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Educational inequalities in cancer mortality differ greatly between countries around the Baltic Sea

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ABSTRACT

Objective: To compare educational inequalities in cancer mortality between Poland, Lithuania, Estonia, Finland and Sweden.
Methods: Data are either follow-up or unlinked cross-sectional studies. The relative index of inequality (RII) and the slope index of inequality (SII) are calculated to express the magnitude of mortality differences according to educational level for all cancers and for specific cancers.
Results: Large educational inequalities in total cancer mortality were observed, particularly amongst men. Inequalities in upper aero-digestive tract and lung cancer in men and cervix cancer in women were larger in Poland, Lithuania and Estonia, whereas inequalities in lung cancer in women were larger in Finland and Sweden.
Conclusions: Countries of the Baltic Sea region differ strongly with regard to the magnitude and pattern of the educational inequalities in cancer mortality.

1. Introduction

Cancer mortality rates differ strongly amongst socio-economic groups.[1,2] For a large number of cancers, the mortality rates show a socio-economic gradient, with the highest rates in groups with lower education, income or occupation. These inequalities are frequently established in Western European countries. However, only little is known about the level of socio-economic inequalities in cancer mortality in Eastern European countries. Some studies indicate that, for instance, in Estonia and Lithuania inequalities in overall cancer mortality are present and increasing.[3,4]

The situation in Eastern Europe is of special interest because of the substantially higher cancer mortality rates in this area than in Western and Northern Europe.[5] Amongst men, higher mortality is observed for total cancer and for most cancer sites, whilst for women a higher mortality is only apparent in certain cancer sites.[5,6] It is still unclear how the

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variations in cancer mortality rates between countries are related to socio-economic factors. It might well be that the higher burden of cancer mortality in the East would be mainly on account of the lower socio-economic groups.

In the present study, we investigate the educational inequalities in cancer mortality in three Eastern countries, Poland, Lithuania and Estonia, and we compared these with the inequalities in Finland and Sweden. It is of interest to compare these countries due to substantial differences in the overall cancer mortality rates (low levels in Sweden, high levels in Eastern European countries and in-between levels in Finland) within a proximal geographic area (around the Baltic Sea). Such differences may imply that factors modifiable by national policies are important in reducing the level of inequalities.

In this paper, we will first describe the educational inequalities in mortality according to cancer type in each of the five countries. Next, for each country, we will estimate the contribution of different cancer types to the inequalities in total cancer mortality. Finally, we will make direct comparisons between these countries with regard to the absolute levels of cancer mortality by educational level.

2. Data and methods

2.1. Data

For Poland, Lithuania and Estonia, unlinked cross-sectional data of the total national populations were used. Data on the number and causes of death are collected from the death registries, whilst the population census provided the corresponding numbers of person–years. We included deaths amongst people aged 35–79. In Poland, the data were collected from 2001 to 2003, in Lithuania from 2000 to 2002 and in Estonia from 1998 to 2002. For Finland and Sweden, we used longitudinal data of the total national population with a follow-up from 1990 to 2000, with the population census of about 1991 as the baseline. We included people aged 30–74 years at the start of the follow-up, which corresponds to the age-group 35–79 of the cross-sectional studies in terms of age at death. For these five countries, we acquired the number of cancer deaths by cancer site, sex, 5-year age groups and educational level.

Table 1 shows the number of person–years and the death rates for men and women for the national populations. Age-standardised death rates were higher in Poland, Lithuania and Estonia than in Finland and Sweden.

We selected the following cancer sites for inclusion in the analysis (with ICD-10 codes between brackets): buccal cavity, pharynx, larynx and oesophagus combined, further named the upper aero-digestive tract (UADT) (C00-15, C30-32), stomach (C16), colorectal (C18–21), liver (C22.0, C22.1 and C22.9), pancreas (C25), trachea, bronchus and lung combined (C33, C34 and C39), breast (C50), cervix uteri (C53), prostate (C61), kidney and bladder combined (C64–68) and Hodgkin's disease and leukaemia combined (C81, C91–95). In the combined group of all cancers, other neoplasms (C00-D48) are included. The selected cancers are common in Europe and/or they tend to have large socio-economic gradients according to overviews from the western part of Europe.[7]

To measure socio-economic inequalities in cancer mortality, we used the highest acquired education based on the international standard classification of education (ISCED).[8] We distinguished four levels of education: 1, no or primary; 2, lower secondary; 3, upper secondary and post-secondary non-tertiary and 4, tertiary. However, data for Finland did not distinguish between levels 1 and 2. The educational distributions differ between countries, possibly due to the differences in educational systems (Table 2).

2.2. Calculations and statistical analysis

To describe absolute cancer mortality rates according to sex, country and educational level we calculated age-standardised mortality rates. For this, we used the direct method using 5-year age groups with the European Standard Population[9] as the standard.

To measure the magnitude of inequalities in mortality, the relative index of inequality (RII) was used.[10] RII is a regression-based measure that takes into account the distribution of the population by educational groups. It assesses the association between the cancer mortality and the relative position of each educational group across all educational groups. This relative position is measured as a cumulative proportion of each educational group within the educational hierarchy. The resulting RII measure can be interpreted as the risk of dying from cancer at the very lowest end of the educational hierarchy as compared to the very top of the educational hierarchy. These outcome measures can be compared between countries, provided that each educational classification is strictly hierarchical. A large score on the RII implies large inequalities in mortality between high and low educated people. The RII was calculated with Poisson regression and

Table 1 – Person–years and all causes death rate (per 100,000) amongst men and women

