Smoking and Inequalities: Quantifying Policies and Interventions

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CHAPTER 1

General Introduction

INTRODUCTION TO THE TOPIC

Burden of disease due to smoking

Smoking has been identified as a risk factor for many decades [1]. The strongest and most comprehensive evidence we have on the association between any risk factor and mortality comes from studies of smoking [2,3]. Smoking is causally related to morbidity and premature mortality from many diseases.

The Global Burden of Disease Project (GBD) [4] has estimated that, 4.83 million deaths occurred due to smoking in the year 2000. Surprisingly, these estimates were nearly evenly divided between developing and industrialized countries. Approximately 80% of the deaths attributable to smoking were observed among men, while 20% were observed among women. By 2010 the overall number of deaths had reached 5.70 million with 75% of deaths among men and 25% among women. It was as high as 6.30 million, including deaths from second-hand smoke. This makes smoking the second leading risk factor for the global disease burden (behind high blood pressure), moving up from third place in 1990. Including second-hand smoke this accounts for 8.4% of the worldwide disease burden among men and 3.7% among women [5]. The burden of disease due to smoking does not only differ by sex but also by socioeconomic status (SES) since smoking is a socially patterned behavior [6].

Smoking is associated with an elevated risk of a number of diseases. These include various cancers (trachea, bronchus and lung, upper aero-digestive, stomach, kidney and other urinary organs, liver, pancreas, cervix uteri, bladder, colon and rectum, leukemia), respiratory diseases (including chronic obstructive pulmonary disease (COPD)), cardiovascular diseases (including ischemic heart disease (IHD) and stroke) diabetes mellitus, and several other diseases in adults over 30 years of age [5,7]. Additionally, second-hand smoke, also known as environmental tobacco smoke (ETS) or as passive smoking, is related to a heightened risk of IHD, lower respiratory infections, asthma and lung cancer [8]. The relative risks (RRs) pertaining to the different diseases related to smoking differ between men and women [9], while the evidence on regional and national variation is scarce.

In Europe, smoking is the largest avoidable health risk with an estimated annual 695,000 premature deaths from tobacco-related causes [10], ranked number one in Western Europe and number three in countries of Central and Eastern Europe in terms of attributable burden of disease [5]. The WHO European Region has one of the highest proportions of deaths due to tobacco use, when compared to other regions in the world. In 2004, 25% of deaths (467/100,000) in Europe were attributable to tobacco among men, and 7% (117/100,000) among women [11]. Even though the numbers of smokers have decreased since the implementation of the WHO Framework Convention on Tobacco Control (FCTC) [12] smoking-

related mortality remains high as there is a considerable lag between smoking and incidence of diseases like lung cancer and COPD and between disease incidence and mortality. These can add up to an average lag time of as long as 20 years, being longer for COPD than for lung cancer [13-15].

Data on the prevalence of smoking

Precise and comparable estimates of the disease burden of smoking require standardized and reliable measurement methods of the prevalence of smoking in a population. The prevalence of smoking can be determined in different ways. The most commonly used approach is to collect self-reported information, e.g. in national health interview surveys. Here, individuals answer questions about their smoking habits, indicating whether they are current, former or never smokers, or if they have ever smoked. Sometimes respondents are also asked how often or how much they smoke, when they started or quit smoking, and what tobacco product they use(d). The prevalence of current smokers can also be assessed biochemically and compared to self-reported information to assess the reliability of the latter [16]. In this approach the level of cotinine is measured from saliva, urine or serum, providing an objective measure of active smoking. Studies show that in most countries the level of misreporting of smoking status in population surveys is negligible, though it might be as high as 3 or 4% in some cases [16-19], and that differences between self-reported and objectively measured smoking prevalence can also vary according to the medium of measurement, i.e. saliva, urine or serum [20]. Furthermore, tobacco sales statistics can be used to estimate the total national consumption of tobacco, i.e. the number of cigarettes per adult per year [21]. However, a smoking prevalence can only be calculated from such information if assumptions about the numbers of cigarettes smoked per adult are made. Also, these consumption estimates may underestimate the true prevalence as in some countries there can be a considerable black market for tobacco products which is not included in the official sales statistics.

For international studies it is important that average prevalence rates are comparable between countries. While individual European countries collect data on national smoking prevalence, this information might not be internationally comparable when different questions are used to ask individuals about smoking habits, when sampling methods differ, or when data is not collected at the same points in time [22]. Hence, international surveys covering many European countries, and applying harmonized methods of data collection would be the preferred choice for international studies.

Figures 1 and 2 below illustrate smoking prevalence rates around the world, distinguishing between men and women. The information is age-standardized, so that levels are comparable between countries. It can be seen that Europe is a region with very diverse smoking prevalence rates. Among men they are highest in Greece and Albania with around 60%, followed by the Russian Federation with 53%. The prevalence is lowest in the Nordic countries

with around 20%. Among women smoking prevalence is highest in Austria and Greece with around 40% and negligible in some former Soviet Republics.

The stages of the smoking epidemic and socioeconomic inequalities in smoking

The initial rise in cigarette consumption in Western countries took place during World War II when cigarettes were handed out as part of rations and advertising made consumers believe in their ability to calm and relax. The growth of mass consumer marketing made cigarettes the most widely advertised consumer product. By the mid-1950s the dangers of smoking were becoming public through epidemiological studies, being followed by the stepwise implementation of tobacco control policies [23].

Many studies have described patterns of smoking prevalence and its relationship to the different stages of the smoking epidemic, i.e. analyzing smoking prevalence by country, sex and an indicator of socioeconomic status, most commonly educational level. The most comprehensive literature on the topic stems from studies covering European countries [24-28]. As the smoking epidemic moves forward, prevalence first rises and then declines. There are four distinct stages of the smoking epidemic which can generally be described as follows: in the first stage smoking is uncommon and mainly found among those with higher SES. In the second stage smoking becomes increasingly common and smoking rates peak among men. Their levels can either be similar for different socioeconomic groups or still higher among those with higher SES. For women the pattern is usually delayed by 10 to 20 years and smoking is first adopted by those from higher socioeconomic groups. In the third stage prevalence rates among men begin to decrease, especially among those with higher SES, while women reach their peak rate. By the end of this stage the smoking prevalence among women also starts to decrease. In the final stage smoking levels keep declining slowly for both men and women, with smoking progressively becoming a habit of those belonging to lower socioeconomic groups. The current variation of sex-specific smoking prevalence rates between the different European countries shows their distinct positions within the smoking epidemic. Differences in the prevalence of smoking between educational groups appear to be particularly large in Northern Europe, and smaller in Southern Europe. Among Southern European women, the higher educated even appear to still smoke more than the lower educated [23,24,26,28-31]. What should be kept in mind is that the gradual and differential decline of smoking between men and women and between different socioeconomic groups on the country level may not only result from policies but also from health behaviors diffusing from high to low socioeconomic groups [32].

While now less individuals smoke in industrial countries with the smoking epidemic progressing, the burden of deaths attributable to smoking is still increasing. This is the case especially among women as they are following the patterns of the epidemic seen among men, but

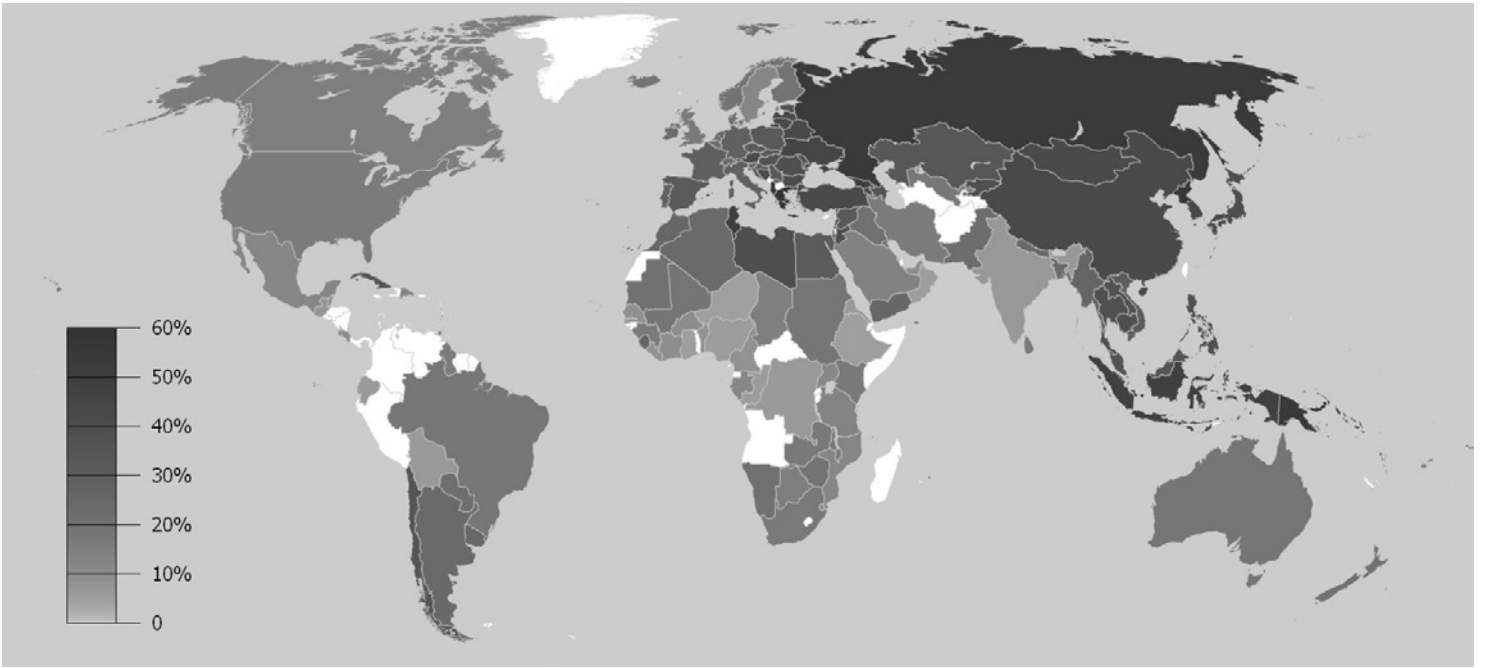

Figure 1: Age-standardized prevalence estimates of daily cigarette smoking among men in percent, 2009
Source: Data from WHO report on the global tobacco epidemic, 2011 (estimates for 2009) (http://www.who.int/tobacco/global_report/2011/appendix_vii/en/index.html)
Note: Information for some countries not available in the 2011 report was taken from the 2009 report (estimates for 2006) (http://www.who.int/tobacco/mpower/2009/appendix_vii/en/index.html)
No information available for the countries which appear in white.
Map was created with GunnMap, available at www.gunn.co.nz/map/

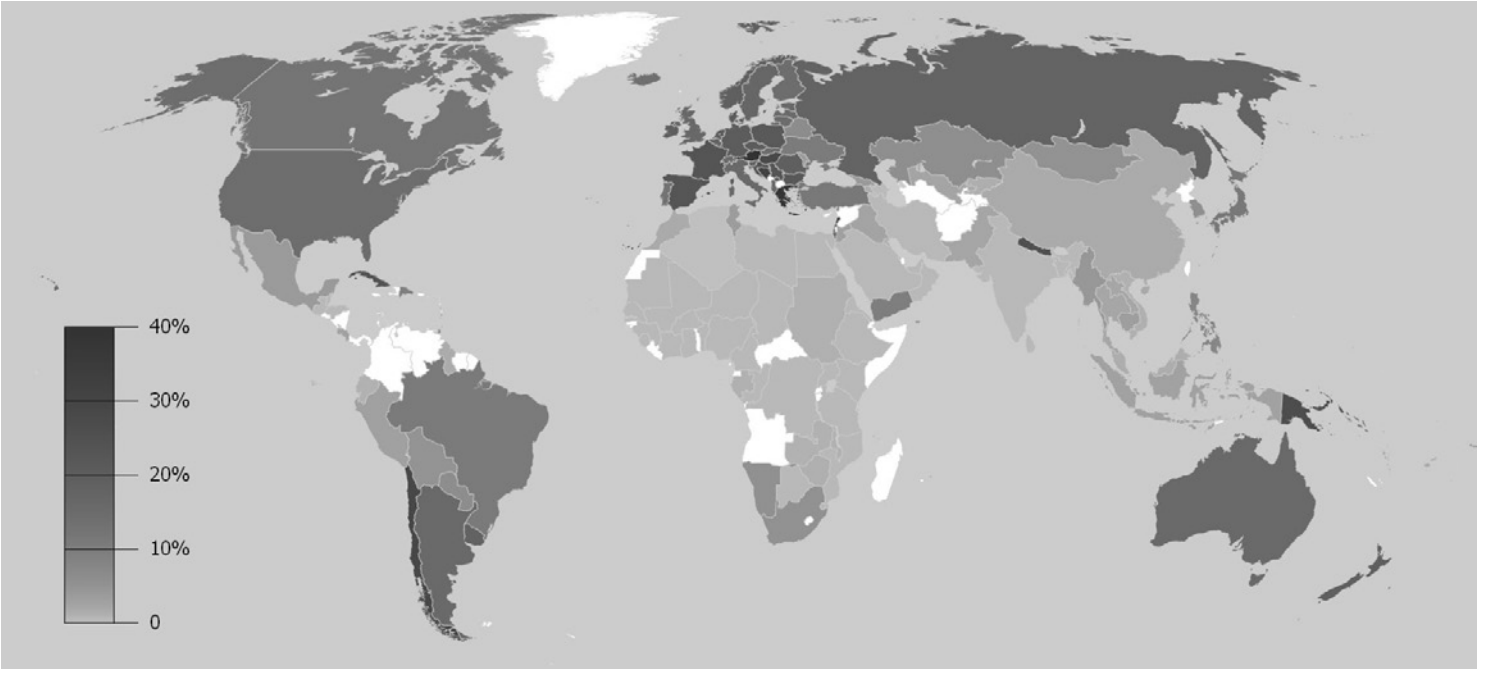

Figure 2: Age-standardized prevalence estimates of daily cigarette smoking among women in percent, 2009
Source: Data from WHO report on the global tobacco epidemic, 2011 (estimates for 2009) (http://www.who.int/tobacco/global_report/2011/appendix_vii/en/index.html)
Note: Information for some countries not available in the 2011 report was taken from the 2009 report (estimates for 2006) (http://www.who.int/tobacco/mpower/2009/appendix_vii/en/index.html)
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entered the process decades later. A recent study has shown that the four-stage model of the smoking epidemic can also be applied to the situation in developing countries, when the distinct stages are described separately for men and women [30]. In the coming decades the issue of smoking and smoking-related mortality will be increasingly about the developing countries as they move through those stages. However, developing countries can draw upon the experiences of the industrialized world [33].

As an intermediate step between assessing average levels of smoking prevalence in different countries and international comparisons of socioeconomic inequalities in smoking-related diseases and mortality from these diseases, inequalities in smoking have to be analyzed, i.e. the variation in smoking levels between individuals with different levels of education or according to other measures of socioeconomic status. For such an evaluation it is important that there is no bias in the reporting of smoking behavior depending on which SES group an individual belongs to. Research has shown that the validity level of self-reported smoking when assessed with serum cotinine is similar among individuals from different geographical areas, ages or socioeconomic groups [34]. Additionally, for such an analysis internationally comparable information for the assessment of e.g. educational attainment is necessary. Also, the sample size per country should be large enough to allow for unbiased analyses of smoking prevalence by population sub-groups [35]. Difficulties remain in obtaining data for such comprehensive international analyses. A number of studies focusing on international variations in smoking used single international surveys [22,24-28,36,37]. However, this has been performed without comparing smoking prevalence levels across the different surveys. Nor has it been investigated whether patterns of smoking inequalities differ significantly, depending on which data source is used.

Socioeconomic inequalities in smoking-related mortality

Given the undisputed association between smoking and mortality, smoking does not only make an important contribution as a major cause of morbidity and mortality but the educational inequalities in smoking also translate into inequalities in all-cause and smoking-related mortality. Depending on the stage of the smoking epidemic a country is in, tobacco use makes an important contribution to the explanation of such inequalities. Some countries with smaller inequalities in smoking have smaller inequalities in mortality [38-41]. Such inequalities are avoidable and therefore unnecessary and unfair, also making them central in the context of achieving health equity [42].

Literature examining the trend in the educational gradient in smoking between 1985 and 2000 revealed that in most European countries the educational differences in smoking converge towards the pattern observed in Northern European countries [28]. This implies that an increasingly selective group of Europeans from the lower socioeconomic strata will

be affected by smoking-related diseases in the next few decades and that this will translate into inequalities in mortality. Analyses monitoring this process and investigating whether the expected trends were indeed realized have thus to be undertaken and updated on a regular basis.

