, Hungary and the Czech Republic smoking inequalities among young adult women were larger than lung cancer mortality inequalities among women aged 20 years older.

In the Southern European populations the positive association between education and lung cancer mortality among women between 40 and 59 years contrasts strongly with the negative association between education and smoking among women between 20 and 39 years.

RIIs for ever smokers were usually smaller than the ones for current smokers, but the geographical pattern was quite similar (Fig. 2).

4. Discussion

4.1. Summary of findings

Our study indicates that there are still important socioeconomic inequalities in lung cancer mortality in Europe. Some regional patterns can be distinguished. Large socioeconomic inequalities, with much higher lung cancer mortality rates among the low educated, are observed in the male populations of some Eastern European countries, like the Czech Republic and Hungary. Among women the largest inequalities in lung cancer mortality are observed in the Northern populations. In most populations there are still important educational inequalities in smoking, both among men and women. In the Southern populations inequalities in lung cancer mortality and smoking are much smaller or (among women) even inverse.

Table 3
European age standardized lung mortality rates per 100,000 person years at risk, by age, sex and level of education

Region	Country	Education*	Sex and age group (in years)									
			Men					Women				
			40–49	50–59	60–69	70–79	40–79	40–49	50–59	60–69	70–79	40–79
North	Finland	Low	17.4	75.4	247.6	505.2	145.8	6.1	18.7	39.9	69.9	25.3
		Middle	12.3	58.4	157.8	387.0	104.6	3.7	10.4	30.3	61.5	18.7
		High	4.6	26.0	84.5	277.0	62.2	3.4	11.9	25.0	58.4	17.6
	Sweden	Low	9.7	43.4	133.1	226.6	74.0	13.5	39.2	67.7	89.9	42.9
		Middle	6.2	36.5	108.4	206.7	62.7	8.2	30.7	61.7	88.5	36.9
		High	3.7	20.6	69.2	151.6	41.5	5.0	16.6	36.0	64.7	22.7
	Norway	Low	23.3	89.4	231.2	359.6	130.9	22.4	57.4	97.3	99.4	59.3
		Middle	14.1	53.9	162.8	283.1	92.2	10.0	29.7	64.9	81.2	37.0
		High	5.3	31.8	106.3	217.7	61.8	5.7	13.0	46.2	63.2	23.9
	Denmark	Low	14.1	69.9	221.0	453.5	130.8	13.8	62.3	159.9	242.0	89.1
		Middle	10.3	50.2	189.6	471.6	118.6	9.6	41.7	115.3	207.9	67.2
		High	4.9	26.6	114.9	286.3	70.2	4.6	22.4	83.8	154.6	45.9
Continental	Belgium	Low	24.2	115.5	335.9	661.3	199.3	8.2	20.8	42.0	57.5	25.6
		Middle	14.6	69.8	216.5	464.1	131.3	5.4	16.1	31.8	66.9	22.1
		High	8.8	45.4	157.4	322.0	91.2	5.1	13.4	28.2	50.6	18.4
	Switzerland	Low	37.3	130.0	302.8	456.2	176.0	15.9	31.8	49.6	61.8	33.9
		Middle	20.2	78.5	196.4	355.4	118.2	8.9	23.7	45.8	65.9	28.7
		High	9.8	43.1	119.8	222.2	70.4	6.7	17.1	36.5	73.7	24.7
South	Turin	Low	28.7	120.1	317.3	569.8	187.0	4.9	20.8	46.3	93.9	29.9
		Middle	15.8	85.8	204.8	406.3	127.1	6.7	18.0	65.9	94.9	34.0
		High	16.1	57.2	146.5	385.0	102.8	5.8	24.5	44.7	130.7	35.5
	Basque C.	Low	13.4	64.4	138.6	338.5	96.7	5.5	8.6	11.1	24.7	10.0
		Middle	10.8	71.9	150.4	269.1	92.3	6.5	19.2	15.8	35.6	16.1
		High	13.9	60.1	102.6	257.8	77.8	14.2	28.4	42.5	24.7	26.2
	Madrid	Low	41.7	119.1	322.7	533.3	187.9	4.1	10.3	22.7	36.3	14.1
		Middle	34.4	123.1	251.1	627.1	182.4	6.3	27.4	41.3	74.4	29.0
		High	30.6	90.7	220.3	425.9	139.4	10.4	20.7	27.9	29.6	19.9
	Barcelona	Low	51.9	128.4	279.1	474.0	177.5	6.5	10.8	18.3	38.1	14.3
		Middle	42.9	95.3	208.5	344.7	132.7	8.6	24.8	32.5	41.1	23.0
		High	36.7	88.5	217.7	373.1	133.9	9.9	19.9	29.4	54.9	22.8
East	Slovenia	Low	45.6	161.9	382.6	487.8	210.4	10.0	20.5	41.5	57.7	26.1
		Middle	31.2	105.3	334.6	456.9	173.2	9.0	24.1	56.6	111.9	36.8
		High	12.9	53.1	178.0	295.4	96.3	7.4	20.7	88.9	116.3	42.8
	Hungary	Low	89.8	280.2	507.4	602.9	304.4	41.5	73.2	89.8	115.7	71.2
		Middle	49.9	144.8	260.7	362.1	164.3	24.5	49.3	95.0	160.1	64.4
		High	16.9	81.6	186.5	337.1	113.7	9.7	45.0	102.2	222.8	67.2
	Czech Rep.	Low	35.8	190.8	459.9	616.6	248.9	9.9	39.6	71.0	98.6	43.5
		Middle	15.9	76.4	199.0	308.9	111.0	6.1	27.2	65.9	128.0	40.8
		High	4.2	31.5	101.2	200.1	58.0	3.0	15.6	44.9	82.7	25.9
	Poland	Low	46.7	208.2	502.3	695.2	277.0	18.3	47.4	64.4	87.7	46.1
		Middle	17.7	94.1	256.6	416.3	143.0	9.3	40.2	69.2	119.3	45.7
		High	7.0	47.4	151.1	257.0	81.9	4.3	24.8	53.9	103.9	33.8
Baltic	Lithuania	Low	72.5	191.9	395.1	521.3	235.9	6.7	15.1	22.4	48.0	17.9
		Middle	26.4	117.0	257.3	378.2	148.7	4.8	7.9	20.5	51.5	14.9
		High	15.8	39.4	131.0	212.2	72.5	2.1	10.4	14.0	19.7	9.5
	Estonia	Low	55.4	192.8	452.7	631.6	256.4	18.1	22.2	31.9	74.1	29.3
		Middle	24.8	140.9	361.3	582.5	203.5	3.2	18.8	35.7	110.9	28.4
		High	7.2	46.7	141.3	319.9	87.3	2.5	9.7	22.3	50.6	15.0