	Poland	Lithuania	Estonia	Finland	Sweden
Men					
Person–years (*1000)	25,605	2265	1483	12,396	21,422
Death rate	1985.2	2346.0	2666.2	1683.1	1137.8
Women					
Person–years (*1000)	29,278	2892	1953	13,478	22,116
Death rate	915.9	972.7	1137.3	811.4	651.8

Table 2 – Distribution of the populations in Poland, Lithuania, Estonia, Finland and Sweden by education

	Poland (%)	Lithuania (%)	Estonia (%)	Finland (%)	Sweden (%)
Men					
No or primary	26	16	10		39
Lower secondary	35	15	22	47[a]	26
Upper secondary; non-tertiary	28	53	50	31	14
Tertiary	11	16	17	22	21
Women					
No or primary	35	21	12		40
Lower secondary	18	11	18	50[a]	33
Upper secondary; non-tertiary	36	51	53	29	7
Tertiary	11	17	18	20	21

a No, primary, and lower secondary education; includes missing.

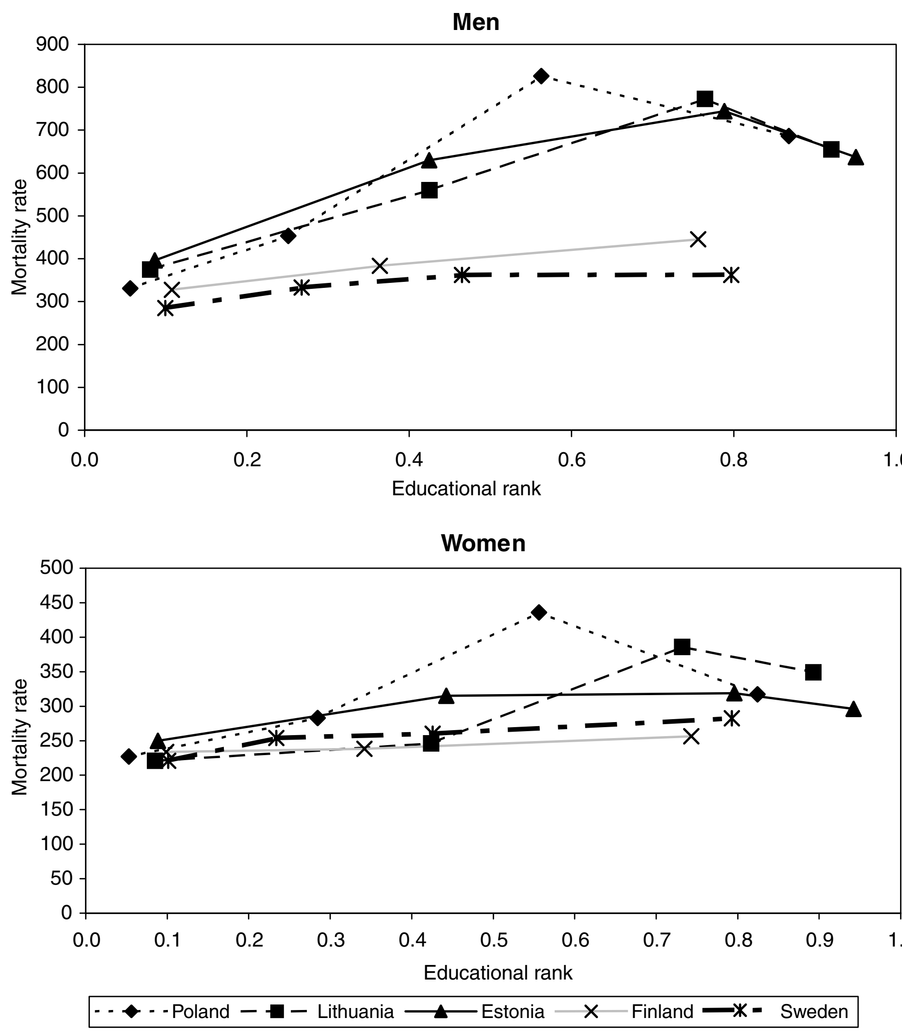

Fig. 1 – Age-adjusted mortality rates (per 100,000 person–years) by educational rank for all cancers combined amongst men and women aged 35–79. The educational rank is a gradient from the highest (rank 0) to the lowest education (rank 1).

adjusted for age by adding the age-categories to the regression model. We used SAS statistical package, version 8.2 for the regression analysis.

In addition to the relative measure RII we computed the SII (slope index of inequality), which is a measure for *absolute* difference between the predicted mortality rate at the lower end of the hierarchy and at the higher end of the hierarchy. The SII was derived from the RII and the overall mortality rate (MR) by the following formula:

$$SII = (2 * MR * (RII - 1))/(RII + 1)$$

The SII will be presented for the four cancers with the largest SII and for all other cancers combined. These five SIIs added up provide the SII for total cancer mortality.

3. Results

3.1. Men

In Fig. 1, age-adjusted rates for the total cancer mortality are plotted against educational level. We observed educational inequalities in total cancer mortality in all countries. However, the magnitude of inequalities, as expressed by the slope of the line, was larger in Poland, Lithuania, Estonia and Finland than in Sweden. The educational gradients were about linear in most cases. However, Poland, Lithuania and Estonia showed a decline in the total cancer mortality for the lowest educational level.

Table 3 presents the relative and absolute levels of inequalities by cancer site for all countries separately. Relative inequalities were the largest in Poland and Finland (RII 2.13 and 1.72, respectively), followed by Lithuania (1.58), Estonia (1.53) and Sweden (1.30). Significant inequalities were observed in cancers of the UADT, lung and stomach cancer in all countries. Sweden had the smallest level of inequalities in all cancers combined, mainly due to small inequalities in lung and UADT cancers. Cancer of the pancreas, colorectum, prostate and Hodgkin's disease and leukaemia showed small or no inequalities in all countries.