Previous studies that have examined inequalities in smoking-related mortality typically focused on lung cancer mortality [40,41,43]. However, there are other causes of death that are also strongly related to smoking. The most important ones have been identified as lung and aero-digestive cancers and COPD, in which smoking causes at least 50% out of all deaths [7].

Modification of smoking behavior through tobacco control policies

There are six policy types which, together, have been shown to be effective in reducing smoking prevalence and are summarized in the MPOWER policy package [44]. This package builds on the WHO FCTC and strongly recommends to: 1) **M**onitor tobacco use and prevention policies, 2) **P**rotect people from tobacco smoke, 3) **O**ffer help to quit tobacco use 4) **W**arn about the dangers of tobacco, 5) **E**nforce bans on tobacco advertising, promotion and sponsorship and 6) **R**aise taxes on tobacco. Such policies and interventions aiming at decreasing the prevalence of smoking are an integral part of a country's health promotion approach geared at identifying and modifying the determinants of an unhealthy behavior while promoting health equality. While personal development is fostered through information and lifelong learning, health promotion policy consists of complementary methods and includes legislation, fiscal measures, taxation and adjustment of organizational structures [45-48]. It can be geared at specific high risk groups or at the entire population, as health promotion is aiming at improving health behavior on the population level, not only through national policy, but also through actions on the individual and community level [45,49].

In order to promote health and influence smoking behavior effectively through interventions and policies it is paramount to understand the complex process of how and why individuals take up occasional smoking, become regular smokers and finally decide to quit. These behaviors are likely to vary by socioeconomic level [50], as socioeconomic differences in health behaviors, including smoking, are often associated with a number of factors such as childhood conditions and education, material hardship and social integration [6,51,52].

Hence, such policies should be tailored in a way that they do not create additional inequalities but rather as having the aim to reduce them. Authors have argued that especially population-level interventions which seek to improve the health of an entire population might be prone to increasing inequalities, as those with higher educational levels might benefit more from interventions than those with a lower SES, i.e. the "inverse care law" will apply [53,54]. Because of this mechanism population approaches should be accompanied by interventions focusing

on particular vulnerable sub-populations and should address possible health inequalities in this way [55,56].

Evidence on which strategies are most effective in this respect is inconsistent. Some systematic reviews show that increasing the price of tobacco products might reduce smoking-related health inequalities as individuals with lower incomes might be more price-sensitive [32,57,58]. On the other hand, some interventions can even generate inequalities when benefitting those in less disadvantaged groups more [59].

Health Impact Assessment and the quantification of the effect of tobacco control on health and on health inequalities

Health Impact Assessment (HIA) is a multi-step procedure which is geared towards ultimately informing the health policy decision making process. According to its definition it is "a combination of procedures, methods, and tools by which a policy, program or project may be judged as to its potential effects on the health of a population, and the distribution of those effects within the population." [60] Some of its parts are explicitly qualitative in nature and focus e.g. on the participation of stakeholders within the assessment process. It is also argued that predictions of the counter factual are not verifiable [61]. Although quantification is crucial in decision-making environments where informed choices have to be made between several policy options, it is less established within HIA, and standard tools for the quantification of health effects in HIA have, until recently, been lacking [62]. It has been argued that equity is a value which should inform the entire process of an HIA [60]. Hence, methods and procedures assessing health inequalities should play an integral part of health impact assessment [63].

The potential effects of tobacco control policies on average population health and on health inequalities should be explicitly quantified so that they can be incorporated into the formulation of health policy, leading to more optimal choices for the reduction of smoking exposure and of inequalities in smoking-related morbidity and mortality.

This thesis

In this thesis we quantify inequalities, and policies and interventions related to the risk factor smoking. We seek to answer the following study questions:

1) Do patterns of smoking prevalence and patterns of smoking inequalities by educational level vary across different data sources?

2) What is the magnitude of smoking-related inequalities in mortality in Europe?

3) What are the potential health gains and health inequality reductions due to different tobacco control policies and interventions?

The first study question is addressed in chapter 2 of this thesis. Here, we compare the prevalence of smoking and patterns of smoking inequalities across Europe in three different surveys. Chapter 3 tackles the second research question by analyzing recent smoking-related inequalities in mortality in Europe and their magnitude. We investigate the size and pattern of relative and absolute inequalities in mortality from different diseases related to smoking. The contribution of these smoking-related diseases to inequality in all-cause mortality is also assessed. The third study question concentrates on the quantification of health gains and potential inequality reductions due to different policies and interventions and is investigated in chapters 4 and 5. Chapter 4 compares the health gains of different tobacco control interventions and policies in terms of timing and size of their overall effects. Chapter 5 quantifies the impact of the elimination of smoking inequalities on inequalities in mortality. Chapter 6 concludes this thesis with summary answers to and further discussion of the study questions listed above.

Introduction to the modeling tools used

The analyses pertaining to answering the third study question were based on two different newly-developed modeling tools. The first one, referred to as the DYNAMO-HIA tool, is a Markov type, multistate simulation software [64]. It was developed to allow researchers and policy makers in the field of Health Impact Assessment (HIA) to 1) quantify the development of risk factor exposure over time and to 2) estimate the impact of these changes in risk factor exposure on disease prevalence, mortality and on summary measures of population health. DYNAMO-HIA is a dynamic tool that synthesizes data according to the causal epidemiological pathway, linking risk factor exposure through relative risks of incidence of associated diseases and death, to prevalence of diseases, mortality and summary measures of population health. The tool also allows to take into account relative risks by "time since quitting smoking" and age, as well as competing risks. Following the epidemiological causal chain implies that the model uses relative risks by risk factor class, i.e. incidence in exposed risk factor classes

are a multiple of the incidence in the non-exposed. A change in risk factor exposure due to the policy or intervention thus changes disease incidence and in turn disease prevalence and mortality. The effect of the risk factor change on mortality through diseases not included in the model, i.e. other-cause mortality, is taken into account by additionally using the relative risk on total, i.e. all-cause, mortality. Other mortality is derived from total mortality and disease specific mortality, assuming additive mortality. In order to isolate the effects of the intervention, DYNAMO-HIA always compares one or more intervention scenarios which result in a modified risk factor prevalence and/or modified transition rates, with the reference or business-as-usual scenario.

The second instrument, referred to as the PAF tool, is an excel-based application built on the principles of the Population Impact Fraction (PIF) and the Population Attributable Fraction (PAF) [65] . We use the term PAF in a generalized sense, also including situations in which the prevalence of the risk factor is set to a level above zero and which would usually be described by the PIF. We used the PAF method to assess the expected changes in mortality that would result from modifying the population distribution of exposure to a risk factor (Formula 1). The PAF is defined as the fraction of deaths attributable to a specific disease which would have been avoided if a modification of the prevalence of a specific risk factor had occurred [66,67].

Formula 1:
$$PAF = \frac{\sum_{i=1}^{n} P_i RR_i - \sum_{i=1}^{n} P_i^{'} RR_i}{\sum_{i=1}^{n} P_i RR_i}$$

n = number of exposure categories (of smoking)
P_i = proportion of population currently in the ith exposure category
P'i = proportion of population in the ith exposure category in the counterfactual (alternative) scenario
RR_i = relative mortality risk for the ith exposure category

The original methodology was adapted to estimate the impact of counterfactual distributions of specific risk factors on the overall level of mortality and on educational differences in mortality. The latter was achieved by stratifying the PAF calculation by educational group. The PAF incorporates the effect of two factors: 1) the degree of social inequality in risk factor prevalence and its changes brought about by the scenario, and 2) the impact of the risk factor on mortality. The potential reduction in relative inequality in mortality was expressed as a percentage change in the relative excess risk (RR-1), comparing the excess risk before and after the implementation of the scenario.

More information about the methodology of the tools can be found in appendices I and II to this thesis.

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CHAPTER 2

Does the pattern of socioeconomic inequalities in smoking in Western Europe depend on the choice of survey?

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ABSTRACT

Objectives: Smoking rates vary according to socioeconomic group. We investigated whether patterns of inequalities in smoking prevalence differ across three major European surveys.

Methods: Data on smoking came from National Health Interview Surveys (NHIS), the European Community Household Panel (ECHP) and the Eurobarometer (EB). We calculated prevalence ratios by education. We controlled for sex, country, data source and age. We used likelihood ratio tests to determine whether inequalities in each country differed between surveys and whether the association of education and smoking across countries was the same in different surveys.

Results: Smoking prevalence tended to be lower in the ECHP than in both other surveys, and was highest in the EB. The pattern of inequalities in smoking also differed between surveys. Statistically significant differences between surveys were found mainly in Southern Europe, where EB-based prevalence ratios often deviated from those found in the other two surveys.

Conclusions: Relative inequalities in smoking prevalence depend on the survey used. Our results suggest that the NHIS and the ECHP are more reliable sources of information on educational inequalities in smoking than the EB.

INTRODUCTION

Smoking continues to be the largest cause of mortality and morbidity in the European Union, and accurate estimates of overall prevalence and information on the risk of smoking by socioeconomic group are necessary for effective targeting of tobacco control policies and interventions [1,2]. While several studies have described smoking prevalence and patterns of socioeconomic inequalities in smoking in European counties [3-9], these studies usually applied single European data sources. For example, using National Health Interview Surveys (NHIS), Schaap et al. [4] investigated socioeconomic inequalities in ever-smokers according to four educational levels, but only for the female part of the population. Data from the 5th wave of the European Community Household Panel (ECHP) was also analyzed in this context. Smoking prevalence ratios were calculated for several indicators of socioeconomic position, including education split into three different levels [3]. Huisman et al. [5,6] used odds ratios and two levels of education for their analyses. In one study they focused on adolescents and young adults, while concentrating on an overall, non-country specific analysis in the other. Bogdanovica et al. [8] used tobacco use information from the 2006 Eurobarometer survey (EB wave 66.2). However, the authors only analyzed the correspondence of overall prevalence between the EB and national surveys, without looking at inequalities in smoking. Each of the studies took a different analytical approach, rendering a direct comparison of the results difficult.

Even though several analyses were carried out using different data sources, we still do not know whether previous estimates are accurate, since no study compared the levels of smoking prevalence and smoking inequality patterns according to educational level between different surveys. We therefore investigated whether patterns of smoking prevalence and patterns of smoking inequalities by educational level differed across three major European surveys.

We first determined whether the smoking information in the three different surveys resulted in significantly different overall levels of prevalence of current smokers and ever-smokers for each country. Secondly, we analyzed whether patterns of social inequalities in smoking differed between the data sources, within and across countries.

METHODS

Description of surveys

For the comparability of smoking prevalence levels between countries, it was important to evaluate data that were collected around the same time. Therefore, our analyses used data on smoking prevalence from three widely used surveys which were all conducted around the year

2000: a collection of NHIS, the ECHP and the EB. The countries included and further information on the data sources are presented in Table 1. The NHIS were nationally representative surveys from 13 countries, usually provided by national statistical offices, with the exception of Finland, for which the data came from the Finbalt Health Monitor, and Belgian data coming from the Scientific Institute of Public Health. The surveys, which entailed cross-sectional country-specific information, were collected and harmonized as part of the Eurothine project [10]. The sample size was always above 10,000 respondents, except in Germany, where the national sample included just above 7,000 individuals. Non-response was highest in the Netherlands, Belgium and Germany at about 40%, and lowest in Spain and Italy (about 15%).

The ECHP is a social survey which was administered in the member states of the European Union between 1994 and 2001. We used the seventh wave (2000) for our analyses. The ECHP used a uniform random sampling design and common questionnaires for all 15 countries included in the survey. National households were the target population of the panel survey. Data was collected by national statistical offices and other research centers, and harmonized by Eurostat, the statistical information office of the European Commission [11]. The national sample sizes varied from approximately 4,000 (Denmark) to 14,500 respondents (Italy). Non-response in the first wave, among the countries included in our analysis, was highest in Ireland (44%) and lowest in Italy at 9% [5].

The EB was our third source of smoking information. We chose the EB 58.2, which was collected in 2002 and included 15 countries. The fieldwork was carried out by the European Opinion Research Group, on behalf of the European Commission [12]. A multi-stage sampling design was used, and all member states received uniform instructions. The EB aims to have a sample size of 1,000 completed interviews.

Other international surveys did not include questions on smoking or it was not measured in the way needed for this analysis. Although it contained appropriate smoking information we chose not to include the Survey of Health, Aging, and Retirement in Europe (SHARE) [13], as it only studies respondents who are 50 years old or older, whereas our analyses include all those 25 and above.

Some countries were excluded from the analyses because information on smoking was incomparable or unavailable. We also excluded countries for which smoking information was missing for more than 20% of the respondents and countries which were only represented by one suitable survey, thus not allowing for a comparison. For these reasons, Ireland, France and Switzerland were excluded from the NHIS collection. Sweden, United Kingdom, the Netherlands, Luxembourg, France and Germany were excluded from the ECHP. Luxembourg and France were excluded from the EB. Further country-specific information about the dif-

ferent surveys can be found in Table 1. Throughout the analyses countries are ordered by region: North, West, South. It would have been highly informative to also compare smoking prevalence rates and inequalities in Central and Eastern European countries. However, this information was only available in the NHISs for the time around the year 2000.

Measures of smoking

In all cases, smoking status was self-reported and referred to general smoking including all common tobacco products (cigarettes, pipe, and cigars). In the NHIS the respondents were classified as current regular smokers, current occasional smokers, ex-smokers or never smokers. In the case of Sweden, England, Germany and Italy, the survey did not include a distinction between regular and occasional smokers, but only asked about smoking in general. Hence, we cannot rule out the possibility that some respondents who might have been occasional smokers counted themselves as regular smokers or as non-smokers. Country-specific questions are listed in Table A3 (in the appendix to this this paper). In the ECHP the respondents were asked whether they smoked daily/ smoked occasionally/ did not smoke but used to smoke daily/ did not smoke but used to smoke occasionally/ never smoked. In the EB subjects were asked to indicate if they smoked regularly or occasionally, given that they had indicated earlier that they smoked packed cigarettes, their own rolled cigarettes, or pipe/cigars. In separate questions they were also asked if they used to smoke but had stopped, and whether they had never smoked. No distinction was made between those smoking cigarettes, a pipe or cigars.

We ran separate analyses for the group of current smokers and for the group of ever-smokers, the latter definition of smoking prevalence often being used when looking beyond current smokers only, and summarizing all individuals who ever chose to take up smoking. We defined current smokers as "current regular smokers" in the NHIS, as "current daily smokers" in the ECHP, and as "regular smokers" in the EB. Ever-smokers were defined as "current regular smokers" or "ex-smokers" in the NHIS, either as "current daily smokers" or "former daily smokers" in the ECHP, and both as "smoking regularly" and "used to smoke but had now stopped" in the EB. Occasional smokers were not counted as current or ever-smokers, since they tend to be different from regular smokers in terms of socioeconomic status and smoking-related health outcomes [14].

Measure of socioeconomic status (SES)

To ensure comparability between surveys, the measure of educational attainment was standardized across the surveys to express high and low final educational attainment. In the NHIS and the ECHP, educational attainment was constructed in the same way, i.e. on the basis of the International Standard Classification of Education (ISCED). We defined higher education as upper secondary education or higher (ISCED levels 3, 4, 5 and 6), and lower education as lower secondary education or less (ISCED levels 0, 1, and 2).