* Low: no, primary and lower secondary education (ISCED 1 + 2). Middle: upper secondary and post-secondary non-tertiary education (ISCED 3 + 4). High: tertiary education (ISCED 5 + 6).

4.2. Methodological considerations

In our data, education was available in a comparable form for a large number of countries. Advantages of this measure are that it allows for classification of individuals regardless of whether they are inside or outside of the labour force market and it largely averts reverse causation since most people acquire their education early in life. We observed large differences between countries in the distribution of population by educational level. These differences mainly reflect true variations between countries of Europe in educational systems and attained levels of education. To cope with these differences, we used RII, a measure that takes educational distributions into account. RII estimates can be compared between countries, provided that a detailed and hierarchical classification of educational levels is used in each country.

Data from Eastern European (except Slovenia) and Baltic countries had cross-sectional unlinked design, while all other European countries and Slovenia were census-linked mortality follow-up studies. Results based on unlinked cross-sectional data may be biased due to differences, e.g. a differential non-response, between the data obtained from the mortality registry (numerator) and the data available from the population census or other surveys (denominator) [24]. Although this bias may affect inequalities in both directions [25] a recent study in Lithuania [26] indicated that unlinked estimates tend to overstate mortality in disadvantaged groups and understate mortality in advantaged groups, at least at older ages. The educational inequalities among men in the countries with unlinked study design may thus be overestimated, but they are so large that we believe that, even taking into account the bias, socioeconomic inequalities

Table 4
Relative indices of inequality (and 95% CI) for lung cancer mortality in 16 European populations, by gender and age group