The absolute size of educational inequalities in all cancer mortality, as expressed by the SII, was highest in Poland (439 deaths per 100,000 person–years), followed by Lithuania, Estonia and Finland. Inequalities were considerably smaller in Sweden (89 deaths per 100,000 person–years; Fig. 2). The contribution of cancers of the UADT to the inequalities in all cancer mortality was much higher in Poland, Lithuania and Estonia than in Finland and Sweden. Inequalities in lung cancer explained a substantial part of the educational inequalities in all countries.

3.2. Women

Amongst women, educational inequalities in total cancer mortality were observed in most countries, although the inequalities were much smaller than amongst men (Fig. 1). Educational inequalities in total cancer mortality were about equally large in Poland, Lithuania, Sweden and Finland (RIIs 1.20–1.31; Table 4). Estonia did not show educational inequalities or even a tendency of higher mortality rates amongst higher educated. Educational inequalities in lung cancer mortality were particularly large in Finland and Sweden (RII 1.85 and 1.73, respectively). In all countries, cervix cancer showed much higher mortality rates in lower educated women (RIIs between 2.60 and 5.59), whilst breast cancer showed an inverse pattern (RIIs 0.81–0.97).

The absolute magnitude of the educational inequalities in cancer mortality, which were much smaller in women than in men, differed between countries (Fig. 2). Large contributors to the total absolute inequalities in cancer mortality were cervix cancer in Poland, Lithuania and Estonia (15–30 deaths per 100,000 person–years), and lung cancer in Finland and Sweden (14–19 deaths per 100,000 person–years). In addition, the combined category of other cancers shows large inequalities, implying that inequalities in many different cancers contributed to the inequalities in cancer mortality in women.

Table 3 – Age-standardised mortality rates (MR) per 100,000 person–years and relative index of inequality (RII), age 35–79, men

	Poland			Lithuania			Estonia			Finland			Sweden		
	MR	RII	(95% CI)	MR	RII	(95% CI)	MR	RII	(95% CI)	MR	RII	(95% CI)	MR	RII	(95% CI)
All cancers	606.7	**2.13**	(2.09–2.18)	575.2	**1.58**	(1.47–1.70)	604.8	**1.53**	(1.41–1.66)	416.7	**1.72**	(1.64–1.80)	339.5	**1.30**	(1.26–1.34)
Upper aero-digestive tract	49.5	**3.95**	(3.67–4.25)	65.2	**3.85**	(3.11–4.76)	51.0	**4.65**	(3.52–6.16)	14.9	**2.02**	(1.62–2.53)	14.2	**1.92**	(1.67–2.21)
Lung	208.2	**3.21**	(3.09–3.33)	166.1	**2.75**	(2.41–3.15)	194.8	**2.24**	(1.94–2.58)	131.4	**3.48**	(3.18–3.81)	66.5	**1.74**	(1.63–1.86)
Stomach	44.5	**2.23**	(2.06–2.41)	62.5	**1.38**	(1.11–1.71)	68.8	**1.30**	(1.03–1.65)	27.8	**2.36**	(1.97–2.83)	17.8	**1.81**	(1.59–2.06)
Liver	12.0	**1.24**	(1.07–1.43)	9.6	0.96	(0.56–1.64)	14.9	0.93	(0.56–1.56)	12.7	**1.35**	(1.05–1.73)	10.6	**1.60**	(1.36–1.88)
Pancreas	23.1	**1.38**	(1.25–1.53)	29.5	1.35	(0.99–1.83)	30.9	1.10	(0.77–1.55)	25.7	1.16	(0.98–1.37)	21.8	**1.14**	(1.02–1.28)
Colorectum	55.6	**1.19**	(1.11–1.28)	53.5	**0.66**	(0.52–0.83)	55.0	0.91	(0.70–1.19)	34.2	0.94	(0.81– 1.09)	37.2	**1.10**	(1.01–1.20)
Prostate	36.2	**1.34**	(1.23–1.47)	51.3	0.87	(0.68–1.11)	51.2	1.12	(0.84–1.50)	49.0	1.01	(0.88–1.16)	55.0	1.05	(0.98–1.13)
Kidney and bladder	42.9	**1.57**	(1.45–1.70)	42.6	1.00	(0.77–1.29)	41.5	0.93	(0.68–1.26)	26.2	**1.50**	(1.26–1.79)	24.6	**1.29**	(1.16–1.43)
Hodgkin's disease/leukaemia	16.0	**1.29**	(1.14–1.46)	17.9	0.99	(0.67–1.46)	14.6	0.74	(0.44–1.25)	12.6	1.18	(0.93–1.51)	11.3	1.14	(0.98–1.33)
Other cancers	117.5	**1.64**	(1.57–1.72)	75.7	1.09	(0.90–1.32)	80.6	1.06	(0.85–1.32)	78.9	**1.25**	(1.14–1.38)	78.2	**1.12**	(1.06–1.19)

Significant RIIs are bold. CI, confidence interval.