Table 1: Overview of information on the different surveys used and the countries included in the analysis (for the comparison a country had to be included in at least two of the three data sources)

Country	Survey Name	Year	Sample Size (Percentage Men)	Non-response/ Attrition Rate* (%)	Age Range	Proportion with high education	
	NHIS					**Men**	**Women**
Finland	Finbalt Health Monitor	1994/1996/1998/2000/ 2002/2004	20,371 (46.43%)	28.0–35.0	16-64	0.72	0.78
Sweden	Swedish Survey of Living Conditions	2000/2001	11,484 (48.65%)	23.9/22.2	16-84	0.77	0.77
Denmark	Danish Health and Morbidity Survey (DHMS/ SUSY)	2000	16,690 (49.06%)	25.8	16-98	0.79	0.72
England	Health Survey for England (HSE)	2001	15,767 (44.60%)	33.0	16-100	0.65	0.60
Ireland	Excluded, more than 20% missing						
the Netherlands	General social survey (POLS)	2003/2004	15,803 (48.54%)	41.7/38.7	16-85	0.70	0.56
Belgium	Health Interview Survey	1997/2001	18,481 (48.48%)	41.5/38.6	16-99	0.59	0.54
France	Excluded, more than 20% missing						
Germany	German National Health Examination and Interview Survey	1998	7,124 (48.43%)	38.6	17-79	0.55	0.50
Switzerland	Excluded, not available in the other sources						
Spain	National Health Survey	2001	20,748 (48.43%)	15.0	16-75+	0.34	0.26
Italy	Health and health care utilization/Multipurpose Family Survey	1999/2000	118,245 (48.16%)	13.4/18.3	16-105	0.37	0.33
Portugal	National Health Survey	1998/1999	40,917 (47.26%)	n.a.	16-103	0.14	0.13
	ECHP						
Finland	ECHP Wave 7	2000	5,614 (49.18%)	27 (31.31)	17-91	0.69	0.68
Sweden	Excluded, more than 20% missing						
Denmark	ECHP Wave 7	2000	3,833 (48.73%)	38 (35.07)	16-91	0.80	0.70

Table 1: (Continued)

Country	Survey Name	Year	Sample Size (Percentage Men)	Non-response/ Attrition Rate* (%)	Age Range	Proportion with high education	
	ECHP					**Men**	**Women**
UK	Excluded, non-comparable coding of smoking variable						
Ireland	ECHP Wave 7	2000	4,528 (48.76%)	44 (54.28)	17-91	0.47	0.46
the Netherlands	Excluded, no information on smoking						
Belgium	ECHP Wave 7	2000	4,713 (46.57%)	16 (29.76)	17-91	0.65	0.61
Luxemburg	Excluded, no information on smoking						
France	Excluded, no information on smoking						
Germany	Excluded, no information on smoking						
Austria	ECHP Wave 7	2000	5,801 (48.39%)	30 (22)	15-91	0.82	0.60
Spain	ECHP Wave 7	2000	12,317 (48.07%)	33 (31.16)	16-91	0.36	0.31
Italy	ECHP Wave 7	2000	14,585 (48.67%)	9 (17.73)	17-91	0.41	0.37
Portugal	ECHP Wave 7	2000	11,054 (47.31%)	11 (4.88)	17-91	0.20	0.19
Greece	ECHP Wave 7	2000	9,437 (47.90%)	10 (24.46)	17-91	0.47	0.38
	EB						
Finland	EB 58.2	2002	1,024 (42.68%)	n.a.	15-92	0.67	0.74
Sweden	EB 58.2	2002	1,000 (46.90%)	n.a.	15-95	0.72	0.77
Denmark	EB 58.2	2002	1,000 (49.60%)	n.a.	15-92	0.85	0.82
UK	EB 58.2	2002	1,312 (36.51%)	n.a.	15-91	0.70	0.61
Ireland	EB 58.2	2002	1,013 (48.47%)	n.a.	15-94	0.60	0.67
the Netherlands	EB 58.2	2002	1,035 (48.31%)	n.a.	15-87	0.74	0.63
Belgium	EB 58.2	2002	1,110 (47.66%)	n.a.	15-93	0.66	0.64
Luxemburg	Excluded, not available in the other sources						

Table 1: (Continued)

Country	Survey Name	Year	Sample Size (Percentage Men)	Non-response/ Attrition Rate* (%)	Age Range	Proportion with high education	
	EB					**Men**	**Women**
France	Excluded, not available in the other sources						
Germany	EB 58.2	2002	2,042 (47.50%)	n.a.	15-90	0.77	0.71
Austria	EB 58.2	2002	1,023 (40.27%)	n.a.	15-90	0.89	0.80
Spain	EB 58.2	2002	1,000 (48.50%)	n.a.	15-89	0.54	0.42
Italy	EB 58.2	2002	1,027 (48.39%)	n.a.	15-93	0.61	0.53
Portugal	EB 58.2	2002	1,002 (45.81%)	n.a.	15-88	0.21	0.18
Greece	EB 58.2	2002	1,003 (49.95%)	n.a.	15-88	0.62	0.38

* Attrition since first wave in the ECHP

In the EB, the respondents had to indicate how old they were when they ended their full-time education. In order to arrive at a comparable classification of education, we recoded this information on the basis of typical graduation ages at different ISCED levels across Europe as presented by the OECD [15]. In this way we were able to assign individuals to the most likely corresponding educational level. In a final step we reclassified the ISCED levels into low (ISCED levels 0, 1, and 2) vs. high (ISCED levels 3, 4, 5 and 6) educational attainment, in order to match those in the other two surveys. Table 1 includes the proportions of those with a high education across the three surveys. We see that the EB results in a slightly higher proportion (up to 20% more) of individuals with a high level of education in Ireland, Germany, Spain, Italy and Greece among men; and in Ireland, Germany, Austria, Spain and Italy among women. The NHIS and the ECHP exhibit similar education distributions.

Statistical analyses

We calculated age-standardized overall smoking prevalence rates using the direct method based on the 1995 European Standard Population [16] and applied regression analysis for further calculations (Table 2).

In all regression analyses we calculated prevalence ratios (PRs) of the two outcome variables - current smokers and ever-smokers - by means of generalized linear regression models for the binomial family and a log link function. Since smoking is a non-rare event, we chose to use PRs rather than calculating odds ratios (ORs), as ORs are likely to be too high for events which occur relatively often [17-20]. The relative differences were expressed as prevalence ratios which represented the risk of being a current smoker or an ever-smoker. The analyses were always stratified by sex, and we controlled for educational level and age. Throughout the analysis we excluded respondents younger than 25 years of age, whose patterns of smoking might still have been unstable before this age, and in order for individuals to be old enough to have achieved their highest level of education. Depending on whether we calculated the PRs by data source and/or country or based on a pooled data set we stratified by or controlled for those two variables, respectively. For all calculations we used the statistical software package STATA, version 11.

To examine whether the sex-specific prevalence of smoking in each country differed between the surveys we calculated PRs of the two outcome variables, controlling for age, education and source, stratifying by country, and focused on the PRs by source and their significance (Table 2).

To calculate sex-specific and country-specific levels of socioeconomic inequalities in smoking between the surveys we applied the same type of regression but now focused on the PR by low vs. high level of education, and additionally stratified by survey. In a further step, in order

to establish whether levels differed significantly between surveys for each country, instead of stratifying by survey we included a two-way interaction of educational level and data source and used a likelihood ratio to compare these country-specific models to the models without the interaction term (Figures 1-4, significance indicated by asterisks).

Using the same likelihood ratio method, we also investigated whether the association of education and smoking across countries was the same in the different data sources. For both sexes separately, we pooled our data over all sources and countries and in a full model controlled for age, educational level, data source, and country, and the interactions of age and country, educational level and country, data source and country, and educational level and source. Additionally we also included the interaction of education, country and source and compared both models, and used the likelihood ratio test to determine the statistical significance of this three-way interaction term (test results listed below Figures 1-4).

RESULTS

Overall prevalence of current smokers and ever-smokers

Country-specific smoking prevalence rates from the three different data sources are summarized in Table 2. In the first three results columns, we display the age-standardized overall prevalence rates for current smokers and ever-smokers, respectively, stratified by sex, country and data source. In columns four through six we show the smoking prevalence ratios based on regression. Since the prevalence rates and the PRs were obtained with different methods, in some cases the results did not match perfectly, as in the case of female current smokers in Finland, where the prevalence rates were 19.2% in the NHIS and 18.1% in the ECHP, while the PR was 1.00.

For both men and women, there were significant differences (marked in bold) between the surveys, in both: the levels of prevalence of current and that of ever-smokers (Table 2). More specifically, the prevalence of current smokers and ever-smokers tended to be lower in the ECHP than in the other two surveys, and was highest in the EB. Among men, the highest current smoking prevalence rates were observed in Spain (38 to 46%) and Greece (48 and 50%). Sweden, on the other hand, had the lowest prevalence level, at about 15 and 18%. Among women, the levels of current smokers were lowest in Portugal (9 to 11%) and highest in Denmark (29 to 33%) and England (25 to 34%).

Educational inequalities in smoking by current smokers and ever-smokers

Generally, educational inequalities in current smokers were larger than those in ever-smokers in all surveys, with both showing a similar pattern across all countries (Figures 1-4). Among

Table 2: Age-standardized overall prevalence (%) of current smokers and ever-smokers, age 25 and older, in the NHIS, ECHP and EB; smoking prevalence risk ratio and significance (in bold) of differences (p<0.05) between the data sources

CURRENT SMOKERS	Age-standardized overall prevalence (%)			smoking PRs and their significance (significant differences in bold)			EVER-SMOKERS	Age-standardized overall prevalence (%)			smoking PRs and their significance (significant differences in bold)		
	NHIS	ECHP	EB	ECHP vs. NHIS	EB vs. NHIS	EB vs. ECHP		NHIS	ECHP	EB	ECHP vs. NHIS	EB vs. NHIS	EB vs. ECHP
MEN							**MEN**						
Finland	29.5	27.7	37.7	0.98	**1.30**	**1.33**	Finland	56.0	54.2	63.7	**0.93**	**1.09**	**1.17**
Sweden	17.8		14.9		0.82		Sweden	55.0		34.9		**0.69**	
Denmark	37.1	33.9	38.9	**0.92**	1.03	1.12	Denmark	64.6	58.8	62.2	**0.90**	**0.92**	1.03
England/UK	26.4		39.1		**1.44**		England/UK	63.5		63.5		0.97	
Ireland		27.8	32.1			**1.36**	Ireland		46.0	57.1			**1.30**
the Netherlands	29.0		33.7		**1.19**		the Netherlands	66.1		67.9		1.02	
Belgium	30.6	28.9	34.3	0.99	**1.16**	**1.17**	Belgium	66.0	53.2	61.9	**0.84**	0.94	**1.13**
Germany	29.2		38.0		**1.34**		Germany	60.8		64.1		1.05	
Austria		31.0	37.6			**1.33**	Austria		48.6	60.6			**1.31**
Spain	40.1	37.8	46.1	0.96	**1.17**	**1.21**	Spain	67.7	55.9	73.4	**0.84**	**1.07**	**1.27**
Italy	32.9	30.3	33.4	**0.93**	1.04	1.12	Italy	63.0	45.3	60.6	**0.71**	0.98	**1.37**
Portugal	32.9	30.4	36.8	0.98	1.13	**1.15**	Portugal	58.6	45.5	62.7	**0.82**	1.07	**1.30**
Greece		47.7	50.2			1.08	Greece		56.2	74.8			**1.34**
WOMEN							**WOMEN**						
Finland	19.2	18.1	26.4	1.00	**1.54**	**1.54**	Finland	35.8	31.9	44.1	0.94	**1.36**	**1.44**
Sweden	21.5		25.5		1.17		Sweden	49.1		50.6		1.04	
Denmark	33.4	33.1	29.4	1.00	0.94	0.94	Denmark	56.9	52.2	57.1	**0.95**	1.02	1.08
England/UK	25.3		33.7		**1.44**		England/UK	54.4		51.9		1.00	
Ireland		26.5	31.4			**1.24**	Ireland		38.3	48.2			**1.31**

Table 2: (Continued)

CURRENT SMOKERS	Age-standardized overall prevalence (%)			smoking PRs and their significance (significant differences in bold)			**EVER-SMOKERS**	Age-standardized overall prevalence (%)			smoking PRs and their significance (significant differences in bold)		
	NHIS	**ECHP**	**EB**	**ECHP vs. NHIS**	**EB vs. NHIS**	**EB vs. ECHP**		**NHIS**	**ECHP**	**EB**	**ECHP vs. NHIS**	**EB vs. NHIS**	**EB vs. ECHP**
the Netherlands	23.1		28.5		**1.32**		the Netherlands	55.9		56.7		1.01	
Belgium	21.1	20.6	22.9	1.03	1.11	1.07	Belgium	46.6	31.9	42.0	**0.71**	**0.89**	**1.25**
Germany	22.1		24.8		**1.19**		Germany	39.2		40.1		1.09	
Austria		19.5	26.1			**1.59**	Austria		28.4	38.7			**1.52**
Spain	24.2	19.4	28.7	**0.84**	**1.21**	**1.43**	Spain	34.6	24.1	39.8	**0.74**	**1.12**	**1.50**
Italy	19.1	15.8	29.7	**0.76**	**1.46**	**1.92**	Italy	32.6	19.5	42.7	**0.56**	**1.21**	**2.17**
Portugal	9.4	9.1	11.3	**0.75**	1.17	**1.56**	Portugal	14.7	11.4	20.4	**0.61**	**1.30**	**2.13**
Greece		20.8	30.7			**1.55**	Greece		21.7	40.9			**1.91**

males within the NHIS, inequalities were largest in Northern and Western Europe, with a PR of around 1.5 among current smokers. They were smallest in the countries of Southern Europe. In the ECHP, male current smokers in Northern and Western Europe had inequality levels that were very similar to those in the NHIS. In Southern European countries, the ECHP showed larger inequalities than the other two surveys. In many of the countries the EB exhibited the least pronounced inequality patterns and even showed reversed inequality gradients in Austria and Spain, i.e. individuals with a lower educational level had a lower risk of smoking than those with a higher education. In this survey there were no significant inequalities among current smokers in the UK, Germany, Austria, Italy, Portugal and Greece. Educational inequalities among male current smokers differed significantly between the data sources in Spain (EB & NHIS, EB & ECHP), Italy (NHIS & ECHP) and Portugal (EB & ECHP, NHIS & ECHP). Among ever-smokers there were no inequalities in the EB in Sweden, Denmark, England, the Netherlands, Austria, Italy, Portugal and Greece, and in the ECHP in Austria. There were significant differences between the sources in Belgium (NHIS & ECHP), Spain (EB & NHIS, EB & ECHP) and Portugal (NHIS & ECHP).

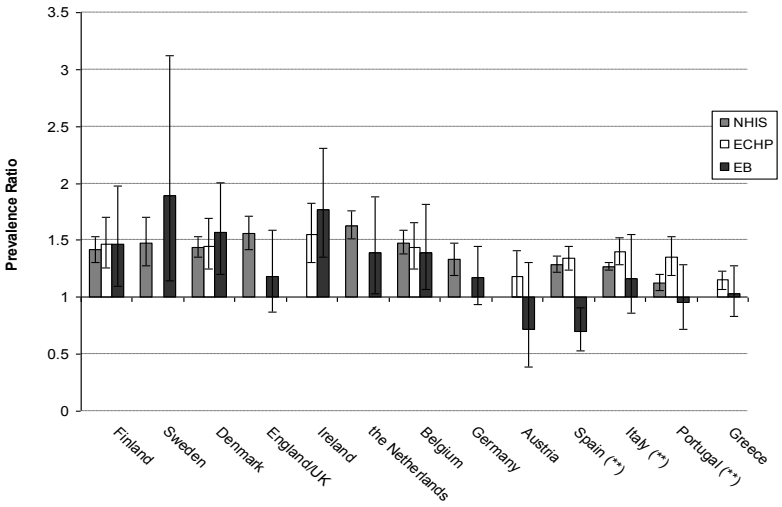

Figure 1: Educational Inequalities in Male Current Smokers (ref = 1, high education), significance between data sources per country is shown in parentheses, per country (* p<0.05, ** p<0.01) Differences in inequality patterns between pairs of surveys, likelihood ratio p-values: NHIS & ECHP: p=0.063, EB & NHIS: p=0.098, EB & ECHP: p=0.027

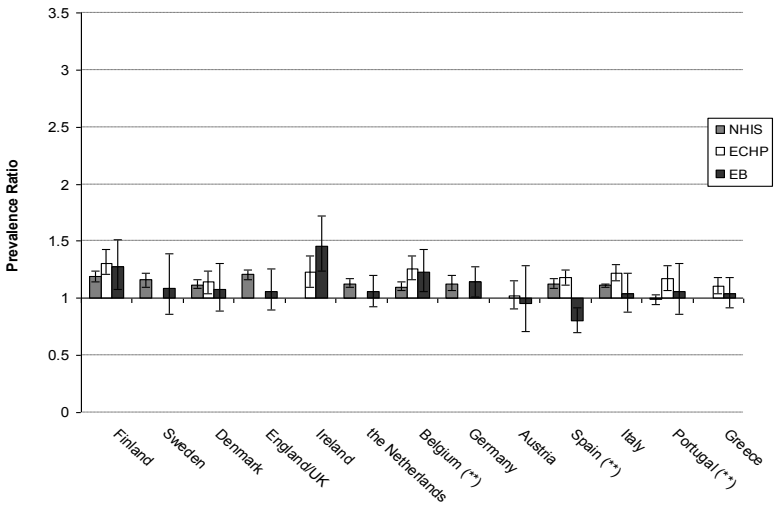

Figure 2: Educational Inequalities in Male Ever-Smokers (ref = 1, high education), significance between data sources per country is shown in parentheses, per country (* p<0.05, ** p<0.01) Differences in inequality patterns between pairs of surveys, likelihood ratio p-values: NHIS & ECHP: p=0.025, EB & NHIS: p=0.115, EB & ECHP: p=0.195

Women in Northern and Western Europe demonstrated a pattern of smoking inequalities that was very different from that of their counterparts in Southern Europe. Smoking women in Southern Europe had an inverse risk pattern. For ever-smoking women this was also the case in Austria. According to the EB inequalities were not significant among female current smokers in Finland, the Netherlands, Belgium, Germany, Austria, Spain, Italy and Greece. They were also not significant in the ECHP in Sweden, Austria, Spain, Italy, and in the NHIS in Spain. The pattern of educational inequalities among female current smokers differed significantly between the data sources in Greece (EB & ECHP). Among ever-smokers in the EB inequalities were only significant in England and Portugal, only being non-significant in the ECHP in Sweden and Austria, and in the NHIS in Sweden and Belgium. Among ever-smokers there were also only significant differences between sources in Greece (EB & ECHP).