	40–49 years	50–59 years	60–69 years	70–79 years
Men				
North				
Finland	4.75 (3.38–6.69)	3.74 (3.05–4.58)	4.54 (3.88–5.32)	2.48 (2.15–2.86)
Sweden	3.39 (2.33–4.94)	2.23 (1.88–2.65)	2.07 (1.84–2.33)	1.46 (1.33–1.61)
Norway	5.90 (4.02–8.68)	3.96 (3.18–4.92)	2.60 (2.27–2.98)	1.86 (1.66–2.09)
Denmark	3.49 (2.01–6.05)	3.25 (2.55–4.14)	1.97 (1.68–2.30)	1.34 (1.18–1.52)
Continental				
Belgium	4.37 (3.10–6.17)	4.11 (3.40–4.98)	3.13 (2.77–3.54)	2.79 (2.48–3.13)
Switzerland	5.36 (3.95–7.27)	4.08 (3.47–4.80)	3.18 (2.86–3.54)	2.27 (2.07–2.49)
South				
Turin	3.05 (1.45–6.42)	2.59 (1.79–3.76)	2.99 (2.24–3.98)	2.05 (1.56–2.68)
Basque Country	1.10 (0.51–2.37)	0.98 (0.66–1.47)	1.19 (0.82–1.74)	1.70 (1.26–2.30)
Madrid	1.63 (0.82–3.25)	1.35 (0.84–2.18)	1.93 (1.31–2.84)	1.15 (0.77–1.70)
Barcelona	1.74 (1.19–2.52)	1.98 (1.49–2.61)	1.68 (1.38–2.05)	1.72 (1.40–2.10)
East				
Slovenia	3.31 (2.34–4.67)	3.29 (2.66–4.09)	1.80 (1.56–2.07)	1.56 (1.29–1.89)
Hungary	6.74 (5.40–8.41)	6.03 (5.27–6.88)	5.10 (4.50–5.78)	2.95 (2.59–3.36)
Czech Rep.	12.09 (8.45–17.30)	10.93 (9.33–12.80)	8.27 (7.28–9.38)	5.46 (4.82–6.18)
Poland	10.86 (8.97–13.15)	7.46 (6.73–8.26)	5.41 (5.01–5.85)	3.95 (3.64–4.29)
Baltic				
Lithuania	7.64 (4.16–14.04)	4.88 (3.58–6.65)	3.83 (3.00–4.88)	2.73 (2.04–3.65)
Estonia	9.02 (4.37–18.65)	3.74 (2.64–5.30)	3.04 (2.38–3.88)	1.86 (1.41–2.45)
Women				
North				
Finland	2.51 (1.45–4.33)	2.57 (1.74–3.78)	2.02 (1.48–2.76)	1.34 (1.01–1.76)
Sweden	3.83 (2.73–5.37)	2.75 (2.28–3.32)	1.73 (1.48–2.03)	1.18 (1.02–1.37)
Norway	6.69 (4.36–10.25)	5.83 (4.37–7.77)	2.60 (2.11–3.20)	1.62 (1.33–1.97)
Denmark	4.56 (2.52–8.27)	3.69 (2.82–4.83)	2.38 (1.95–2.91)	1.64 (1.36–1.97)
Continental				
Belgium	2.36 (1.37–4.08)	1.96 (1.30–2.96)	1.88 (1.35–2.62)	0.95 (0.69–1.30)
Switzerland	3.33 (2.28–4.86)	1.97 (1.52–2.54)	1.25 (1.02–1.53)	0.85 (0.70–1.04)
South				
Turin	0.63 (0.17–2.36)	1.03 (0.45–2.38)	0.59 (0.32–1.08)	0.79 (0.44–1.41)
Basque Country	0.26 (0.10–0.73)	0.14 (0.05–0.34)	0.16 (0.05–0.54)	0.60 (0.20–1.77)
Madrid	0.24 (0.05–1.28)	0.18 (0.05–0.65)	0.42 (0.12–1.48)	0.43 (0.11–1.65)
Barcelona	0.50 (0.21–1.18)	0.25 (0.12–0.51)	0.35 (0.19–0.67)	0.62 (0.33–1.15)
East				
Slovenia	1.42 (0.74–2.73)	0.81 (0.49–1.33)	0.43 (0.31–0.61)	0.26 (0.18–0.38)
Hungary	4.99 (3.80–6.56)	2.28 (1.87–2.78)	0.87 (0.71–1.06)	0.43 (0.35–0.53)
Czech Rep.	3.70 (2.22–6.15)	2.69 (2.10–3.43)	1.36 (1.08–1.71)	0.70 (0.55–0.88)
Poland	5.47 (4.28–6.98)	1.90 (1.64–2.20)	0.99 (0.87–1.14)	0.57 (0.50–0.66)
Baltic				
Lithuania	3.62 (0.71–18.55)	1.72 (0.63–4.65)	1.52 (0.75–3.09)	1.27 (0.68–2.37)
Estonia	25.31 (4.02–159.56)	2.35 (0.97–5.67)	1.15 (0.61–2.17)	0.68 (0.42–1.09)

in these countries are indeed larger than in the other populations.