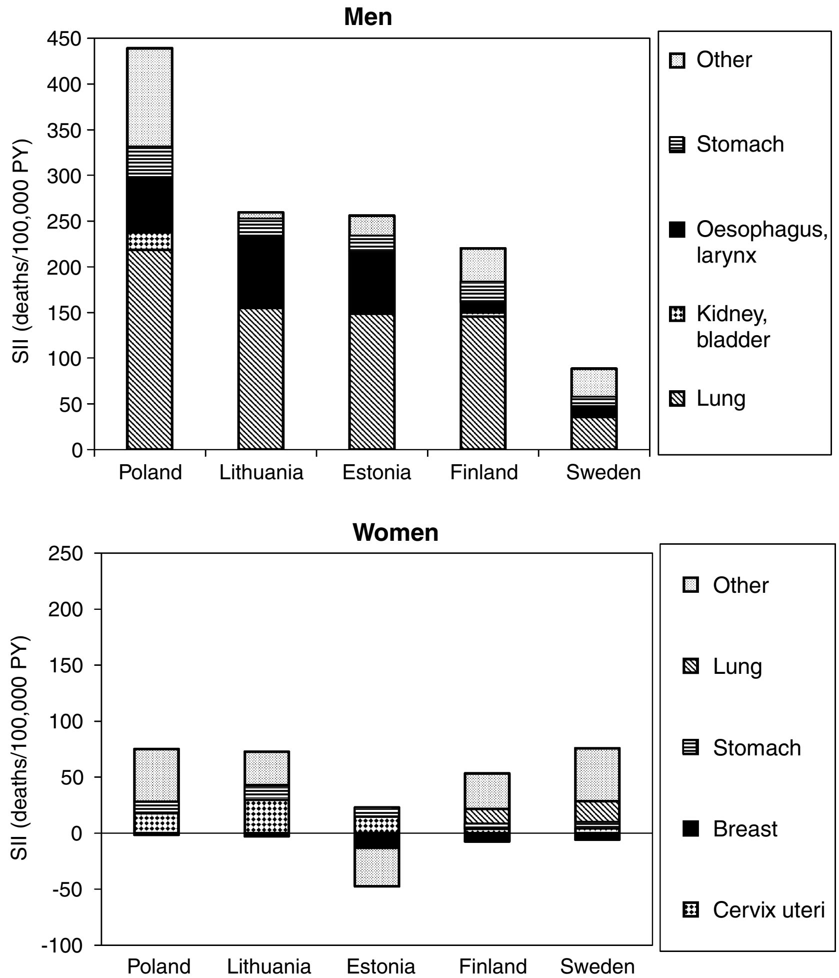

Fig. 2 – Absolute educational differences in cancer mortality rates for men and women aged 35–79, expressed as the slope index of inequality (SII).

3.3. *Variations in mortality rate between countries by education*

The mortality rates by the educational level are presented in Fig. 3 for specific cancer sites that showed a large variation in national mortality rate between the five countries. For Poland, Lithuania and Estonia, national mortality rates were especially high for cancers of the UADT and the lung in men and the cervix and stomach in women. This mortality excess was observed particularly when comparing people with the lowest education. In the higher educational groups, on the other hand, the variations in mortality rates between countries were relatively small.

4. Discussion

4.1. *Principal findings*

Amongst men, relative and absolute educational inequalities in total cancer mortality were large in Poland, Lithuania, Estonia and Finland, whereas these inequalities were more modest in Sweden. Lung cancer was the largest contributor to the educational inequalities in all countries. UADT cancers were important contributors to the educational inequalities in Poland, Lithuania and Estonia.

Amongst women, the differences in inequalities were smaller than in men. Cervix cancer was the largest single contributor to educational inequalities in Poland, Lithuania and Estonia, whereas lung cancer made an important contribution to the educational inequalities in Finland and Sweden.

The higher mortality rates for UADT and lung cancers amongst men and cervix and stomach cancers amongst women in Poland, Lithuania and Estonia were particularly observed amongst lowest educated, whereas the differences between countries were much smaller amongst higher educated.

4.2. *Study limitations*

We conducted the first study on the educational inequalities in overall and site-specific cancer mortality in a multiple country study including countries from both the east and west of Europe. We optimised the comparability of the data of the different countries. However, this comparability might be compromised in four ways.

First, the data for Finland and Sweden were from longitudinal studies, whereas the data for Poland, Lithuania and

Table 4 – Age-standardised mortality rates (MR) per 100,000 person–years and relative index of inequality (RII), age 35–79, women

	Poland			Lithuania			Estonia			Finland			Sweden		
	MR	RII	(95% CI)	MR	RII	(95% CI)	MR	RII	(95% CI)	MR	RII	(95% CI)	MR	RII	(95% CI)
All cancers	303.5	**1.28**	(1.24–1.31)	267.9	**1.30**	(1.19–1.42)	287.1	0.92	(0.84–1.01)	247.5	**1.20**	(1.15–1.26)	260.9	**1.31**	1.25–1.35)
Upper aero-digestive tract	6.7	**3.95**	(3.67–4.25)	5.6	**2.40**	(1.31–4.41)	4.6	1.70	(0.81–3.55)	5.6	**1.90**	(1.33–2.71)	4.5	**1.52**	(1.20–1.93)
Lung	39.1	1.01	(0.94–1.08)	14.4	1.08	(0.75–1.55)	23.6	0.93	(0.67–1.27)	22.8	**1.85**	(1.56–2.21)	35.4	**1.73**	(1.59–1.89)
Stomach	15.4	**1.96**	(1.73–2.22)	24.6	**1.63**	(1.23–2.18)	29.2	1.31	(0.98–1.75)	13.3	**1.39**	(1.12–1.73)	9.0	**1.87**	(1.58–2.22)
Liver	7.4	**1.26**	(1.06–1.51)	3.5	1.79	(0.83–3.86)	6.3	0.85	(0.46–1.56)	7.0	**1.81**	(1.31–2.50)	6.2	**1.85**	(1.51–2.28)
Pancreas	14.6	1.00	(0.98–1.13)	13.3	1.24	(0.85–1.81)	15.1	1.06	(0.71–1.58)	18.8	**1.45**	(1.20–1.75)	18.5	**1.19**	(1.06–1.33)
Colorectum	31.3	**1.12**	(1.03–1.21)	29.9	1.16	(0.90–1.49)	34.4	0.83	(0.64–1.08)	23.4	1.03	(0.88–1.21)	27.4	**1.29**	(1.17–1.41)
Breast	40.8	0.97	(0.90–1.04)	48.2	0.95	(0.77–1.16)	52.6	0.81	(0.64–1.01)	45.4	**0.85**	(0.76–0.94)	44.0	**0.88**	(0.82–0.95)
Cervix uteri	16.2	**3.47**	(3.09–3.90)	21.5	**5.59**	(3.94–7.93)	14.1	**3.28**	(2.07–5.22)	3.5	**3.47**	(2.20–5.46)	4.9	**2.60**	(2.05–3.29)
Kidney and bladder	10.9	1.10	(0.96–1.27)	12.1	1.00	(0.68–1.48)	11.4	0.75	(0.48–1.18)	9.9	1.10	(0.85–1.41)	11.2	**1.70**	(1.46–1.98)
Hodgkin's disease/leukaemia	9.2	1.17	(1.00–1.36)	10.7	1.30	(0.85–1.99)	10.4	0.96	(0.56–1.58)	8.3	1.10	(0.84–1.44)	7.6	1.02	(0.85–1.22)
Other cancers	111.8	**1.33**	(1.27–1.39)	84.3	1.15	(0.99–1.34)	85.7	0.74	(0.62–0.88)	89.1	**1.21**	(1.12–1.32)	91.8	**1.31**	(1.24–1.38)