The likelihood ratio analysis of the regression models (p-values listed below Figures 1-4) based on the pooled data sets confirmed the differences in inequality levels found in the analyses above. We can see that the association of education and smoking across countries was not the same in all three data sources. For male current smokers there were significant differences between the EB and ECHP. For ever-smokers there were differences between the ECHP and the NHIS. Among women there was a significant difference only among ever-smokers between the EB and the ECHP.

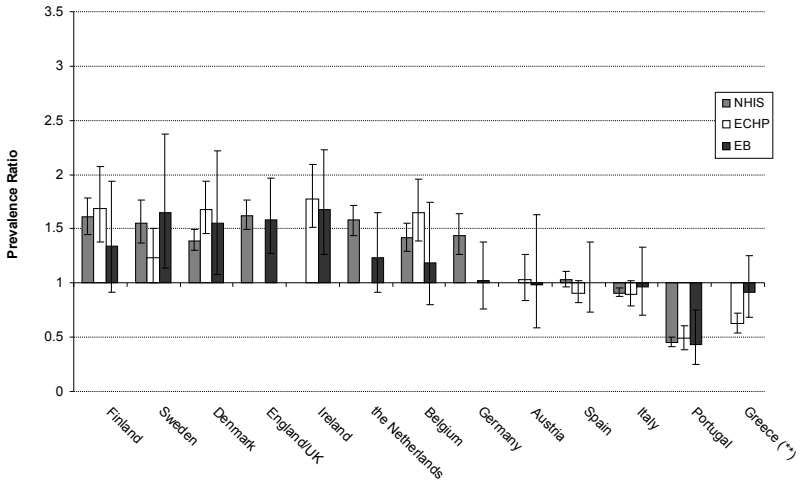

Figure 3: Educational Inequalities in Female Current Smokers (ref = 1, high education), significance between data sources per country is shown in parentheses, per country (* p<0.05, ** p<0.01) Differences in inequality patterns between pairs of surveys, likelihood ratio p-values: NHIS & ECHP: p=0.119, EB & NHIS: p=0.364, EB & ECHP: p=0.087

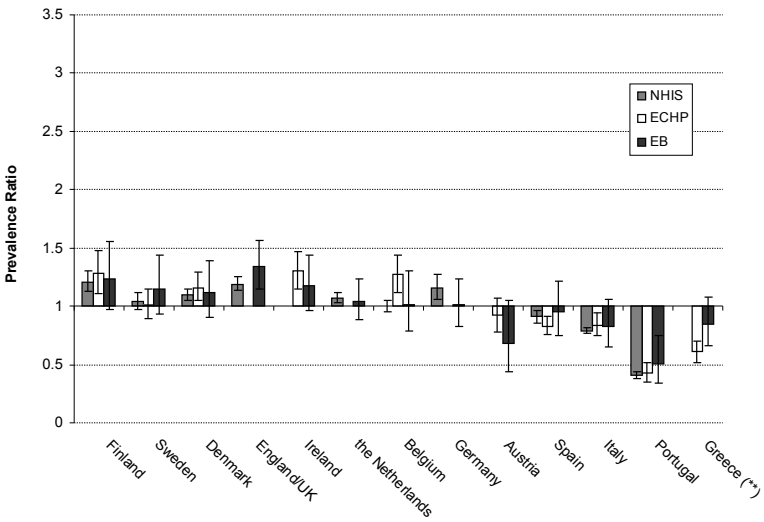

Figure 4: Educational Inequalities in Female Ever-Smokers (ref = 1, high education), significance between data sources per country is shown in parentheses, per country (* p<0.05, ** p<0.01) Differences in inequality patterns between pairs of surveys, likelihood ratio p-values: NHIS & ECHP: p=0.073, EB & NHIS: p=0.650, EB & ECHP: p=0.005

DISCUSSION

The prevalence of current smokers and ever-smokers differed significantly between the three sources. The percentages tended to be lower in the ECHP than in the other two surveys, and were highest in the EB. The pattern of educational inequalities in ever and current smoking also differed significantly between surveys. Statistically significant differences between surveys were found mainly in Spain, Portugal, Italy and Greece, where PRs based on the EB often deviated from those found in the other two surveys.

For our analysis we selected three widely used European data sources that include information on smoking behavior: two international surveys and a harmonized collection of national health interview surveys. A relevant concern might be whether the questions used to ask about the respondents' smoking behavior were comparable between the surveys. As all used the same or very similar wording and categories to inquire about current regular/occasional smoking, former smoking and never smoking, we do not expect bias.

All responses were self-reported. However, this was not a major problem in our analysis since we were comparing surveys which all included self-reported information. Furthermore, studies have concluded that self-reported estimates are quite accurate with only small socioeconomic differences in reporting bias [21,22]. We also excluded individuals below the age of 25 from our analyses and underreporting is usually expected at youngest ages. We are aware that there might be potential bias concerning the non-response or attrition rate since first wave in the ECHP, if smoking status and/or educational level were not distributed equally between those who responded and those who did not. No detailed information on the relationship between non-response and education could be found for the surveys used. However, it was found that while non-response can cause bias in the level of smoking prevalence, the association between smoking and socioeconomic status is not biased [23].

There is some evidence that smoking prevalence might be higher when collected face-to-face than in self-administered surveys [24]. The ECHP and EB were both collected face-to face, while the NHIS comprised both methods. We do not consider this issue a possible source of bias since the prevalence levels of the NHIS usually lay between those of the other two surveys.

Education is a widely used indicator of SES. Unlike occupation or income, it has the advantage that it avoids the problem of health-related social mobility later in life, as it is normally completed before ill-health in mid-life starts [25]. The main strength of using education as a measure of SES is that it is relatively easy to measure, obtains high response rates, and is a relevant indicator for everyone from younger adulthood on, regardless of working circum-

stances. Because it is a fundamental determinant of both occupation and income, education also lies at the heart of people's position in society [26,27]. While the NHIS and the ECHP used the same variable to measure education, we had to construct a comparable variable for the EB which would be as similar as possible. Still, as our results show, in some countries this solution led to a proportion of those with high education that was higher than the proportions in the two other data sources, possibly pointing to some misclassification of educational level.

Neither can we rule out differences in our data sources due to sampling and survey methods. While the ECHP and the EB used the same methods and questions for all countries included in those surveys, our harmonized collection of National Health Interview Surveys might be more heterogeneous. Although the EB survey is the largest continuous and standardized source of smoking information, its relatively small sample size only allows for less detailed analyses of smoking prevalence in population subgroups. A study comparing smoking prevalence levels in the 2006 EB with prevalence from national surveys found discrepancies within countries and concluded that the EB's sample size was too small for reliable analyses by sex or educational level [8]. More detailed analyses are likely to require sources with a larger sample size and with an educational variable that is more directly comparable to the education information available elsewhere. The minimal sample size recommended for an analysis by educational group being N = 5.000 [28].

The different distribution of educational levels and its sample size make the EB a less reliable source and may explain why it is more often the prevalence ratios based on the EB that deviate from those found in the other two surveys.

In order to further asses which of the surveys might yield the most reliable estimates of smoking inequalities we compared them to levels of inequality in lung cancer mortality. Estimates showed that in Spain and Italy in the early 2000s mortality from lung cancer was higher in men with a low educational level, supporting estimates of inequality in smoking based on the NHIS [29]. A country that has moved through the early stages of the smoking epidemic, as indicated by higher lung cancer mortality among those with a lower education based on past smoking patterns will have already passed through the earlier stage of having relatively many smokers with a higher educational level [7].

While the authors are not aware of any analyses that have compared the extent of educational inequalities in current and ever-smoking across different surveys, the magnitude and the geographical patterns of inequalities do conform to other authors' single-survey studies of earlier waves of the ECHP or (older) sets of harmonized NHISs [6,7]. Bogdanovica et al. [8] compared the smoking prevalence levels in the EB in 2006 with national prevalence survey data. However, they focused only on officially reported overall non-sex-specific prevalence

levels, and did not study educational inequalities in particular. Finally, it should be kept in mind that although we only present relative inequalities, absolute inequalities in smoking prevalence will also strongly depend on the survey used, since they depend on both the average prevalence and on relative inequalities.

Conclusion

Relative inequalities in prevalence of ever and current smoking depend on the survey used. Our results suggest that the NHIS and the ECHP are more reliable sources of information on educational inequalities in smoking than the EB. When undertaking comparative analyses of prevalence and inequalities of other risk factors it should be taken into account that results might also differ depending on the data source.

The authors would like to thank Caspar Looman for his statistical advice.

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APPENDIX TABLE

Table A3: Harmonized categories of smoking status and initial country-specific smoking questions asked in the NHIS

1 = current regular smoker
2 = current occasional smoker
3 = former smoker
4 = never smoker

Country	Categories in harmonized files	Categories based on the following questions
Finland	1, 2, 3, 4	Have you ever smoked? Have you ever smoked regularly/daily? Have you ever smoked at least 100 times?
Sweden	1, 3, 4	Do you smoke daily? Have you previously smoked daily for any period of your life?
Denmark	1, 2, 3, 4	Do you smoke? If no, have you been a smoker?
England	1, 3, 4	Have you ever smoked a cigarette, a cigar or a pipe? Do you smoke cigarettes at all nowadays?
the Netherlands	1, 2, 3, 4	Do you smoke? Do you smoke every day? Did you ever smoke?
Belgium	1, 2, 3, 4	Do you smoke? (every day / now or then) Did you ever smoke?
Germany	1, 3, 4	Have you smoked in the past or do you smoke at present?
Spain	1, 2, 3, 4	Do you smoke?
Italy	1, 3, 4	Do you smoke? Yes/ I did / No
Portugal	1, 2, 3, 4	Did you smoke in the last two weeks? How long ago did you stop smoking?

Source: [10]

CHAPTER 3

Educational inequalities in three smoking-related causes of death in 18 European populations

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ABSTRACT

Introduction: Smoking is an important determinant of socioeconomic inequalities in mortality in many countries. As the smoking epidemic progresses, updates on the development of mortality inequalities attributable to smoking are needed. We provide estimates of relative and absolute educational inequalities in mortality from lung cancer, aero-digestive cancers and COPD/asthma in Europe for the early 2000s, and assess the contribution of these smoking-related diseases to inequalities in all-cause mortality.

Methods: We use data from 18 European populations covering the time period 1998-2007. We present age-adjusted mortality rates, Relative Indices of Inequality and Slope Indices of Inequality. We also calculate the contribution of inequalities in smoking-related mortality to inequalities in overall mortality.

Results: Among men, relative inequalities in mortality from the three smoking-related causes of death combined are largest in the Czech Republic and Hungary and smallest in Spain, Sweden and Denmark. Among women, these inequalities are largest in Scotland and Norway and smallest in Italy and Spain. They are often larger among men, and tend to be larger for COPD/asthma than for lung and aero-digestive cancers. Relative inequalities in mortality from these conditions are often larger in younger age-groups, particularly among women, suggesting a possible further widening of inequalities in mortality in the coming decades. The combined contribution of these diseases to inequality in all-cause mortality varies between 13% and 32% among men, and between -5% and 30% among women.

Conclusion: Our results underline the continuing need for tobacco control policies which take into account socioeconomic position.

INTRODUCTION

It is well-established that smoking behavior varies by socioeconomic status and that several causes of death (CoD) are related to smoking [1,2]. The strongest links with smoking have been identified for lung and aero-digestive cancers and Chronic Obstructive Pulmonary Disease (COPD), in which smoking causes at least 50% out of all deaths [3]. Previous studies of inequalities in mortality from smoking- related causes in Europe used data from the 1980s and 1990s as more recent data had not yet become available for most European countries [4,5]. However, due to the progression of the smoking epidemic, smoking rates and social inequalities in smoking have changed dramatically in Europe during the last decades, especially among women [6,7], suggesting that socioeconomic inequalities in smoking-related mortality may have changed as well. In a more advanced stage of the epidemic relatively more individuals with a lower socioeconomic status (SES) smoke compared to more higher-SES smokers in earlier stages, with women lagging behind men in this progression [8]. An analysis of the magnitude of inequalities in smoking-related mortality in Europe in the 2000s is therefore urgently needed.

Previous studies mostly focused on inequalities in lung cancer as the most prominent CoD related to smoking [4,5], but much less is known about inequalities in mortality from aero-digestive cancer [9] or COPD [2]. However, the latter causes, particularly COPD, are non-negligible as far as numbers of deaths are concerned and have to be part of an overall picture. Also, socioeconomic inequalities in COPD mortality may well be different from those for other smoking-related CoD, because the time-lag between taking up smoking and the manifestation of COPD, as well as the time spent with this disease, are different from the other two diseases [10-13].

The aim of this study was to provide estimates of educational inequalities in mortality from three smoking-related causes, for those 30-74 years old, for the early 2000s in 18 European populations, and to also compare the inequality patterns between the different CoD. We also assessed the contribution of the different smoking-related CoD to inequalities in all-cause mortality. In order to distinguish different trends in inequalities in connection with the different stages of the smoking epidemic, we further present age-specific relative inequalities in mortality from lung cancer and from the three selected smoking-related causes combined.

DATA AND METHODS

We obtained mortality data from 18 European populations based on population censuses and vital registries, covering the time period between 1998 and 2007. The data came from

the following European countries and regions: Finland, Sweden, Norway, Denmark, England & Wales, Scotland, the Netherlands, Belgium, France, Switzerland, Austria, Spain (Barcelona, Basque Country, Madrid), Italy (Turin, Tuscany), Hungary, the Czech Republic, Poland, Lithuania, and Estonia. We combined regional data from Barcelona, the Basque Country and Madrid to represent Spain, and data from Turin and Tuscany to represent Italy since national data was not available, and in order to ensure sufficient numbers of deaths for a meaningful analysis. Most datasets were longitudinal and census-linked, except for cross-sectional data from the Czech Republic, Estonia, Hungary and Poland and data from Barcelona and Madrid which were cross-sectional with a linkage between vital registries and population censuses (Table 1). Due to the different study designs and follow-up times, specific correction factors were used to obtain comparable average ages at death [14].

Socioeconomic status was measured by the highest level of education obtained by a person, coded according to the International Standard Classification of Education (ISCED) into three groups: up to a lower secondary education (ISCED 0, 1 and 2), completed secondary education (ISCED 3 and 4), and tertiary education (ISCED 5 and 6).

The analyses were performed by country and sex and for the age range 30 to 74 and for those aged 30-44, 45-59 and 60-74. The analysis for all age groups combined focused on lung cancer (ICD-Code 10: C33-C34) with a population attributable fraction (PAF) of smoking of 86%, (upper) aero-digestive cancers (cancers of lip, oral cavity, pharynx, esophagus, larynx; ICD-Code 10: C00-C15, C32) with a PAF of 71% and COPD/asthma (ICD-Code 10: J40-J47) with a PAF of 76% [3], and on all these smoking-related CoD combined. Due to small numbers of deaths in some age groups we only carried out age-specific analyses for lung cancer and for all combined smoking-related CoD presented here.

Age-standardized mortality rates were calculated by applying direct standardization and using the European standard population [15]. We calculated the standardized rates stratified by sex for the entire population of those 30 to 74 and for the three age groups. The age standardized mortality rates per 100,000 person-years, by sex and level of education for all CoD studied are available in Table A2.3 (in the data summary in appendix II to this thesis). Mortality rates for all combined smoking-related diseases and lung cancer are also shown by age group in Tables A5 and A6 (in the appendix to this paper).

Since both relative and absolute measures of inequality are of importance we present the Relative Index of Inequality (RII) and the Slope Index of Inequality (SII). The RII can be interpreted as the Rate Ratio of mortality among those with the lowest educational level as compared to those with the highest educational level, and the SII can be interpreted as the Rate Difference of mortality among those with the lowest educational level as compared to

those with the highest educational level. Both measures are regression-based and take into account the mortality rates of each educational group as well as the sizes of those groups within each population [16]. To do so, they use the educational level of each person expressed as a rank. This rank places each individual within an educational hierarchy ranging from zero (highest education) to one (lowest education), indicating someone's relative position in a distribution. In this way comparisons of countries with different educational classifications are possible. We used separate education distributions for men and for women.