In our study death rates and RIIs were calculated by age groups based on the age of death, rather than on the age cohort. This means that the death rates of several birth cohorts were grouped together, while we know that in many western European countries inequalities in the rates of smoking changed drastically across the past decades. Unfortunately we could not use age cohorts as longitudinal data were not available for all populations. For the 11 populations for which such data were available we repeated the analyses making use of age cohorts. Age specific inequalities in lung cancer mortality appeared to be very similar to the ones obtained by using the first approach.

Also in previous work [27] a north–south gradient in smoking inequalities was found for women, showing larger educational inequalities in the Northern countries. Such a gradient was not observed for men. Even though differences in the questionnaires, survey methodology, response rates and missing values across European countries may have affected the comparability of survey data on smoking, the fact that our results are in line with previous research is an indication of the validity of the findings.

The comparison of inequalities in lung cancer mortality with inequalities of current smoking should be done with caution, due to the time lag between exposure and established disease. This time lag varies and depends on smoking duration and intensity [28,29], but in overall terms a 20–50-year delay is assumed between the uptake of regular smoking and the occurrence of lung cancer [30]. We tried to take this time lag into account by using information on inequalities in smoking as proxy for information on inequalities in lung cancer mortality 20 years later. It is clear that this assumption has serious limitations. Educational inequalities in trends in smoking behaviour and in smoking cessation rates have indeed been observed in several European countries [13,31] and may result in changing inequalities in smoking and lung cancer mortality by socioeconomic group.

Even though it is unfortunate that lung cancer mortality data from two southern urban areas (Madrid and Turin) had to be compared with smoking data from two national health interviews, the

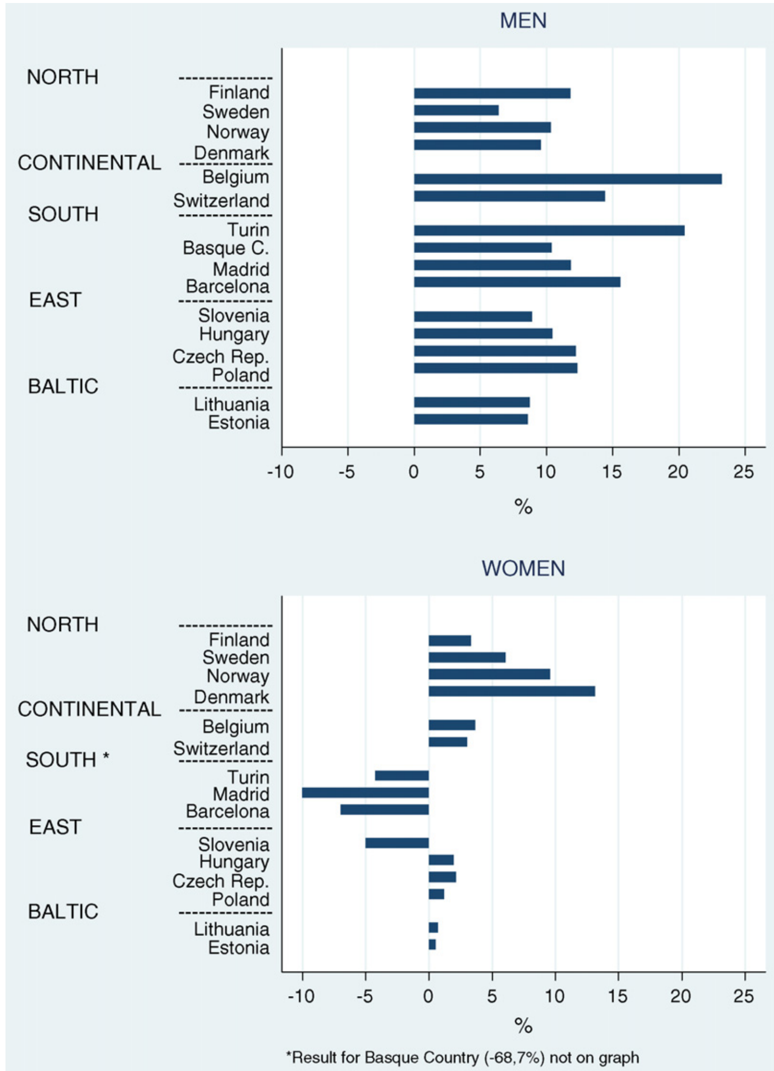

Fig. 1. Contribution of inequalities in lung cancer mortality to inequalities in total mortality in 16 European populations, age group 40–79 years.