Significant RIIs are bold. CI, confidence interval.

Estonia were from unlinked cross-sectional studies. A problem that is inherent to unlinked cross-sectional studies is the numerator–denominator bias. This bias relates to the fact that deaths (the numerator) are classified according to educational information on the death certificates, whereas the population (the denominator) is classified using the educational information from the population census. The educational levels could be reported differently in these two sources.[11,12] An important mechanism might be 'promoting the death', where surviving relatives describe the educational level of deceased relatives higher than is true.[12] Several studies have shown that this type of bias can compromise validity of mortality inequality estimates in unpredictable ways.[11–13] The relatively low mortality levels we observed for the lowest educated group in Poland, Lithuania and Estonia might perhaps be affected by this type of bias. To have an indication of the extent of this bias, we applied a sensitivity analysis to the data for Poland, Lithuania and Estonia. Appendix A explains the rationale, calculation method and conclusions of this sensitivity analysis. We observed that correction for the numerator/denominator bias somewhat reduced the level of inequalities, but did not change the direction of inequalities, suggesting that the effects of this bias would not challenge the findings of this paper.

Second, in Finland, three educational groups could be distinguished, whereas four educational groups were used in the other countries. We evaluated possible effects by applying three instead of four educational groups for the calculation of RIIs. These additional calculations showed that in all countries RIIs were mostly about equal and sometimes somewhat higher when three instead of four educational categories are distinguished. This implies that, in the current paper, the magnitude of inequalities in Finland was probably hardly affected by the lesser number of educational levels that were distinguished in Finland compared to the other countries.

Third, the distribution by education varied between countries. Partly these differences may be due to real variation in educational attainment in different countries. However, these variations might also be the result of fitting the country's educational system into the international classification of education, consequently compromising the comparability of educational inequalities between countries. We used the RII as a measure to handle this problem, because the RII takes the variation in the educational distribution of the population into account. We also assessed the sensitivity of the results to alternative educational classification by comparing the results of analysis with four and three educational categories. Three educational categories provide a more similar distribution between countries. The results were quite robust to this alternative classification, indicating that it is unlikely that misclassification of education affected our conclusions.

Fourth, causes of death could be coded differently between countries due to variations in national diagnosing practices. For relative measures of inequalities, this problem could only bias our estimates when diagnosing practices differ between the educational levels of the deceased. There is no evidence to support this possibility. For absolute measures of inequalities, this problem might affect the international comparability of our estimates to the extent that international differences in diagnostic practices affect absolute national