We calculated the RII, using Poisson regression and including 95% confidence intervals. The SII is a measure of absolute inequality and incorporates the RII and the respective mortality rate resulting in an absolute measure of inequality. The formula is as follows: SII = 2*mortality rate*(RII-1)/(RII+1). The size of the SII depends on the mortality level in the population under study. If it is low the SII will also be low, even if the RII is high. Absolute measures of inequality allow for assessing the contribution of specific CoD to inequalities in all-cause mortality [17]. Hence, SIIs were used to approximate the contribution of inequalities in smoking-related mortality to inequalities in all-cause mortality. A European average value for RIIs and SIIs was calculated as a simple arithmetic mean of the country-specific values.

RESULTS

Figure 1 presents the RIIs for all three smoking-related CoD combined. Countries were ordered geographically in groups, with countries in the North of Europe on the left, then a group of countries in the West, then Spain and Italy in the South, and finally a group of countries in the Center and the East. Among men, there was no clear geographical pattern. The largest RIIs were found in the Czech Republic, Hungary and Scotland, and the smallest RIIs in Sweden, Denmark and Spain. Among women, however, the largest RIIs were found in the North and West, and the smallest RIIs in the South and Center and East. Reverse RIIs were seen in Italy and Spain, only being statistically significant in the latter, and indicating that those with a higher education had higher death rates from these CoD.

The RIIs for the separate CoD studied were usually larger among men with the exception of the Nordic countries, England & Wales and Scotland, where no clear difference between the sexes was observed (Table 2). In addition, larger RIIs were observed among women for COPD/asthma in the Nordic countries and most countries in Western Europe. The RIIs for lung cancer were particularly high in Hungary, the Czech Republic, England & Wales and Scotland among men, and in the Nordic countries, the Netherlands, England & Wales and Scotland among women. Among the latter, smaller RIIs were found in Poland and Estonia as well as in Southern Europe with reverse RIIs in Italy and Spain. The RIIs for COPD/asthma did not show

Table 1: Characteristics of the mortality data used

European Region	Population	Type of dataset	Period	Geographic coverage	Demographic coverage	Person-years of follow-up in dataset	Number of deaths in dataset	% with lower secondary or less education (age 30-74)		% with upper secondary education (age 30-74)		% with post-secondary education (age 30-74)	
								male	female	male	female	male	female
Nordic	Finland	longitudinal	2001-2007	National	20% of Finns are excluded (at random)	17,424,239	264,940	34.7%	33.2%	38.1%	35.4%	27.2%	31.4%
	Sweden	longitudinal	2001-2006	National	whole population	32,008,135	546,267	27.9%	25.6%	52.2%	49.0%	19.9%	25.4%
	Norway	longitudinal	2001-2006	National	whole population	13,286,050	205,702	17.8%	20.9%	56.6%	53.8%	25.6%	25.4%
	Denmark	longitudinal	2001-2005	National	whole population	15,979,413	278,609	34.9%	41.5%	42.4%	33.6%	22.7%	24.9%
West	England & Wales	longitudinal	2001-2006	National	1% of the population	1,639,070	26,941	47.9%	52.5%	31.8%	28.6%	20.3%	19.0%
	Scotland	longitudinal	2001-2006	National	whole population	923,784	15,636	36.3%	38.6%	34.7%	35.2%	28.9%	26.1%
	Netherlands	longitudinal	1998-2003->2003-2007	National	from labor force survey	1,881,763	14,697	32.7%	43.5%	41.5%	38.3%	25.8%	18.2%
	Belgium	longitudinal	2004-2005	National	whole population	12,979,204	200,233	47.4%	49.5%	26.0%	24.6%	26.5%	25.9%
	France	longitudinal	1999-2005	National	1% of the population (born outside France mainland excluded)	1,859,166	27,510	35.4%	45.2%	46.6%	37.1%	18.1%	17.7%
	Switzerland	longitudinal	2001-2005	National	Non-Swiss nationals excluded	18,557,583	267,653	12.9%	25.7%	54.3%	61.1%	32.7%	13.2%
	Austria	longitudinal	2001-2002	National	whole population	5,146,749	73,937	20.0%	38.6%	62.9%	51.4%	17.1%	9.9%
South	Spain (Barcelona)	cross-sectional, linked	2000-2006	Urban	whole population	8,077,659	113,580	51.8%	58.6%	25.0%	19.7%	23.2%	21.7%
	Spain (Basque Region)	longitudinal	2001-2006	Regional	whole population	7,187,634	93,179	51.8%	58.6%	25.0%	19.7%	23.2%	21.7%
	Spain (Madrid)	cross-sectional, linked	2001-2003	Regional	whole population	5,593,910	68,809	51.8%	58.6%	25.0%	19.7%	23.2%	21.7%

Table 1: (Continued)

European Region	Population	Type of dataset	Period	Geographic coverage	Demographic coverage	Person-years of follow-up in dataset	Number of deaths in dataset	% with lower secondary or less education (age 30-74)		% with upper secondary education (age 30-74)		% with post-secondary education (age 30-74)	
								male	female	male	female	male	female
South	Italy (Turin)	longitudinal	2001-2006	Urban	whole population	2,824,493	41,278	55.5%	59.9%	30.0%	27.3%	14.5%	12.8%
	Italy (Tuscany)	longitudinal	2001-2005	Florence, Leghorn, Prato	whole population	1,711,727	16,771	55.5%	59.9%	30.0%	27.3%	14.5%	12.8%
Central/East	Hungary	cross-sectional	1999-2002	National	whole population	24,953,908	531,270	37.0%	49.3%	48.7%	38.5%	14.3%	12.2%
	Czech Republic	cross-sectional	1999-2003	National	whole population	30,308,765	535,309	61.4%	60.3%	25.0%	31.0%	13.6%	8.7%
	Poland	cross-sectional	2001-2003	National	whole population	65,844,117	1,058,745	23.2%	29.4%	65.2%	58.5%	11.7%	12.0%
	Lithuania	longitudinal	2001-2005	National	whole population	9,883,611	179,537	24.3%	22.5%	59.4%	58.6%	16.3%	18.9%
	Estonia	cross-sectional	1998-2002	National	whole population	4,141,440	89,559	28.8%	24.2%	54.1%	56.9%	17.1%	18.9%

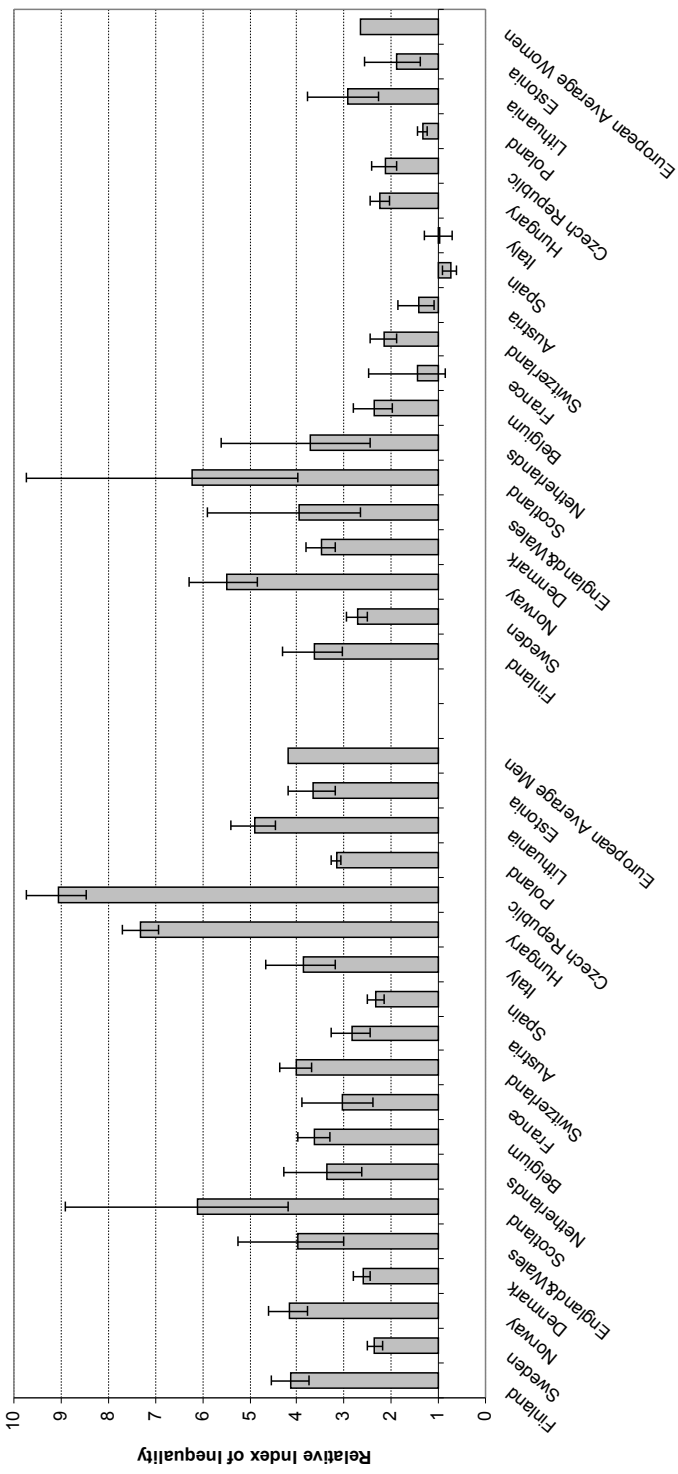

Figure 1: All-age Relative Indices of Inequality (RII) in the rate of death from all selected smoking-related causes of death combined, including 95% confidence intervals (CI), by population and sex, ages 30-74, men left half, women right half

any consistent pattern across countries. They were generally the largest RIIs among all RIIs presented. With regard to aero-digestive cancers, the larger RIIs in men were found in Central and Eastern Europe and in France and Scotland. Among women, the RIIs were largest in England & Wales. Though, since in some countries the confidence intervals were fairly wide, some results have to be interpreted with caution.

In most cases relative inequalities in mortality from the three smoking-related causes decreased with increasing age (Table 3). In France, Austria, Hungary, Poland and Southern Europe the educational gradient for lung cancer was even reversed for older women. This suggests a later start or slower progression of the smoking epidemic in the latter countries. Spain was also the only country in which the RII was smaller than one for women as old as 45-59. Inequalities among Central and Eastern European women were most similar to those in the South of Europe, while Austria and France also displayed a similar pattern. Sex-specific and age-group specific relative inequalities in mortality from all three smoking-related diseases combined were very similar to the inequalities in lung cancer. Further, among women the gradient of the RII against age was steeper than among men, indicating that there is more scope for a further increase of inequalities in mortality among women.

Absolute inequalities in smoking-related mortality associated with education are indicated by the SII (Table 4). As the SII partly depends on the average mortality rate in the population, we present both next to each other, and also include the contribution of inequalities in individual CoD to the inequalities in all-cause mortality. The level of the SII for all three smoking-related CoD combined was extremely high among Hungarian men, followed by those in the other countries in Central and Eastern Europe and Scotland, being the result of both high average mortality rates and large RIIs (Table 2). Except for Sweden with its very low values of the SII, the remaining countries displayed absolute inequalities of a similar level, with slightly higher inequalities in Belgium. Among women the SIIs were generally much lower than among men, as a result of both lower average mortality rates and often smaller RIIs. The largest SII in all smoking-related deaths was found in Scotland, followed by Denmark, Norway and England & Wales. The lowest values were found in France, Austria, Poland and Estonia. In Italy and Spain the values for the SII for all smoking-related deaths combined and for lung cancer were reversed.

The contribution of social inequalities in all three smoking-related diseases combined to inequalities in all-cause mortality amounted to a European average of 22% among men, ranging from 13% in Sweden and Estonia to 32% in Italy. Inequalities in the death rate due to lung cancer on average contributed 12% to the educational inequalities in all-cause mortality, those due to COPD/asthma and aero-digestive cancer contributed 5% and 4% respectively. The contribution of inequalities in lung cancer mortality to inequalities in all-

Table 2: All-age Relative Indices of Inequality (RII) in the rate of death from different causes related to smoking including 95% confidence intervals (CI), by population and sex, ages 30-74

		MEN			WOMEN		
European Region	Population	Lung Cancer	Aero-digestive Cancer	COPD/asthma	Lung Cancer	Aero-digestive Cancer	COPD/asthma
		RII (95% CI)	RII (95% CI)	RII (95% CI)	RII (95% CI)	RII (95% CI)	RII (95% CI)
Nordic	Finland	4.05 (3.59-4.57)	2.77 (2.18-3.53)	5.83 (4.70-7.21)	3.36 (2.71-4.16)	1.91 (1.20-3.04)	6.69 (4.52-9.89)
	Sweden	2.20 (2.02-2.40)	1.89 (1.61-2.22)	3.26 (2.82-3.77)	2.45 (2.21-2.70)	1.80 (1.35-2.40)	3.73 (3.22-4.33)
	Norway	3.86 (3.41-4.37)	3.63 (2.79-4.72)	5.38 (4.42-6.54)	4.60 (3.89-5.44)	2.76 (1.65-4.60)	8.75 (6.91-11.07)
	Denmark	2.08 (1.89-2.28)	2.41 (2.05-2.83)	4.44 (3.87-5.10)	3.11 (2.77-3.50)	1.69 (1.24-2.30)	4.84 (4.16-5.63)
West	England & Wales	4.78 (3.24-7.06)	2.84 (1.56-5.14)	3.57 (2.07-6.14)	2.98 (1.76-5.05)	8.29 (2.28-30.21)	4.94 (2.46-9.94)
	Scotland	6.00 (3.63-9.91)	5.43 (2.46-12.00)	7.19 (3.12-16.61)	6.14 (3.39-11.13)	1.77 (0.57-5.53)	11.03 (4.70-25.93)
	Netherlands	3.51 (2.61-4.73)	1.55 (0.90-2.67)	8.31 (4.09-16.86)	3.15 (1.94-5.11)	1.54 (0.55-4.30)	24.2 (6.22-94.20)
	Belgium	3.56 (3.16-4.00)	2.25 (1.83-2.77)	6.35 (5.06-7.96)	1.95 (1.57-2.43)	2.50 (1.53-4.08)	3.52 (2.48-4.99)
	France	2.55 (1.87-3.48)	4.29 (2.74-6.70)	3.13 (1.28-7.68)	1.09 (0.56-2.13)	1.22 (0.40-3.71)	7.49 (1.43-39.29)
	Switzerland	3.50 (3.14-3.90)	3.60 (3.00-4.33)	7.38 (5.99-9.09)	1.91 (1.62-2.26)	1.65 (1.14-2.38)	3.57 (2.66-4.78)
	Austria	2.46 (2.04-2.98)	2.84 (2.08-3.88)	4.29 (3.05-6.02)	1.22 (0.88-1.69)	1.48 (0.70-3.16)	2.21 (1.24-3.95)
South	Spain	1.82 (1.65-2.00)	3.74 (3.15-4.43)	3.46 (2.77-4.31)	0.56 (0.45-0.70)	1.17 (0.71-1.95)	1.87 (1.09-3.21)
	Italy	3.61 (2.91-4.48)	3.68 (2.23-6.06)	7.23 (3.71-14.10)	0.87 (0.61-1.25)	1.42 (0.56-3.60)	1.12 (0.47-2.67)
Central/East	Hungary	5.61 (5.25-6.00)	8.78 (7.99-9.66)	16.10 (13.72-18.90)	1.62 (1.44-1.81)	2.60 (2.05-3.28)	6.28 (4.95-7.95)
	Czech Republic	8.41 (7.74-9.13)	11.53 (9.79-13.58)	9.69 (7.95-11.80)	1.75 (1.51-2.02)	2.71 (1.82-4.02)	4.40 (3.16-6.11)
	Poland	2.72 (2.61-2.82)	3.06 (2.84-3.30)	7.64 (6.94-8.40)	1.01 (0.93-1.09)	2.39 (1.95-2.94)	2.84 (2.40-3.36)
	Lithuania	3.84 (3.39-4.35)	5.34 (4.39-6.50)	9.07 (7.20-11.44)	1.68 (1.19-2.36)	2.40 (1.25-4.62)	7.45 (4.69-11.84)
	Estonia	3.03 (2.58-3.56)	5.82 (4.24-7.99)	5.10 (3.48-7.48)	1.43 (0.97-2.10)	2.22 (0.91-5.39)	3.50 (1.86-6.59)
	European Average	3.77	4.35	6.42	2.22	2.35	4.95

Table 3: Age-group-specific Relative Indices of Inequality (RII) in the rate of death from lung cancer and all smoking-related causes combined including 95% confidence intervals (CI), by population and sex