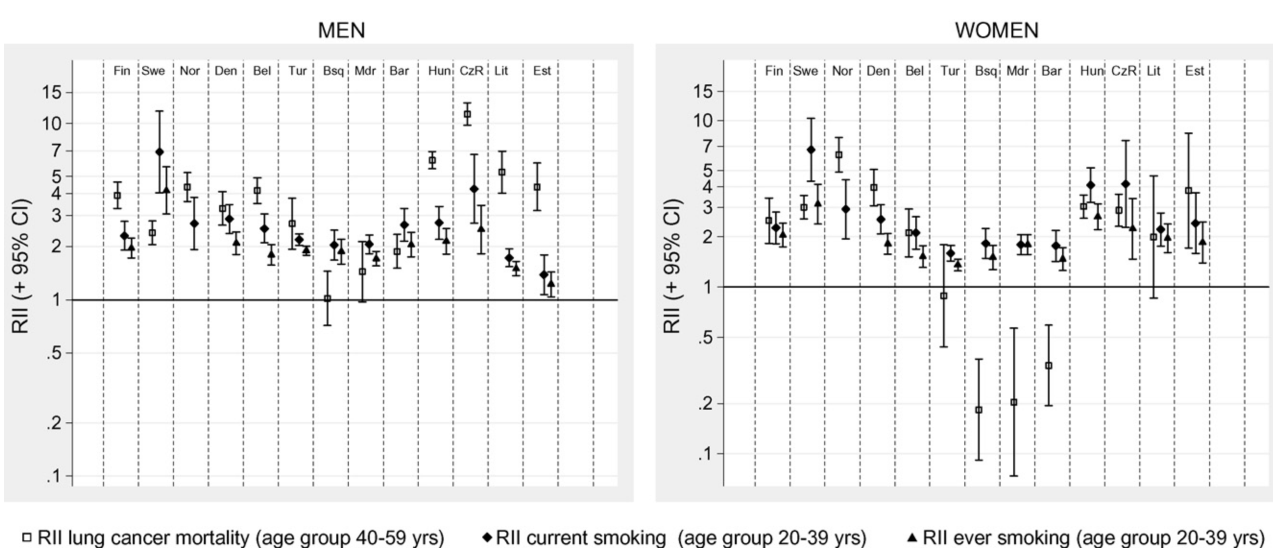

Fig. 2. Relative indices of inequality (and 95% CI) for lung cancer mortality and smoking in 13 European populations.

conclusion based on this comparison was very similar to the one in the other Southern urban area (Barcelona) for which we were able to compare with a corresponding health survey.

The use of mortality data at a European level has unavoidably some limitations. Discrepancies may exist in models of death certificates, nature and amount of information entered, way to establish the diagnosis, degree of consistency of the certification process, autopsy practices, certifiers practices, implementation of the ICD-10 and implementation of automated coding systems [32]. The results of our study would be biased only to the extent that coding practices are associated with educational level within populations. Although there are no specific indications for variations in coding according to the educational level of the deceased, we cannot completely rule out such bias. However, such bias is unlikely to explain the results for broader groups as analysed here.

4.3. Comparison with other studies and interpretation of results

Generally speaking our findings are in line with the Mackenbach et al. [12] paper that explored inequalities in lung cancer mortality by educational level in 10 European populations. This is not surprising. Our study population includes eight populations that were also included in this study, although we have been working with more recent data. The typical Southern European pattern with higher lung cancer mortality rates among the low educated men and the high educated women, which is also reported in other studies [33], is confirmed by our data from the Basque Country, and is also observed in Slovenia, that suggests that the north–south gradient is also prevalent among Eastern European countries.

If we would apply our findings on lung cancer mortality in the Eastern European countries to the concept of the spread of the smoking epidemic, as described in several papers [34,14,13], we would stage lung cancer mortality among men in Eastern European countries (relative high mortality rates, higher mortality in low educated groups) as more advanced than the Southern European populations but not yet having reached the situation of the Northern European countries (relative low mortality rates, higher mortality in low educated group).