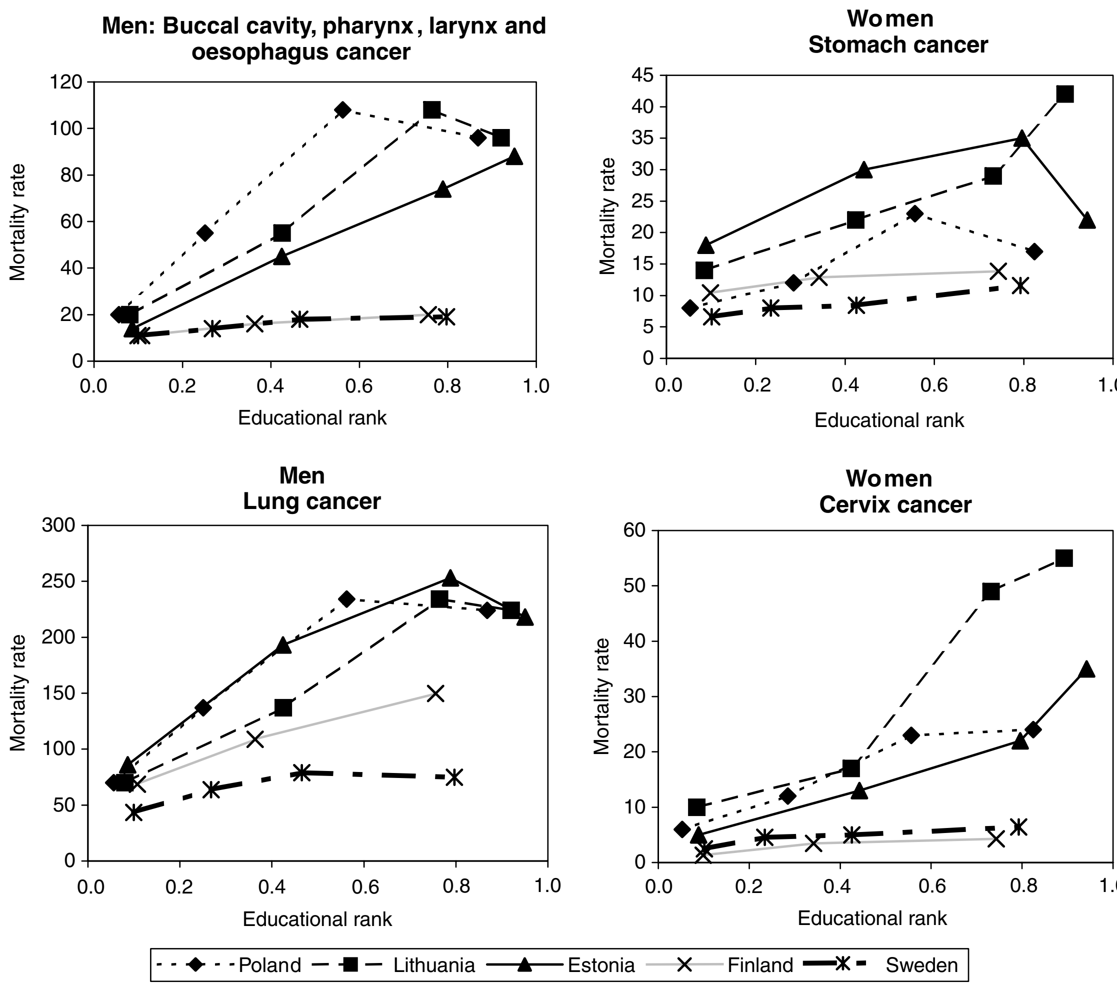

Fig. 3 – Age-adjusted mortality rates (per 100,000 person years) by rank amongst men or women aged 35–79. The educational rank is a gradient from the highest (rank 0) to the lowest education (rank 1).

levels. This potential problem might affect specific cancer sites, but is unlikely to greatly affect estimates for total cancer mortality.

4.3. *Comparison with existing literature*

The observed international patterns in mortality rates for site-specific cancers are comparable with patterns earlier documented.[5,14] Few studies are published about socio-economic inequalities in cancer mortality rates in Poland and the Baltic states. Estimates of the magnitude of inequalities in cancer mortality in Lithuania[4] and Estonia[3] are comparable to our estimates, thus supporting our results.

4.4. *Explanation and interpretation of results*

The larger inequalities that we have observed for cancers of the UADT amongst men in Poland, Lithuania and Estonia might be related to the larger intake of alcohol in these countries in general and in the lower socio-economic groups in particular. This is consistent with previous literature,[15,16] that suggests that the alcohol consumption levels are the highest in Poland, Lithuania and Estonia, intermediate in Finland, and are the lowest in Sweden. Moreover, those of higher social status may be better protected against health risks associated with drinking, which contributes to a steep gradient in mortality by cancers of the UADT.[16]

Determinants of liver cancer are alcohol consumption and hepatitis B and C. The relative importance of these determinants seems to differ between geographical regions.[17–19] Variations in the magnitude of inequalities in liver cancer mortality between regions are not directly related to the regional distribution of these determinants. This might explain that, although inequalities in alcohol related cancer mortality of the UADT are large in all countries (and you would expect inequalities in liver cancer mortality also to be large in all countries), inequalities in liver cancer mortality are not present in Poland, Lithuania and Estonia.

Lung cancer is strongly associated with tobacco smoking[17] and smoking is more prevalent amongst lower socio-economic groups in all countries included in our study.[20–22] Amongst men, the relative inequalities in lung cancer mortality were large in all countries. In Sweden, the absolute inequalities were smallest, possibly due to lower smoking prevalence in Sweden.[23] Amongst women, we found that the relative inequalities in lung cancer mortality were large in Sweden and Finland, but were small in Poland, Lithuania and Estonia, being in accordance with the magnitudes of inequalities in smoking prevalence in these countries.[22,24] However, since smoking can only account for a part of the higher lung cancer mortality in lower socio-economic groups,[25,26] other risk factors must add to the inequalities in lung cancer mortality.

Inequalities in cervix cancer mortality might be related to the differences in the incidence of cervix cancer (which is in turn related to sexual behaviour), availability and use of screening programmes and access to and utilisation of health care facilities. Systematic national cervix screening programmes have been shown to decrease national levels of cervix cancer mortality.[27] The large educational inequalities in cervix cancer mortality in Poland, Lithuania and Estonia might be caused by the poor or late development of national screening programmes. Opportunistic screening might be more accessible for and used by the higher educated and, moreover, inequalities in the use of opportunistic screening might be larger than the inequalities in the use of organised screening programmes. In addition, large inequalities were shown for the utilisation of health care services, especially specialist services, in Estonia.[28,29] Similarly large inequalities might exist in Lithuania and Poland.

4.5. *Implications*

Countries differ with respect to the magnitude of educational inequalities in cancer mortality, particularly for cancer of the UADT and lung in men, and lung and cervix cancer in women. Policies for the prevention and treatment of cancer should pay particular attention to lower socio-economic groups, especially in Poland, Lithuania and Estonia. A particular area of concern amongst men in these countries is the prevention of excessive alcohol consumption and their health effects. For women, it is essential to decrease high rates of cervix cancer mortality through the implementation of a nationwide cervix screening programme, HPV vaccination for children, and a greater equality in access and use of healthcare facilities.

Conflict of interest statement

None declared.