		MEN			WOMEN		
European Region	Population	all smoking-related CoD			all smoking-related CoD		
		ages 30-44	ages 45-59	ages 60-74	ages 30-44	ages 45-59	ages 60-74
		RII (95% CI)	RII (95% CI)	RII (95% CI)	RII (95% CI)	RII (95% CI)	RII (95% CI)
Nordic	Finland	6.58 (2.91-14.88)	5.03 (4.22-6.01)	3.77 (3.36-4.22)	7.44 (2.42-22.89)	6.89 (5.09-9.31)	2.50 (2.03-3.09)
	Sweden	4.84 (2.94-7.98)	3.12 (2.74-3.56)	2.07 (1.91-2.24)	7.06 (4.23-11.80)	3.61 (3.15-4.14)	2.26 (2.05-2.49)
	Norway	5.97 (2.83-12.58)	6.78 (5.61-8.21)	3.45 (3.08-3.86)	3.32 (1.55-7.12)	9.12 (7.23-11.49)	4.34 (3.69-5.10)
	Denmark	6.51 (4.26-9.96)	3.51 (3.08-4.00)	2.22 (2.04-2.41)	6.00 (3.76-9.58)	4.29 (3.67-5.02)	3.04 (2.73-3.39)
West	England & Wales	0.74 (0.16-3.38)	4.38 (2.54-7.55)	4.13 (2.95-5.76)	5.80 (0.48-70.12)	3.09 (1.46-6.54)	4.30 (2.66-6.98)
	Scotland	9.97 (0.78-127.22)	4.98 (2.36-10.53)	6.92 (4.37-10.97)	*	8.64 (3.66-20.44)	5.30 (3.16-8.88)
	Netherlands	10.29 (2.07-51.18)	3.20 (2.05-4.98)	3.29 (2.45-4.43)	2.70 (0.57-12.79)	3.88 (2.10-7.17)	3.71 (2.05-6.73)
	Belgium	5.30 (3.07-9.14)	4.88 (4.13-5.76)	3.08 (2.75-3.46)	3.34 (1.63-6.85)	2.98 (2.28-3.90)	1.87 (1.48-2.36)
	France	7.40 (1.94-28.17)	2.82 (1.94-4.12)	3.04 (2.19-4.24)	1.69 (0.32-8.95)	1.34 (0.61-2.93)	1.53 (0.68-3.42)
	Switzerland	8.07 (4.75-13.71)	5.12 (4.36-6.01)	3.53 (3.19-3.91)	4.34 (2.31-8.14)	2.75 (2.20-3.44)	1.75 (1.48-2.08)
	Austria	3.25 (1.39-7.62)	3.47 (2.66-4.53)	2.55 (2.14-3.05)	2.08 (0.66-6.54)	1.81 (1.18-2.77)	1.16 (0.82-1.65)
South	Spain	4.97 (3.39-7.30)	2.58 (2.27-2.94)	2.07 (1.87-2.28)	2.25 (1.28-3.96)	0.77 (0.58-1.02)	0.55 (0.42-0.73)
	Italy	5.96 (1.66-21.39)	4.99 (3.40-7.35)	3.49 (2.80-4.34)	6.18 (1.46-26.19)	1.43 (0.79-2.61)	0.70 (0.49-1.02)
Central/East	Hungary	10.98 (8.98-13.43)	10.81 (10.04-11.64)	4.49 (4.17-4.82)	11.07 (7.99-15.34)	3.49 (3.05-3.99)	1.00 (0.88-1.14)
	Czech Republic	16.21 (9.89-26.58)	13.61 (12.04-15.37)	7.13 (6.55-7.76)	7.06 (3.58-13.94)	3.55 (2.90-4.34)	1.35 (1.15-1.59)
	Poland	9.21 (7.29-11.63)	4.36 (4.11-4.62)	2.69 (2.59-2.80)	11.22 (7.74-16.26)	2.01 (1.79-2.25)	0.96 (0.89-1.05)
	Lithuania	12.17 (6.05-24.47)	6.36 (5.38-7.53)	4.22 (3.76-4.73)	1.37 (0.29-6.46)	4.88 (3.00-7.94)	2.50 (1.87-3.34)
	Estonia	17.49 (6.22-49.20)	4.90 (3.80-6.32)	3.14 (2.69-3.68)	3.60 (0.53-24.55)	3.96 (2.03-7.70)	1.51 (1.07-2.13)
	European Average	7.98	5.39	3.65	6.86	3.80	2.15

Table 3: (Continued)

		MEN			WOMEN		
European Region	Population	Lung Cancer			Lung Cancer		
		ages 30-44	ages 45-59	ages 60-74	ages 30-44	ages 45-59	ages 60-74
		RII (95% CI)	RII (95% CI)	RII (95% CI)	RII (95% CI)	RII (95% CI)	RII (95% CI)
Nordic	Finland	3.92 (1.38-11.13)	5.61 (4.48-7.03)	3.54 (3.07-4.08)	6.15 (1.56-24.20)	5.71 (4.03-8.11)	2.33 (1.78-3.04)
	Sweden	4.15 (2.17-7.97)	3.00 (2.55-3.52)	1.90 (1.72-2.11)	6.77 (3.72-12.33)	2.98 (2.55-3.49)	2.02 (1.78-2.31)
	Norway	8.33 (3.10-22.42)	6.26 (4.96-7.91)	3.11 (2.68-3.60)	2.50 (1.04-6.02)	7.80 (5.92-10.28)	3.41 (2.75-4.22)
	Denmark	4.85 (2.75-8.58)	2.83 (2.39-3.36)	1.75 (1.57-1.96)	5.98 (3.45-10.39)	3.39 (2.82-4.08)	2.76 (2.38-3.24)
West	England & Wales	0.49 (0.06-3.69)	6.04 (2.70-13.54)	4.95 (3.12-7.85)	4.44 (0.25-77.38)	2.35 (0.87-6.34)	3.21 (1.69-6.10)
	Scotland	2.06 (0.03-141.21)	5.19 (1.92-14.00)	6.72 (3.66-12.33)	*	6.14 (2.03-18.56)	5.94 (2.94-11.98)
	Netherlands	34.25 (4.01-292.50)	3.80 (2.21-6.52)	3.12 (2.17-4.48)	3.02 (0.59-15.46)	4.49 (2.15-9.34)	2.24 (1.12-4.49)
	Belgium	6.83 (3.20-14.58)	5.18 (4.18-6.41)	2.89 (2.50-3.33)	1.93 (0.83-4.45)	2.63 (1.91-3.61)	1.43 (1.05-1.96)
	France	14.79 (1.88-116.04)	2.63 (1.63-4.24)	2.31 (1.53-2.48)	3.06 (0.46-20.48)	1.10 (0.41-2.94)	0.82 (0.31-2.19)
	Switzerland	4.42 (2.29-8.53)	4.67 (3.80-5.74)	3.08 (2.71-3.51)	4.00 (1.98-8.09)	2.29 (1.77-2.98)	1.55 (1.24-1.94)
	Austria	1.39 (0.40-4.88)	3.42 (2.42-4.85)	2.17 (1.73-2.73)	1.36 (0.31-5.92)	1.92 (1.14-3.22)	0.87 (0.57-1.34)
South	Spain	3.58 (2.26-5.67)	1.96 (1.67-2.29)	1.65 (1.46-1.86)	1.89 (1.00-3.56)	0.59 (0.43-0.81)	0.36 (0.26-0.51)
	Italy	3.75 (0.80-17.67)	4.93 (3.15-7.70)	3.26 (2.55-4.18)	5.33 (1.09-26.00)	1.60 (0.82-3.11)	0.56 (0.37-0.86)
Central/East	Hungary	9.67 (7.06-13.26)	9.15 (8.27-10.12)	3.52 (3.22-3.84)	9.08 (6.06-13.60)	2.65 (2.25-3.13)	0.70 (0.60-0.81)
	Czech Republic	13.57 (6.67-27.63)	11.05 (9.54-12.81)	7.24 (6.55-8.01)	4.25 (1.92-9.41)	2.79 (2.22-3.50)	1.15 (0.95-1.38)
	Poland	6.89 (5.09-9.33)	3.98 (3.70-4.27)	2.29 (2.18-2.39)	10.92 (7.06-16.90)	1.67 (1.47-1.90)	0.66 (0.60-0.73)
	Lithuania	6.07 (2.04-18.03)	5.13 (4.06-6.49)	3.39 (2.93-3.93)	1.39 (0.18-10.78)	2.94 (1.55-5.56)	1.35 (0.90-2.01)
	Estonia	7.08 (1.79-28.02)	4.15 (3.03-5.69)	2.66 (2.21-3.20)	1.47 (0.12-18.01)	3.82 (1.66-8.79)	1.08 (0.70-1.66)
	European Average	5.99	5.01	3.32	6.33	3.08	1.78

* too few cases of death for a meaningful analysis

Table 4: All-age mortality rates (MR) per 100,000 person-years and Slope Indices of Inequality (SII) for different causes of death related to smoking, by population and sex, ages 30-74

		All-cause		all smoking-related CoD			Lung Cancer			Aero-digestive Cancer			COPD/asthma		
European Region	Population	MR	SII	MR	SII	Inequality contribution to all-cause SII*	MR	SII	Inequality contribution to all-cause SII*	MR	SII	Inequality contribution to all-cause SII*	MR	SII	Inequality contribution to all-cause SII*
MEN															
Nordic	Finland	843	768	93	114	14.8%	59	71	9.3%	12	12	1.5%	22	31	4.1%
	Sweden	623	405	66	53	13.1%	40	30	7.4%	12	7	1.8%	14	15	3.7%
	Norway	634	573	95	116	20.3%	58	68	11.9%	14	16	2.7%	23	31	5.5%
	Denmark	850	628	146	130	20.7%	79	56	8.8%	28	23	3.7%	38	48	7.7%
West	England & Wales	683	500	127	151	30.2%	68	90	17.9%	26	24	4.9%	33	37	7.3%
	Scotland	775	756	144	207	27.4%	80	114	15.0%	30	41	5.5%	34	52	6.9%
	Netherlands	604	464	127	138	29.7%	85	94	20.3%	22	9	2.0%	21	33	7.0%
	Belgium	785	662	154	175	26.5%	96	107	16.2%	27	21	3.1%	32	46	7.0%
	France	771	714	148	149	20.9%	89	78	10.9%	47	58	8.1%	12	13	1.8%
	Switzerland	523	461	90	109	23.5%	56	62	13.4%	21	24	5.1%	15	23	4.9%
	Austria	793	556	130	124	22.3%	76	64	11.6%	29	28	5.1%	25	30	5.5%
South	Spain	698	474	156	124	26.3%	96	56	11.8%	37	42	8.9%	23	26	5.4%
	Italy	577	436	119	140	32.2%	90	102	23.5%	17	19	4.4%	12	18	4.2%
Central/East	Hungary	1676	2274	310	471	20.7%	175	244	10.7%	89	141	6.2%	47	83	3.6%
	Czech Republic	1192	1598	190	305	19.1%	130	205	12.8%	36	61	3.8%	24	39	2.4%
	Poland	1333	1154	217	226	19.6%	148	137	11.9%	39	40	3.5%	30	46	4.0%
	Lithuania	1622	1491	202	268	17.9%	111	130	8.7%	49	67	4.5%	43	69	4.6%
	Estonia	1932	1762	206	235	13.3%	137	138	7.8%	41	58	3.3%	28	37	2.1%
	European Average	940	871	151	180	22.1%	93	103	12.8%	32	38	4.3%	26	38	4.9%

Table 4: (Continued)

		All-cause		all smoking-related CoD			Lung Cancer			Aero-digestive Cancer			COPD/asthma		
European Region	Population	MR	SII	MR	SII	Inequality contribution to all-cause SII*	MR	SII	Inequality contribution to all-cause SII*	MR	SII	Inequality contribution to all-cause SII*	MR	SII	Inequality contribution to all-cause SII*
WOMEN															
Nordic	Finland	375	318	28	31	9.9%	18	19	6.0%	3	2	0.7%	7	10	3.2%
	Sweden	378	269	51	47	17.3%	33	28	10.3%	4	2	0.8%	14	16	6.1%
	Norway	375	322	60	83	25.9%	37	47	14.7%	4	3	1.1%	19	30	9.4%
	Denmark	543	421	114	126	30.0%	64	66	15.7%	8	4	0.9%	42	55	13.0%
West	England & Wales	446	369	68	81	21.9%	35	35	9.5%	8	13	3.5%	24	32	8.6%
	Scotland	510	523	106	154	29.4%	59	84	16.2%	10	6	1.1%	38	63	12.0%
	Netherlands	362	277	56	64	23.1%	37	38	13.8%	7	3	1.1%	12	22	7.8%
	Belgium	430	279	44	36	12.8%	26	17	6.1%	6	5	1.7%	13	14	5.0%
	France	327	236	30	11	4.7%	19	2	0.7%	7	1	0.6%	5	8	3.2%
	Switzerland	269	150	34	25	16.5%	23	15	9.8%	5	2	1.5%	7	7	4.9%
	Austria	396	208	39	14	6.6%	26	5	2.4%	5	2	0.9%	9	7	3.1%
South	Spain	283	133	23	-6	-4.8%	15	-8	-6.3%	3	1	0.6%	4	3	1.9%
	Italy	307	100	32	-1	-1.5%	24	-3	-3.3%	4	1	1.4%	4	0	0.5%
Central/East	Hungary	725	707	75	57	8.1%	47	22	3.1%	11	10	1.4%	17	24	3.4%
	Czech Republic	558	473	40	29	6.1%	28	15	3.2%	4	4	0.8%	8	10	2.1%
	Poland	546	349	42	12	3.5%	30	0	0.0%	5	4	1.2%	8	7	2.1%
	Lithuania	582	483	21	20	4.2%	10	5	1.1%	3	2	0.5%	8	12	2.4%
	Estonia	711	595	25	16	2.6%	15	5	0.9%	3	2	0.4%	7	7	1.2%
	European Average	451	345	49	44	12.0%	30	22	5.8%	6	4	1.1%	13	18	5.0%

*This column is computed by dividing the SII for each CoD by the SII for all-cause mortality. The separate inequality contribution of lung cancer, aero-digestive cancers, and COPD/asthma to the inequality in those smoking-related CoD combined can be computed by dividing the SII of each of these CoD by the SII column "all smoking-related CoD".

cause mortality was particularly high in Italy, the Netherlands and England & Wales, 24%, 20% and 18% respectively. The contribution of COPD/asthma was largest in Denmark, while that of aero-digestive cancer was about twice as high in France and Spain when compared with the other countries.

Among women the combined contribution of the three smoking-related diseases to the inequality in all-cause mortality amounted to a European average of about 12%. While there was a negative contribution in the South of Europe due to the reverse inequalities observed for lung cancer, it was above 20% in countries like Norway, Denmark, England & Wales, Scotland and the Netherlands. Among women in Europe as a whole these figures were 6%, 5% and 1% for lung cancer, COPD/asthma and aero-digestive cancer, respectively. At the same time, the contribution of lung cancer among women was marginal or even negative in some countries such as Spain, Italy, France and Poland, while these contributions were highest in Scotland and Denmark. The contribution of COPD/asthma to inequalities in total deaths was similar among women and men.

DISCUSSION

Summary of results

Among men, relative inequalities in mortality from the three smoking-related causes of death combined are largest in the Czech Republic, Hungary and Scotland and smallest in Spain, Sweden and Denmark. Among women, these inequalities are largest in Scotland and Norway and smallest in France, Austria, and Poland, and especially in Italy and Spain. They are often larger among men than among women, and also tend to be larger for COPD/asthma than for lung and aero-digestive cancers. Relative inequalities in mortality from these conditions are often larger in younger than in older age-groups, particularly among women, suggesting a possible further widening of inequalities in mortality in the coming decades. The combined contribution of these three smoking-related diseases to inequality in all-cause mortality varies between 13% and 32% among men, and between -5% and 30% among women.

Limitations

In international comparisons comparability of information is crucial for arriving at valid conclusions, and in this respect some limitations must be kept in mind. The data we used came from countries in which practices of data collection might differ, influencing comparability and potentially also the size of country-specific inequalities. For example, it has been shown that social inequalities in mortality may be biased in cross-sectional studies when compared to longitudinal studies because of possible numerator/denominator bias [18]. The direction and the magnitude of this bias are not easily assessed and may differ between countries.

A Lithuanian study reported overestimation of educational inequalities in cross-sectional studies. However, this study also showed that despite some over-estimation of mortality rate ratios in the lowest education category, census-unlinked estimates reflect the same pattern of relative mortality inequality as the census-linked estimates [19].

No single SES indicator fully captures the complexity of socioeconomic position. Other SES indicators like wealth or income could also be used [20]. Although the meaning of education can differ by cohort, sex and region the use of education for indicating SES has several advantages. The variable is usually available for men and for women and for older people. It is also easily classifiable according to ISCED. Hence, it fits well with the purpose of this study.