It is striking that among females (40–49 years) educational inequalities in the Eastern European countries are very similar to what we find in the Northern European countries, while inequalities in the oldest age group (70–79 years) are quite in line with the observations in Southern European countries. This could confirm the hypothesis that the lung cancer mortality inequalities in Eastern European are shifting from a Southern to a Northern European pattern. This will lead to increasing socioeconomic inequalities among women in the coming years. The findings that in some Eastern European countries lung cancer mortality rates are decreasing in male populations and increasing in women [35,36] support this hypothesis.

Up to now, few other studies have explored socioeconomic differences in lung cancer mortality rates in Central and Eastern European countries. One study in Estonia reported an important increase in lung cancer mortality differences by education between 1989 and 2000, both in men and women [37]. The magnitude of the inequalities that are reported in this study are in line with our findings.

As has also been observed in previous research [17] the contribution of inequalities in lung cancer mortality to inequalities in total mortality is quite heterogeneous across different European countries. In our study it is more than 10% in most male populations. This confirms that among men inequalities in lung cancer mortality remain an important factor to explain inequalities in overall mortality. Among women the relative contribution of inequalities in lung cancer mortality is less important, although quite substantial in two Northern countries (Denmark and Norway).

From Fig. 2 it appears that all over Europe there are still large socioeconomic inequalities in lung cancer mortality, but also in smoking among young adults. There is no doubt that smoking is the main factor that explains the socioeconomic differences that are observed in lung cancer mortality. From this perspective inequalities in smoking could be a good indicator of inequalities in lung cancer mortality in the future. The large inequalities in smoking found in younger age groups do not give much hope towards reduction of inequalities in lung cancer mortality in the future.

Inequalities in lung cancer mortality are usually larger among men than among women. Smoking inequalities, on the contrary, are more or less of the same magnitude in women and in men. It is therefore plausible that the inequalities in lung cancer mortality among men and women may in the future converge towards the present pattern among men. Northern European countries already reached this stage, especially the younger age groups.

Whereas in previous research the hope was expressed that in Southern European countries large inequalities in lung cancer mortality among women could be avoided [12], our results suggest that the reversal from a positive to a negative association between socioeconomic status and lung cancer mortality is ongoing.

It cannot be excluded that other factors than smoking have contributed to the observed inequalities in lung cancer mortality. Some studies have suggested a possible role of other environmental and occupational exposures [38], poor lung health, deprivation and poor socioeconomic conditions throughout life [8], differences in access to treatment [39,40] and differences in survival [41]. Some of these factors are more plausible than others. More specific research is needed to explore further the relation between socioeconomic inequalities in lung cancer mortality and other factors than smoking, especially in Eastern European and Baltic countries.

4.4. Conclusions and recommendations

Our study confirms that regional patterns of socioeconomic inequalities in lung cancer mortality persist and are consistent with the geographical spread of the smoking epidemic. The pattern of inequalities in Eastern and Baltic countries is more or less similar as the one observed in the Northern countries although the absolute rates are higher. During the coming decades, we may expect in Southern European countries a reversal from a positive to a negative association between socioeconomic status and lung cancer mortality. Among men inequalities in lung cancer mortality account for a substantial fraction of inequalities in total mortality. Among women the inequalities are still smaller, but there are some indications of an increasing trend, and especially in some Northern European countries the contribution of lung cancer mortality inequalities to inequalities in total mortality is substantial. Further efforts to tackle socioeconomic inequalities in lung cancer mortality in Europe are necessary in all countries. This can be done by increasing specific tobacco control measures in lower socioeconomic groups, including strict enforcement of laws and agreements, increase of financial and other barriers to smoking, geographic or social targeting of smoking cessation services, and tailoring of communication approaches [15].

Although the efforts should primarily target smoking prevention, there is also need for further research to establish the role of other factors than smoking, such as other environmental and occupational factors, and differences in access to treatment and survival.

Conflict of interest statement

None declared.

Acknowledgements

We wish to thank the European Commission that through the Public Health Program financed the Eurothine project (grant agreement 2003125). We also thank all the study sites that provided data, as well as all partners and international experts who have contributed to this EC project.