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Table 5 – Rate ratios for primary, lower secondary and upper secondary non-tertiary versus tertiary education as reference category, age 35–79

	Men			Women		
	Poland	Lithuania	Estonia	Poland	Lithuania	Estonia
Colorectal						
Primary*	**1.36**	0.91	0.92	**1.23**	1.19	0.95
Lower secondary*	**1.97**	**1.49**	**1. 30**	**1.75**	**1.60**	**1.03**
Upper secondary*	**1.29**	**1.50**	1.21	**1.17**	1.12	**1.20**
Tertiary	1.00	1.00	1.00	1.00	1.00	1.00
Pancreas						
Primary*	**1.33**	**1.39**	0.90	1.10	1.35	1.06
Lower secondary*	**1.72**	**1.70**	**1.87**	**1.67**	1.20	1.51
Upper secondary*	**1.12**	**1.36**	**1.43**	1.09	1.24	1.30
Tertiary	1.00	1.00	1.00	1.00	1.00	1.00
Prostate						
Primary*	**1.34**	1.05	1.10			
Lower secondary*	**1.74**	1.24	**1.41**			
Upper secondary*	1.08	1.24	1.15			
Tertiary	1.00	1.00	1.00			

Significant rate ratios in bold.

Table 6 – Correction factors for the numerator–denominator bias

	Poland men	Poland women	Lithuania	Estonia
No or primary	1.00	0.99	0.95	0.97
Lower secondary	1.38	1.47	1.31	1.17
Upper and post secondary	0.88	0.93	1.04	1.04
Tertiary	0.73	0.83	0.93	1.01

Table 7 – Relative index of inequality (RII) with and without the application of the correction factor (CF) on the data

	Poland				Lithuania				Estonia			
	Without CF		With CF		Without CF		With CF		Without CF		With CF	
	RII	(95% CI)	RII	(95% CI)	RII	(95% CI)	RII	(95% CI)	RII	(95% CI)	RII	(95% CI)
Men												
All cancers	**2.14**	(2.09–2.18)	**1.71**	(1.68–1.75)	**1.58**	1.48–1.70)	**1.62**	(1.51– 1.75)	**1.53**	(1.41–1.66)	**1.51**	(1.40–1.64)
Buccal cavity/pharynx/oesophagus	**3.30**	(3.01–3.61)	**2.71**	(2.46–2.99)	**3.78**	(2.96–4.84)	**3.64**	(2.83–4.68)	**5.33**	(3.79–7.50)	**5.27**	(3.72–7.46)
Larynx	**5.42**	(4.79–6.14)	**4.85**	(4.25–5.54)	**4.04**	(2.66–6.12)	**4.14**	(2.70– 6.35)	**3.48**	(2.13–5.70)	**3.51**	(2.12–5.80)
Trachea/bronchus/lung	**3.21**	(3.09–3.33)	**2.73**	(2.62–2.83)	**2.75**	(2.41–3.15)	**2.92**	(2.55–3.35)	**2.24**	(1.94–2.58)	**2.25**	(1.95–2.60)
Stomach	**2.23**	(2.06–2.41)	**1.80**	(1.66–1.96)	**1.38**	(1.11–1.71)	**1.42**	(1.14– 1.77)	**1.30**	(1.03–1.64)	1.27	(1.00–1.61)
Liver	**1.24**	(1.07–1.43)	0.94	(0.81–1.10)	0.96	(0.56–1.64)	0.96	(0.55–1.67)	0.93	(0.56–1.56)	0.91	(0.54–1.53)
Pancreas	**1.38**	(1.25–1.53)	1.04	(0.93–1.16)	1.35	(0.99–1.83)	1.36	(0.99–1.86)	1.10	(0.77–1.55)	1.06	(0.74–1.50)
Colorectum	**1.19**	(1.11–1.28)	**0.91**	(0.85–0.98)	**0.66**	(0.52–0.83)	**0.67**	(0.53–0.84)	0.91	(0.70–1.19)	0.89	(0.68–1.18)
Prostate	**1.34**	(1.23–1.47)	1.08	(0.99–1.19)	0.87	(0.68–1.11)	0.95	(0.74–1.22)	1.12	(0.84–1.49)	1.15	(0.86–1.55)
Kidney and bladder	**1.57**	(1.45–1.70)	**1.23**	(1.14–1.34)	1.00	(0.77–1.29)	1.02	(0.78–1.32)	0.93	(0.68–1.26)	0.91	(0.67–1.24)
Hodgkin's disease/leukaemia	**1.29**	(1.14–1.46)	0.96	(0.84–1.09)	0.99	(0.67–1.46)	1.00	(0.67–1.49)	0.74	(0.44–1.25)	0.72	(0.42–1.23)
Other	**1.64**	(1.57–1.72)	**1.26**	(1.20–1.32)	1.09	(0.90–1.32)	1.07	(0.88–1.30)	1.06	(0.85–1.31)	1.02	(0.82–1.27)
Women												
All cancers	**1.28**	(1.24–1.31)	**1.10**	(1.07–1.13)	**1.30**	(1.19–1.42)	**1.36**	(1.25– 1.48)	0.92	(0.84–1.01)	0.91	(0.83–1.00)
Buccal cavity/pharynx/oesophagus	**1.99**	(1.61–2.47)	**1.75**	(1.40–2.18)	1.85	(0.94–3.66)	1.93	(0.97–3.86)	1.54	(0.68–3.52)	1.54	(0.67–3.55)
Trachea/bronchus/lung	1.01	(0.94–1.08)	**0.85**	(0.79–0.92)	1.08	(0.75–1.55)	1.16	(0.80–1.69)	0.93	(0.67–1.27)	0.93	(0.67–1.29)
Stomach	**1.96**	(1.73–2.22)	**1.77**	(1.56–2.01)	**1.63**	(1.22–2.18)	**1.79**	(1.33–2.39)	1.31	(0.98–1.75)	1.33	(0.99–1.78)
Liver	**1.26**	(1.06–1.51)	1.14	(0.96–1.37)	1.79	(0.83–3.86)	1.94	(0.89–4.24)	0.85	(0.46–1.58)	0.85	(0.45–1.59)
Pancreas	1.00	(0.99–1.13)	0.89	(0.79–1.01)	1.24	(0.85–1.81)	1.37	(0.94–2.02)	1.06	(0.71–1.58)	1.07	(0.71–1.60)
Colorectum	**1.12**	(1.03–1.21)	1.00	(0.92–1.09)	1.16	(0.90–1.49)	1.26	(0.98–1.63)	0.83	(0.64–1.08)	0.83	(0.64–1.09)
Breast	0.97	(0.90–1.04)	**0.78**	(0.73–0.84)	0.95	(0.77–1.16)	0.92	(0.75–1.13)	0.81	(0.64–1.01)	0.77	(0.61–1.04)
Cervix	**3.40**	(3.09–3.90)	**2.86**	(2.54–3.23)	**5.59**	(3.94–7.93)	**5.40**	(3.80–7.67)	**3.28**	(2.07–5.22)	**3.18**	(2.00–5.07)
Kidney and bladder	1.10	(0.96–1.27)	0.99	(0.86–1.15)	1.00	(0.68–1.47)	1.10	(0.74–1.63)	0.75	(0.48–1.18)	0.76	(0.48–1.20)
Hodgkin's disease/leukaemia	1.17	(1.00–1.36)	1.00	(0.86–1.18)	1.30	(0.85–1.99)	1.38	(0.89–2.13)	0.96	(0.59–1.56)	0.96	(0.59–1.58)
Other	**1.33**	(1.27–1.39)	**1.16**	(1.11–1.22)	1.15	(0.99–1.34)	**1.20**	(1.03–1.40)	**0.74**	(0.62–0.87)	**0.72**	(0.61–0.86)