For France the study population excluded those born outside of the country, and in Switzerland all foreign nationals irrespective of place of birth were excluded. Hence, this might have resulted in a more homogenous population leading to an underestimation of inequalities in mortality. As we did not have access to nationally representative data from Spain and Italy these two countries were represented by combining data collected in Barcelona, Madrid and the Basque Country, and in Turin and Tuscany, respectively, and hence mostly include urban areas. National data from Spain and Italy [21], however, also show smaller inequalities in all-cause mortality in these two countries, suggesting that any bias is limited.

We chose to include CoD for which it had been shown that smoking causes at least 50% of their deaths, namely lung and aero-digestive cancers and COPD/asthma, in order to focus on those diseases that are for their most part caused by smoking as opposed to other risk factors. The PAF is considerably lower (33%) only for younger women in the case of lung cancer [3], probably reflecting exposure to other risk factors. As this was the case only for one age group, with a relatively small share in the total number of deaths from lung cancer, it does not change our main conclusions. Further, there are many more CoD related to smoking which we did not include in our analyses because their population attributable fraction is less than 50% (e.g. cancer of the stomach, liver, pancreas, bladder, or ischemic heart disease and stroke [3]). This implies that our results should not be interpreted as indicating the contribution of smoking (i.e., all smoking-related mortality) to inequalities in mortality.

While some CoD like cancers are usually clearly identifiable and easily coded within the ICD-Code system, other CoD like COPD might be less clear-cut [22] and underreporting or misreporting might occur, creating scope for variability in certification and coding practices between countries [23,24]. When defining our variable for COPD/asthma we chose to use a broader definition including chronic bronchitis, emphysema, and asthma (COPD & related conditions: ICD-Code 10: J40-J47). This broad definition might at least partly guard against

the fact that deaths of individuals with COPD are often attributed to other CoD causing underestimation [25].

Interpretations and comparison with other studies

A comparison of our results with those of a previous analysis clearly suggests a further progression of the smoking epidemic in European countries, particularly among women. Among men, the contribution of the inequalities in lung and aero-digestive cancer and in COPD/asthma to inequalities in all-cause mortality remained constant between the 1990s and the 2000s at around 22% for Europe as a whole [17]. We find that relative inequalities due to lung cancer among men increased slightly between the 1990s and the early 2000s [5], as did the contribution of inequalities from lung cancer to all-cause mortality, rising from 11% to 13%. Our results are consistent with previous analyses of inequalities in mortality due to aero-digestive cancer among men [9], showing similar levels of absolute inequalities, while including a wider range of countries.

Among women, since the 1990s several countries seem to have moved to the next stage of the smoking epidemic. We find that among younger women in Spain and Italy relative inequalities in lung cancer mortality are reversing from a positive to a negative association between education and this CoD when compared to the earlier decade [5]. Relative inequalities are often larger in younger than in older age-groups. This may suggest a possible further widening of inequalities in mortality in the future, although it should be kept in mind that rate ratios (RR) observed at a particular point in time are often higher among younger individuals.

When comparing the two countries which are in a similarly early stage of the smoking epidemic, younger women in Italy seemed much further progressed than in Spain, displaying much higher inequalities within the younger age group. We also see indications of a progression of the smoking epidemic in Central & Eastern European countries. Our analysis further illustrates that for women in countries where the smoking epidemic set in slightly earlier than in the South, but still later than in the North, inequalities in lung cancer mortality have been increasing, being a trend that has been driven by younger women. This is not only true for France, as previously shown [26], but also for Austria. As a consequence of this progression of the smoking epidemic among women, the contribution of inequalities in mortality due to the three smoking-related conditions to inequalities in all-cause mortality increased from 6% to 12%, and that of mortality inequalities due to lung cancer from 2% to 6%, when comparing estimates between the 1990s and the 2000s [17]. This is in accordance with a Finnish study which showed that for women, based on indirect estimation of smoking-attributable mortality through lung cancer death rates, the contribution of smoking to inequalities in mortality has increased up to 16% in the period 2006-2010, while remaining at a constantly high level among men [27].

The inequalities in smoking-related mortality documented here are generally consistent with the European pattern of inequalities in smoking. The reversal of inequalities in smoking among women in the South was also found in survey data [28-30]. The larger RIIs for mortality from three smoking-related causes in Scotland as compared to England & Wales mirror larger inequalities in survey-reported smoking in Scotland [31,32]. On the other hand, RIIs were often higher in Norway and Finland compared to Sweden and Denmark, without inequalities in survey-reported smoking being a clear explanation [17,29,30].

Different inequality patterns between lung cancer, aero-digestive cancer and COPD

Inequalities in alcohol consumption may partly explain the differences in the European patterns of relative inequalities between lung and aero-digestive cancers, as heavy alcohol consumption is a risk factor for aero-digestive cancer, being strongly socially patterned in Southern and Eastern Europe [9,33].

The different patterns of the RIIs for lung cancer and COPD/asthma are particularly interesting. Contrary to lung cancer, RIIs for COPD/asthma were similar among men and women in the majority of the countries. In addition, while for women in Spain and Italy the RII was below one for lung cancer it was above one for COPD/asthma, with both countries being in a similar late-comer position within the smoking epidemic. This phenomenon might be explained by one or more of the following factors. First, partly different risk factors affect lung cancer and COPD/asthma. The PAF of smoking is higher for mortality from lung cancer (86%) than for COPD (76%) [3]. As a consequence, lung cancer mirrors inequalities in smoking prevalence more closely than COPD/asthma, and inequalities in other risk factors such as housing and working conditions or early-age lower respiratory tract infections could partly drive inequalities in COPD/asthma [34]. Secondly, the two diseases differ with respect to the time-lag between taking up smoking and the manifestation of the disease as well as in the time spent with the disease [11-13]. Whereas the lag time between smoking and the development of disease is usually shorter for COPD (10-20 years) than for lung cancer (20-30 years), the time with disease is much longer for COPD than for lung cancer which is usually rapidly fatal. Although the time-lag between smoking and mortality may be similar for lung cancer and COPD, given the long time spent with COPD inequalities in mortality due to this disease are likely to also reflect possible effects of health care. Inequalities in health care utilization are less gender-patterned than inequalities in smoking and are likely to show similar inequalities by level of education among men and women. In their systematic review of COPD and socio-economic status Gershon et al. [35] find a significant inverse relationship between income and the rate of hospitalization for COPD. Prescott and Vestbo [34] arrive at similar conclusions. Finally, gender itself may also be a relevant factor in why the typically female inequality pattern is less pronounced for COPD/asthma. The excess mortality among subjects

suffering from COPD/asthma was larger among women than among men, even though the severity of the disease was similar and smoking rates were lower [36,37].

Policy implications and conclusion

The contribution of smoking to inequalities in all-cause mortality differs between countries and between men and women. Hence, the scope for the reduction of inequalities in mortality by tackling inequalities in smoking will differ accordingly. The effectiveness of policies and interventions to reduce inequalities in smoking is limited, with only some policies, such as price increases having proven to be effective in reducing inequalities [38,39]. We show that with effective policies a significant reduction of absolute inequalities in mortality could be achieved among men in all European countries but Sweden. The scope for reduction is particularly large in Central and Eastern Europe, even if absolute inequalities in total mortality still remained extremely high, and it is also substantial in Scotland and Belgium. Interestingly, inequalities could also be strongly reduced in Italy and the Netherlands, where inequalities in all-cause mortality are moderate. Such policies could also prevent a large widening of inequalities due to the foreseen progression of the smoking epidemic in many countries. Tackling smoking would also reduce inequalities in other CoD not included in our analyses.

There obviously is a continuing need for tobacco control policies which take into account socioeconomic position. Given the time-lag between taking up smoking, disease incidence and mortality, potential inequality reductions will only become visible in the medium and long run [40]. In addition, relative inequalities are likely to remain high. Absolute inequalities will be the ones to mirror any decreases in mortality rates and should therefore be monitored closely.

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APPENDIX TABLES

Table A5: Age-standardized mortality rates per 100,000 person-years, by age, sex and level of education; all smoking-related mortality

Cause of Death	European Region	Population	Level of Education	MEN				WOMEN			
				30-44	45-59	60-74	30-74	30-44	45-59	60-74	30-74
All smoking-related	Nordic	Finland	low	6.1	85.2	381.1	120.9	3.4	36.6	96.8	37.1
			middle	3.1	56.7	266.1	82.9	1.8	18.4	68.8	23.2
			high	1.6	23.6	140.3	41.3	0.9	10.2	53.6	16.3
		Sweden	low	7.3	61.9	250.3	82.9	9.5	66.5	172.3	67.9
			middle	3.9	43.1	193.9	61.7	4.0	43.4	134.9	48.5
			high	1.9	21.4	124.1	36.9	2.1	22.1	76.4	26.5
		Norway	low	9.4	112.4	435.9	144.9	7.5	97.4	242.8	94.7
			middle	4.5	61.9	278.1	88.1	4.8	43.2	136.9	49.2
			high	2.4	20.3	144.3	41.3	2.8	15.5	69.3	22.6
		Denmark	low	16.8	136.9	549.1	182.7	14.1	115.8	420.2	144.4
			middle	8.2	99.1	436.2	139.4	7.0	65.4	286.6	92.3
			high	4.0	43.4	260.2	76.9	4.0	40.2	168.0	54.8
	West	England & Wales	low	6.2	115.0	502.9	159.7	5.8	56.4	262.1	82.9
			middle	12.1	68.4	290.7	96.4	3.5	25.3	148.0	44.4
			high	5.9	40.7	198.1	62.5	1.5	34.7	100.0	36.3
		Scotland	low	8.0	116.2	611.1	185.4	5.4	104.3	411.6	134.7
			middle	9.5	55.9	336.4	101.0	2.5	42.6	235.5	70.4
			high	0.0	44.8	164.0	54.0	0.0	28.2	125.3	39.0
		Netherlands	low	12.3	110.8	550.7	171.4	7.7	63.6	181.8	68.2
			middle	4.5	75.2	390.9	118.7	5.1	40.8	122.7	45.2
			high	2.7	47.3	202.4	64.7	4.4	21.5	63.7	24.2

Table A5: (Continued)

Cause of Death	European Region	Population	Level of Education	MEN				WOMEN			
				30-44	45-59	60-74	30-74	30-44	45-59	60-74	30-74
All smoking-related	West	Belgium	low	14.1	166.0	534.2	189.1	7.3	56.5	119.9	51.4
			middle	7.9	96.6	362.9	121.8	4.2	40.7	91.2	37.6
			high	4.7	57.7	249.1	80.1	3.5	26.5	80.9	29.7
		France	low	18.3	188.3	457.1	181.8	4.7	33.0	67.2	29.5
			middle	10.4	151.0	313.6	132.1	10.1	34.9	56.3	29.9
			high	3.0	66.1	167.0	64.0	1.1	23.9	52.0	21.2
		Switzerland	low	15.1	135.8	409.1	149.8	7.5	50.6	98.7	44.4
			middle	7.7	75.6	266.2	91.9	4.4	30.6	75.3	30.3
			high	2.8	36.5	142.6	47.2	1.7	22.0	55.7	21.6
		Austria	low	15.2	170.4	460.2	174.5	5.3	50.9	92.7	42.3
			middle	10.1	122.5	335.7	126.2	5.1	41.0	94.1	38.8
			high	5.5	48.2	193.6	64.2	1.7	28.5	46.4	21.9
	South	Spain	low	18.7	165.4	473.1	177.0	6.4	24.5	44.8	21.9
			middle	9.6	123.6	362.2	132.5	5.5	33.2	79.4	32.7
			high	7.1	87.9	298.7	103.6	3.5	26.5	52.0	23.2
		Italy	low	9.1	106.1	436.5	142.5	6.7	27.9	88.3	33.2
			middle	4.5	56.9	273.6	85.2	4.0	28.1	104.3	35.8
			high	2.5	33.6	172.8	52.8	0.8	17.6	106.0	31.0

Table A5: (Continued)

Cause of Death	European Region	Population	Level of Education	MEN				WOMEN			
				30-44	45-59	60-74	30-74	30-44	45-59	60-74	30-74
All smoking-related	Central/East	Hungary	low	85.7	611.9	888.1	465.9	29.8	112.7	163.2	91.3
			middle	34.0	215.1	417.7	189.2	11.3	65.9	158.4	65.2
			high	6.8	95.1	313.9	109.6	3.3	44.1	175.7	57.7
		Czech Republic	low	14.6	229.7	688.6	248.4	4.9	42.8	114.3	44.0
			middle	5.3	86.0	313.7	105.6	2.0	26.5	108.5	35.4
			high	1.5	31.2	173.6	51.7	1.3	12.9	73.2	21.9
		Poland	low	25.3	271.0	797.5	292.8	10.5	53.1	104.5	47.9
			middle	10.6	168.1	607.4	205.1	4.0	45.5	120.1	46.0
			high	2.2	44.3	221.3	67.7	1.1	21.9	79.4	26.7
		Lithuania	low	25.9	300.9	750.2	293.6	2.8	45.2	66.7	33.3
			middle	8.8	159.9	443.0	164.1	2.3	16.5	45.4	17.4
			high	3.6	50.7	214.0	69.0	2.3	12.8	32.8	13.1
		Estonia	low	28.0	255.9	767.8	281.5	5.4	34.1	77.4	32.5
			middle	7.7	157.5	569.9	191.5	3.7	21.2	82.2	28.1
			high	4.0	52.3	247.7	77.4	2.2	9.4	35.5	12.5

Table A6: Age-standardized mortality rates per 100,000 person-years, by age, sex and level of education; Lung cancer mortality

Cause of Death	European Region	Population	Level of Education	MEN				WOMEN			
				30-44	45-59	60-74	30-74	30-44	45-59	60-74	30-74
Lung Cancer	Nordic	Finland	low	3.0	55.3	238.6	76.1	2.3	25.1	57.5	23.4
			middle	1.8	34.8	174.3	53.3	1.2	14.2	39.0	14.6
			high	1.1	14.3	90.1	26.3	0.7	7.6	35.7	11.2
		Sweden	low	4.2	40.4	145.8	50.0	7.1	49.6	97.6	43.6
			middle	2.3	28.6	114.2	37.6	3.1	35.3	79.7	32.6
			high	1.3	14.7	79.5	24.1	1.6	19.0	47.2	18.5
		Norway	low	7.1	74.8	253.5	88.4	5.4	67.5	133.5	57.9
			middle	2.2	40.5	167.6	54.1	3.7	31.6	82.2	32.0
			high	1.5	15.6	93.6	27.7	2.4	12.5	45.6	16.0
		Denmark	low	8.5	72.8	282.4	94.8	10.5	77.8	208.2	80.6
			middle	4.6	57.4	242.6	78.4	5.6	48.4	151.0	54.7
			high	2.6	27.9	164.8	48.9	2.8	31.3	84.5	32.1
	West	England & Wales	low	3.1	59.2	285.8	88.3	3.7	28.9	131.3	42.1
			middle	6.9	32.6	157.7	50.8	2.0	16.4	79.0	24.9
			high	4.5	14.8	95.1	28.9	1.5	19.4	64.2	22.4
		Scotland	low	0.0	67.0	343.8	103.1	3.0	55.3	234.2	75.0
			middle	4.1	34.4	209.2	62.0	1.2	26.7	128.2	39.6
			high	0.0	23.7	84.2	28.0	0.0	17.9	65.7	21.6
		Netherlands	low	10.7	79.6	366.1	117.2	7.0	47.6	102.7	44.0
			middle	2.8	49.6	250.5	76.5	5.1	26.8	97.5	34.2
			high	0.9	30.5	150.4	45.9	3.3	16.4	42.7	17.2

Table A6: (Continued)

Cause of Death	European Region	Population	Level of Education	MEN				WOMEN			
				30-44	45-59	60-74	30-74	30-44	45-59	60-74	30-74
Lung Cancer	West	Belgium	low	7.6	103.1	332.9	117.3	4.4	38.6	59.7	29.8
			middle	4.9	58.3	232.4	76.6	3.4	29.1	51.2	23.9
			high	1.8	34.8	162.2	50.6	2.9	19.7	46.7	19.2
		France	low	10.2	118.3	268.6	109.5	4.7	19.0	34.8	16.9
			middle	3.4	88.5	194.0	78.7	6.9	23.5	36.6	19.9
			high	1.5	51.9	136.0	51.0	0.0	14.5	44.1	15.5
		Switzerland	low	7.0	82.4	239.3	88.1	5.8	37.2	60.0	29.9
			middle	4.9	44.8	168.8	57.1	3.8	24.1	47.2	21.3
			high	2.2	24.1	92.6	30.9	1.3	18.8	39.4	16.5
		Austria	low	4.1	99.6	262.5	98.6	2.9	34.6	56.1	26.9
			middle	5.3	70.0	203.7	74.6	3.2	28.1	64.2	26.4
			high	3.0	30.0	129.9	42.0	1.7	15.9	37.7	15.2
	South	Spain	low	11.6	101.0	279.0	105.9	4.8	16.7	24.8	13.8
			middle	6.9	79.3	237.7	86.5	4.3	26.4	51.7	23.4
			high	5.3	66.0	201.3	72.6	3.0	20.9	38.0	17.7
		Italy	low	5.2	78.1	332.1	106.8	5.3	23.7	59.3	24.5
			middle	3.4	44.4	212.6	66.2	3.3	22.5	79.4	27.8
			high	1.7	22.8	139.9	41.0	0.8	14.2	78.6	23.5
	Central/East	Hungary	low	34.0	310.9	531.4	251.1	18.0	68.7	95.0	54.6
			middle	13.5	113.5	281.3	111.9	7.6	44.3	110.4	44.7
			high	4.4	61.7	219.8	74.8	2.3	34.6	127.5	42.8

Table A6: (Continued)

Cause of Death	European Region	Population	Level of Education	MEN				WOMEN			
				30-44	45-59	60-74	30-74	30-44	45-59	60-74	30-74
Lung Cancer	Central/East	Czech Republic	low	6.5	144.0	494.7	168.9	2.9	30.7	76.6	30.1
			middle	2.6	58.8	221.7	73.4	1.6	21.0	80.5	26.8
			high	0.8	23.0	125.9	37.5	1.0	11.5	49.7	16.0
		Poland	low	13.8	177.6	530.1	192.5	7.4	37.8	62.8	31.4
			middle	6.7	113.4	436.5	144.3	2.9	35.5	87.3	34.3
			high	1.7	34.5	171.2	52.5	0.7	18.5	62.8	21.5
		Lithuania	low	7.8	142.5	418.2	151.6	0.0	23.4	26.1	14.7
			middle	4.2	81.3	262.4	91.8	1.6	9.9	23.5	9.7
			high	1.6	32.1	150.2	46.8	0.9	9.0	20.3	8.3
		Estonia	low	11.9	154.4	509.8	178.4	3.6	23.4	41.3	19.6
			middle	4.9	105.5	400.7	132.5	1.7	13.3	53.8	17.9
			high	3.2	33.8	194.0	58.0	2.2	6.9	23.8	8.9

CHAPTER 4

Comparison of tobacco control scenarios: quantifying estimates of long-term health impact using the DYNAMO-HIA modeling tool

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ABSTRACT

Background: There are several types of tobacco control interventions/policies which can change future smoking exposure. The most basic intervention types are 1) smoking cessation interventions 2) preventing smoking initiation and 3) implementation of a nationwide policy affecting quitters and starters simultaneously. The possibility for dynamic quantification of such different interventions is key for comparing the timing and size of their effects.