References

[1] Ferlay J, Autier P, Boniol M, Heanue M, Colombet M, Boyle P. Estimates of the cancer incidence and mortality in Europe in 2006. Ann Oncol 2007;18(3):581–92.
[2] Bosetti C, Levi F, Lucchini F, Negri E, La Vecchia C. Lung cancer mortality in European women: recent trends and perspectives. Ann Oncol 2005;16(10):1597–604.
[3] Zatonski WA, Manczuk M, Powles J, Negri E. Convergence of male and female lung cancer mortality at younger ages in the European Union and Russia. Eur J Public Health 2007;17(5):450–4.
[4] Bray F, Tyczynski JE, Parkin DM. Going up or coming down? The changing phases of the lung cancer epidemic from 1967 to 1999 in the 15 European Union countries. Eur J Cancer 2004;40:96–125.
[5] Huisman M, Kunst AE, Bopp M, Borgan JK, Borrell C, Costa G, et al. Educational inequalities in cause-specific mortality in middle-aged and older men and women in eight western European populations. Lancet 2005;365(9458):493–500.
[6] Mackenbach JP, Bos V, Andersen O, Cardano M, Costa G, Harding S, et al. Widening socioeconomic inequalities in mortality in six Western European countries. Int J Epidemiol 2003;32(5):830–7.
[7] van Loon AJ, Goldbohm RA, Van Den Brandt PA. Lung cancer: is there an association with socioeconomic status in The Netherlands? J Epidemiol Community Health 1995;49(1):65–9.
[8] Hart CL, Hole DJ, Gillis CR, Smith GD, Watt GC, Hawthorne VM. Social class differences in lung cancer mortality: risk factor explanations using two Scottish cohort studies. Int J Epidemiol 2001;30(2):268–74.
[9] Martikainen P, Lahelma E, Ripatti S, Albanes D, Virtamo J. Educational differences in lung cancer mortality in male smokers. Int J Epidemiol 2001;30(2):264–7.
[10] Mao Y, Hu J, Ugnat AM, Semenciw R, Fincham S. Socioeconomic status and lung cancer risk in Canada. Int J Epidemiol 2001;30(4):809–17.
[11] Chan-Yeung M, Koo LC, Ho JC, Tsang KW, Chau WS, Chiu SW, et al. Risk factors associated with lung cancer in Hong Kong. Lung Cancer 2003;40(2):131–40.
[12] Mackenbach JP, Huisman M, Andersen O, Bopp M, Borgan JK, Borell C, et al. Inequalities in lung cancer mortality by the educational level in 10 European populations. Eur J Cancer 2004;40:126–35.
[13] Giskes K, Kunst AE, Benach J, Borrell C, Costa G, Dahl E, et al. Trends in smoking behaviour between 1985 and 2000 in nine European countries by education. J Epidemiol Community Health 2005;59(5):395–401.
[14] Cavelaars AE, Kunst AE, Geurts JJ, Crialesi R, Grotvedt L, Helmert U, et al. Educational differences in smoking: international comparison. BMJ 2000;320(7242):1102–7.
[15] Kunst A, Giskes K, Mackenbach J, for the EU Network on Interventions to Reduce Socio-economic Inequalities in Health. Socio-economic inequalities in smoking in the European Union. Applying an equity lens to tobacco control policies. Rotterdam: Department of Public Health, Erasmus Medical Center Rotterdam; 2004. pp. 1–92.
[16] Alberg AJ, Brock MV, Samet JM. Epidemiology of lung cancer: looking to the future. J Clin Oncol 2005;23(14):3175–85.
[17] Kunst AE, Groenhof F, Mackenbach JP, Health EW. Occupational class and cause specific mortality in middle aged men in 11 European countries: comparison of population based studies. EU Working Group on Socioeconomic Inequalities in Health. BMJ 1998;316(7145):1636–42.
[18] Mackenbach, JP, Stirbu I, Roskam AJ, Schaap MM, Menvielle G, Leinsalu M, Kunst AE, European Union Working Group on Socioeconomic Inequalities in Health. Socioeconomic inequalities in health in 22 European Countries. N Engl J Med 2008;358(23):2468–2481.
[19] Borrell C, Azlor E, Rodriguez-Sanz M, Puigpinós R, Cano-Serral G, Pasarin MI, et al. Trends in socioeconomic mortality inequalities in a Southern Urban setting at the turn of the century. J Epidemiol Community Health 2008.
[20] Pamuk E. Social class inequality in mortality from 1921 to 1972 in England and Wales. Popul Stud 1985;39:17–31.
[21] Mackenbach JP, Kunst AE. Measuring the magnitude of socio-economic inequalities in health: an overview of available measures illustrated with two examples from Europe. Soc Sci Med 1997;44(6):757–71.