paper was drafted with the Netherlands Institute of Health Sciences.

Appendix A. Applying a correction factor for the numerator–denominator bias in unlinked cross-sectional data

A.1. Rationale

To evaluate if our unlinked cross-sectional data from Poland, Lithuania and Estonia suffered from numerator–denominator bias we examined the educational patterns of three cancers that show no or no clear gradient, namely pancreatic, prostate and colorectal cancer. We compared this with the data from Slovenia and Western Europe.[30] Data from Slovenia are of particular interest as these are the only longitudinal data available from an Eastern European (although much more southern) country.

Table 5 demonstrates that particularly Poland, but also Lithuania and Estonia, showed a strong and recurrent divergent pattern compared to Slovenia and other West European countries,[30] where rate ratios around 1 were observed in Slovenia and small inequalities in mortality were observed in Western European countries. On the contrary, Poland, Lithuania and Estonia revealed very high rate ratios in these cancers. In these countries, we identified a recurrent higher rate ratio in the lower secondary education versus the tertiary education, and also as compared to the two nearby educational levels. This pattern is not seen in Slovenia and the Western European countries.

It is likely that this divergent pattern is due to the numerator–denominator bias. For example, this pattern may be due to the phenomenon of 'promoting the dead', which would result in a transfer of deceased patients from the lowest to the next lowest educational levels. Given the likelihood that inequality estimates are seriously affected, we adjusted the cross-sectional data for this numerator–denominator bias.

A.2. Calculation

First, we calculated the rate ratios for the educational groups against the total population for the three cancers combined for Poland, Lithuania and Estonia. In Poland, this was done for men and women separately, because the educational distribution was quite different amongst men and women. In Estonia and Lithuania, this was done for men and women combined because the educational distribution of men and women was quite similar in these countries. In addition, because of the smaller numbers (deaths) in Lithuania and Estonia, it would not be very reliable to make separate estimates for men and women.

Second, we used these rate ratios as a correction factor (Table 6). We thereby assumed these cancers to show no educational gradient, and therefore the rate ratios would have been close to 1 if no data problems occurred. The magnitude of the correction factors thus indicates the extent to which the observed rates should be adjusted to get an approximate estimate of the 'true' rate ratio. For example, an observed rate ratio of 1.50 was taken as evidence that the true rate was overestimated by about 50%, and that therefore this rate should be adjusted by dividing it by a factor of 1.50.

In our calculations, the correction factor was used to redistribute the person–years at risk over the educational levels. We multiplied the number of person–years of each educational level with the correction factor observed of that level. Thus, the number of deaths at each level remained the same, whereas the person–years were adjusted in such a way that this new 'denominator' corresponds more closely to the unchanged 'numerator'.

For all calculations presented in this paper, we made use of the newly calculated person–years per educational level.

A.3. Effect of applying correction factor on RII

The effect of applying the correction factor on our estimates is diverse. The mortality rates according to educational level changed substantially, with the magnitude of change corresponding to the (inverse of the) correction factors that are presented in Table 6. However, the effects on the RII are more modest (Table 7). In Poland, the RIIs are lower after application of the correction factor, because the mortality levels of lower secondary educational level were substantially decreased (with the factor 1/1.38), whilst those of higher educational levels were increased (with the factors 1/0.88 and 1/0.73). Without this correction, the RII for all cancer together would have been estimated to be 2.14 instead of 1.71.

In Lithuania and Estonia, on the other hand, the effects are smaller. RIIs retain approximately the same values, because the correction factors are smaller and not consistently related to high or low educational levels.

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