[22] Hayes LJ, Berry G. Sampling variability of the Kunst–Mackenbach relative index of inequality. J Epidemiol Community Health 2002;56(10):762–5.
[23] Ezendam NP, Stirbu I, Leinsalu M, Lundberg O, Kalediene R, Wojtyniak B, et al. Educational inequalities in cancer mortality differ greatly between countries around the Baltic Sea. Eur J Cancer 2007.
[24] Kunst AE, Groenhof F, Borgan JK, Costa G, Desplanques G, Faggiano F, et al. Socio-economic inequalities in mortality. Methodological problems illustrated with three examples from Europe. Rev Epidemiol Sante Publique 1998;46(6):467–79.
[25] Monitoring of trends in socioeconomic inequalities in mortality: experiences in mortality, experiences from a European project. Paper presented to the IUSSP seminar on “Determinants of Diverging Trends in Mortality” Session 6. Increasing socio-economic inequalities in mortality within countries-1. Rostock, Germany: 2002.
[26] Shkolnikov VM, Jasilionis D, Andreev EM, Jdanov DA, Stankuniene V, Ambrozaitiene D. Linked versus unlinked estimates of mortality and length of life by education and marital status: evidence from the first record linkage study in Lithuania. Soc Sci Med 2007;64:1392–406.
[27] Huisman M, Kunst AE, Mackenbach JP. Educational inequalities in smoking among men and women aged 16 years and older in 11 European countries. Tob Control 2005;14(2):106–13.
[28] Shibuya K, Inoue M, Lopez AD. Statistical modeling and projections of lung cancer mortality in 4 industrialized countries. Int J Cancer 2005;117(3): 476–85.
[29] Flanders WD, Lally CA, Zhu BP, Henley SJ, Thun MJ. Lung cancer mortality in relation to age, duration of smoking, and daily cigarette consumption: results from Cancer Prevention Study II. Cancer Res 2003;63(19):6556–62.
[30] Wingo PA, Ries LA, Giovino GA, Miller DS, Rosenberg HM, Shopland DR, et al. Annual report to the nation on the status of cancer, 1973–1996, with a special section on lung cancer and tobacco smoking. J Natl Cancer Inst 1999;91(8):675–90.
[31] Schaap MM, Kunst AE, Leinsalu M, Regidor E, Ekholm O, Dzurova D, Helmert U, Klumbiene J, Santana P, Mackenbach JP. Effect of nation-wide tobacco control policies on smoking cessation in high and low educated groups in 18 European countries. Tob Control 2008, doi:10.1136/tc.2007.024265.
[32] Jougla E, Pavillon G, Rossollin F, De Smedt M, Bonte J. Improvement of the quality and comparability of causes-of-death statistics inside the European Community. EUROSTAT Task Force on “causes of death statistics”. Rev Epidemiol Sante Publique 1998;46(6):447–56.
[33] Borrell C, Regidor E, Arias LC, Navarro P, Puigpinos R, Dominguez V, et al. Inequalities in mortality according to educational level in two large Southern European cities. Int J Epidemiol 1999;28(1):58–63.
[34] Lopez AD, Collishaw NE, Piha T. A descriptive model of the cigarette epidemic in developed countries. Tob Control 1994;3:242–7.
[35] Kubik A, Plesko I, Reissigova J. Prediction of lung cancer mortality in four Central European countries, 1990–2009. Neoplasma 1998;45(2):60–7.
[36] Tyczynski JE, Bray F, Aareleid T, Dalmas M, Kurtinaitis J, Plesko I, et al. Lung cancer mortality patterns in selected Central, Eastern and Southern European countries. Int J Cancer 2004;109(4):598–610.
[37] Leinsalu M, Vagero D, Kunst AE. Estonia 1989–2000: enormous increase in mortality differences by education. Int J Epidemiol 2003;32(6):1081–7.
[38] Fano V, Michelozzi P, Ancona C, Capon A, Forastiere F, Perucci CA. Occupational and environmental exposures and lung cancer in an industrialised area in Italy. Occup Environ Med 2004;61(9):757–63.
[39] Jack RH, Gulliford MC, Ferguson J, Moller H. Explaining inequalities in access to treatment in lung cancer. J Eval Clin Pract 2006;12(5):573–82.
[40] Campbell NC, Elliott AM, Sharp L, Ritchie LD, Cassidy J, Little J. Rural and urban differences in stage at diagnosis of colorectal and lung cancers. Br J Cancer 2001;84(7):910–4.
[41] Woods LM, Rachet B, Coleman MP. Origins of socio-economic inequalities in cancer survival: a review. Ann Oncol 2006;17(1):5–19.