Methods and Results: We developed a software tool, DYNAMO-HIA, which allows for a quantitative comparison of the health impact of different policy scenarios. We illustrate the outcomes of the tool for the three typical types of tobacco control interventions if these were applied in the Netherlands.
The tool was used to model the effects of different types of smoking interventions on future smoking prevalence and on health outcomes, comparing these three scenarios with the business-as-usual scenario. The necessary data input was obtained from the DYNAMO-HIA database which was assembled as part of this project.
All smoking interventions will be effective in the long run. The population-wide strategy will be most effective in both the short and long term. The smoking cessation scenario will be second-most effective in the short run, though in the long run the smoking initiation scenario will become almost as effective. Interventions aimed at preventing the initiation of smoking need a long time horizon to become manifest in terms of health effects. The outcomes strongly depend on the groups targeted by the intervention.

Conclusion: We calculated how much more effective the population-wide strategy is, in both the short and long term, compared to quit smoking interventions and measures aimed at preventing the initiation of smoking. By allowing a great variety of user-specified choices, the DYNAMO-HIA tool is a powerful instrument by which the consequences of different tobacco control policies and interventions can be assessed.

INTRODUCTION

After half a century of tobacco control policy, a vast range of interventions has been proposed, evaluated and implemented with varying degrees of success, though none of these have turned out to be fully effective in the worldwide eradication of tobacco consumption as a deadly habit [1,2,3]. In the Netherlands overall smoking prevalence is still high at 27% and has remained relatively constant over the past decade. Among adolescents 21% declared to be smoking in 2010 [4]. Policymakers are required to choose which of the numerous interventions to implement, but lack quantitative information on the long term impact of such interventions on population health. Would it be more effective to target smoking interventions to stimulate smokers to quit, or to discourage adolescents from initiating smoking, or should policy measures be targeted population-wide by advertisement restrictions, smoke-free public places or tobacco price adjustments? And how will this affect the smoking distribution and population health in the short and long term? Existing Dutch tobacco control policies and interventions currently include some in-school smoking prevention interventions for those aged 10 to 12 and smoking cessation interventions for adults. The latter mainly consist of telephone help lines, intensive telephone coaching, and tailored online quit smoking advice. Regarding population-wide tobacco control policies the Netherlands has implemented advertising restrictions, health warnings and smoke-free legislation, but there is potential for even more stringent legislation like a further tax increases, as currently the tax percentage of the retail price of cigarettes is still below the officially recommended level [3].

Interventions differ in terms of their effectiveness and their ability to reach different population groups. All vary in terms of efforts and implementation costs [5]. Changing demographic characteristics, competing morbidity as well as age-dependent patterns of disease incidence, mortality and relative risks (RRs) associated with smoking complicate the possibilities to quickly oversee the consequences of tobacco control scenarios on future population health, and hamper informed decision making.

We developed a software tool, DYNAMO-HIA, which allowed us to make a quantitative comparison of the health impact of different policy scenarios over time, by comparing the policy scenario with the "business-as-usual" scenario, i.e. no change as compared to the current situation. The tool has been described in more detail elsewhere [6]. Here we will illustrate the capacities of the DYNAMO-HIA model to estimate the long term health impact of three typical types of tobacco control interventions if these were applied in the Netherlands, alluding to Rose's distinction between high-risk vs. population wide approaches [7]. We concentrate on the following interventions: 1) smoking cessation interventions in adult smokers 2) preventing smoking initiation in adolescents and 3) implementation of a nationwide intervention affecting quitters and starters simultaneously, by adjusting the price of cigarettes

through increased taxation. Using these three scenarios, we demonstrate the possibilities to dynamically quantify notions which are known intuitively. To measure the impact on health we focus on the future prevalence of smoking-related chronic diseases such as lung cancer, chronic obstructive pulmonary disease (COPD) and ischemic heart disease (IHD), as well as on mortality.

METHODS

Description of DYNAMO-HIA

DYNAMO-HIA is a recently-developed Markov type, multi-state simulation software. It was developed to allow researchers and policy makers in the field of Health Impact Assessment (HIA) to 1) quantify the development of risk factor exposure over time and to 2) estimate the impact of these changes in risk factor exposure on disease prevalence, mortality and on summary measures of population health. DYNAMO-HIA is a dynamic tool that synthesizes data according to the causal epidemiological pathway, linking risk factor exposure through relative risks (RRs) of incidence of associated diseases and death, to prevalence of diseases, mortality and summary measures of population health, and allowing to take into account relative risks by "time since quitting smoking" and age, as well as competing risks. Following the epidemiological causal chain implies that the model uses relative risks by risk factor class, i.e. incidence in exposed risk factor classes are a multiple of the incidence in the non-exposed. A change in risk factor exposure due to the policy or intervention thus changes disease incidence and in turn disease prevalence and mortality. The effect of the risk factor change on mortality through diseases not included in the model, i.e. other-cause mortality, is taken into account by additionally using the relative risk on total, i.e. all-cause, mortality. Other mortality is derived from total mortality and disease specific mortality, assuming additive mortality [8].

In order to isolate the effects of the intervention DYNAMO-HIA always compares one or more intervention scenarios which result in a modified risk factor prevalence and/or modified transition rates, with the reference or business-as-usual scenario.

DYNAMO-HIA requires input such as 1) demographic data, including population numbers, numbers of future newborns and all-cause mortality, and 2) epidemiological information on incidence, prevalence and mortality (IPM) for relevant diseases, risk factor exposure, as well as relative risks linking exposure to disease and to all-cause mortality, all by age and sex. The present version of the DYNAMO-HIA software package, which is publicly available at: www.dynamo-hia.eu, includes input data on risk factor prevalence, relative risks, and IPM information for nine diseases for a large set of EU member states. The diseases included in

the model are diabetes, ischemic heart disease, stroke, lung cancer, oral cancer, esophageal cancer, colorectal cancer, breast cancer and COPD. The risk factors include the body mass index (BMI), alcohol and tobacco consumption. Time since quitting smoking is taken into account by including prevalence and relative risks in former smokers by time since quitting. The model provides output on summary measures of population health such as life expectancy with and without disease, mortality, survival as well as disease and risk factor prevalence by age and sex. The effect of an intervention or policy on future risk factor exposure and future health is assessed by comparing one or more scenarios with a specific intervention or policy change to a scenario without any intervention, so business-as-usual. The effects of the intervention or policy on the risk factor prevalence in the first year and/or on transitions between risk factor states (i.e. smoking (re) start and quit rates) are given by the user. The risk factor prevalence in future years is an outcome of the model. The theoretical specifications of the model have been described elsewhere [6].

Three smoking intervention scenarios and a reference scenario

We evaluated the effects of three intervention scenarios, each reflecting one of the three basic types of tobacco control: 1) interventions to increase quitting, 2) interventions to reduce smoking initiation and 3) policies reducing population-wide smoking. Interventions to increase the quit rate among smokers are usually targeted towards adults and include measures such as counseling and personal or grouped pharmacological and/or psychological therapy. Interventions to decrease or prevent smoking initiation usually target adolescents and are often school-based interventions. Nationwide policy measures for population-wide smoking reduction, such as the use of tobacco price taxation, affect quitting and starting simultaneously.

Each intervention scenario is characterized by a change in smoking prevalence in the first year, i.e. just after the intervention or policy, and/or by changed (re)start and quit rates, as compared to the reference scenario. In addition, the proportion of the target population that will effectively be reached by the intervention characterizes the intervention scenario. We modeled both a maximum scenario, which gives a better impression of the varying effects over age and time for maximally effective interventions, versus a more realistic scenario version. To quantify the order of magnitude of the change in smoking prevalence and/or (re) start and quit rates in the target population, we evaluated systematic reviews/meta-analyses, and where necessary, primary articles of intervention studies, based on a PubMed literature search.

Reference scenario

The reference scenario starts from the current prevalence of never, former and current smokers by age and sex, and from current transition probabilities between the risk factor

states over the life course. The current prevalence e.g. specifies what percentage of those presently 20 years old are never, former or current smokers and the current transition rates, i.e. (re)start and quit rates of smoking, specify how many of the currently 20 years old never smokers will remain never smokers when they are 21, 22 etc. years old, and how many start smoking when they are 21, 22 etc. years old. The current prevalence and transition rates relate to the business-as-usual situation, that is, a situation with smoking control measures that are already in place, but without the specific intervention. Dutch baseline prevalence of smokers, former smokers and never smokers and smoking (re)start and quit rates used here can be found in Tables A1.1 and A1.2 (in the data summary in appendix I to this thesis). The DYNAMO-HIA database provided information on smoking prevalence, i.e. the percentage of current smokers, former smokers and never smokers for ages 16 and over, based on the POLS study [9] (for further information please refer to the data documentation section of the DYNAMO-HIA project website: www.dynamo-hia.eu). Smoking prevalence, i.e. the percentage of smokers and the percentage of non-smokers for ages 10 to 15 was derived from Stivoro's Jeugdmonitor (Youth monitor) [10], which is the Dutch center for expertise on tobacco prevention. The age- and sex specific start, quit and restart rates for ages 16 years and over were also based on information available through Stivoro [11]. For ages up to age 16, "net" smoking initiation rates were estimated using a standard life table of a cohort of non-smokers, whose number decreases with age because persons take up smoking. Using net initiation rates means that flows into the non-smoking state are not explicitly modeled, e.g. if 100 adolescents start smoking and 4 quit, the net uptake is 96. Also restart rates are not separately modeled at these ages.

Relative risks from smoking categories to diseases and all-cause mortality used in this analysis as well as an overview of the age-specific disease prevalence at baseline are also included in appendix I to this thesis (Tables A1.3 and A1.4).

The "smoking cessation intervention": change in quit behavior

For the first scenario, the "smoking cessation intervention", we chose an odds ratio (OR) of 2.0 reflecting that the ORs quantifying the effects of interventions on cessation rates varied from 1.4 to 2.2 among persons aged 18 years and over to which these interventions are usually targeted [12,13,14,15,16]. This resulted in post-intervention cessation rates about twice as large as in the reference scenario. These were assumed to remain constant over the entire projection period.

The "smoking initiation intervention": change in start behavior

For the second scenario, the "smoking initiation intervention", we assumed a 50% decrease in the smoking initiation rate for those at school ages 10-18 in the maximum scenario, and a 20% reduction in the realistic scenario version, reflecting that the literature showed mixed

results varying from no effects to a significant reduction in start rates [17,18,19]. These post-intervention initiation rates were assumed to remain constant over the entire projection period.

The "population-wide smoking control policy": change in (re)start and quit behavior

For the third scenario, the "population-wide smoking control policy", we almost doubled the price of tobacco products. That is, we chose to use a 95% increase in the price of tobacco in the maximum scenario, which reflects the price adjustment if the Netherlands was to increase the price of tobacco to match the price of tobacco in Ireland, which currently has the highest tobacco price in the EU [20]. In the realistic scenario version, we assumed a smaller price increase of 20%.

The effect of the price increase on smoking is based on a price elasticity, which measures the average proportional reduction in demand when the price of a commodity increases. We used a price elasticity of smoking prevalence of -0.4 for persons aged 21 and over and of -0.7 for persons up to age 20, who usually show greater responsiveness [21]. Hence, we assumed that a 95% increase in price in the maximum scenario leads to a 66.5% (i.e. 0.7*95%) reduction in smoking prevalence among persons below age 21, and for persons aged 21 and over to a 38% (i.e. 0.4*95%) reduction. In the realistic scenario, we used 14% and 8%, respectively. Given that most smokers start smoking before age 21, we further assumed that for adults the decrease in prevalence of smokers originates from an increase of former smokers, i.e. higher quit rates and not from lower start rates, and that the adults who quit smoking do so immediately after the price increase, that is, we assumed that they will not show any delayed change in smoking status in the years after the price change. Therefore, we left their future transition probabilities unchanged, except for the restart rates. Restart rates were adjusted by the same percentage as the start rates, based on the assumption that if persons quit because of the higher price, this high price will also reduce their likelihood to restart smoking in the future. These new start rates were assumed to be valid during the whole projection period. For persons up to the age of 20 we assumed that decreases in the prevalence of smoking originate from an increase in never smokers, i.e., fewer people starting to smoke. We also assumed that children in future years, upon reaching the ages where they would take up smoking, would have the same smoking prevalence as their peers after the intervention. Given the higher price they are assumed to be less likely to start smoking as compared to the situation with the lower price. To ensure that the future prevalence of smoking among adolescents remained at this post-intervention level, starting rates were obtained that are consistent with the new, lower smoking prevalence, also using the above life table approach.

Reach of the interventions

In the maximum scenarios, we assumed that 100% of the target population will be reached by the interventions. However, given that the size of the population that will be reached by an intervention is likely to be smaller, and is likely to differ by type of intervention, we assumed a lower reach for the smoking cessation intervention and the smoking initiation intervention in the realistic scenario versions. Considering that approximately 40% of smokers are willing to give up smoking in the coming year [22], and assuming that, due to possible supply-side constraints of such interventions, only about 50% of those wanting to quit will actually participate in the interventions, we used a reach of 20%. In the realistic version of the smoking initiation intervention we assumed that, while virtually all adolescents are at risk of taking up smoking, only half of them will be reached by these school interventions. For the population-wide smoking control policy, we assume that both in the maximum and realistic scenarios virtually the whole population will face the higher price, and hence made no distinction between the reach of the maximum and realistic scenario versions. The assumptions for the maximum and realistic scenario versions are summarized in Table 1.

We compared the changing patterns of smoking prevalence and health impact of each of these scenarios with the reference scenario over time, using DYNAMO-HIA.

Table 1: Interventions used in this paper, maximum vs. realistic scenarios versions

Scenario	Maximum scenario versions+		Realistic scenario versions++	
	Impact	Reach	Impact	Reach
1. "Smoking Cessation Intervention" Targeting adult smokers (18 yrs and over) to quit through quit intervention	OR: 2.00 on quit rate	100% of smokers	OR: 2.00 on quit rate	20% (40% smokers want to quit * 50% of those are reached)
2. "Smoking Initiation Intervention" Targeting adolescents (10-18 yrs) not to start through an in-school intervention	50% decrease of start rate	100% of non-smokers	20% decrease of start rate	50% (100% at risk to start, 50% reached)
3. "Population-wide Smoking Control Policy" Targeting entire population through a price increase (95% in max. and 20% realistic scenario)	Ages up to 20: increase never smokers by 66.5% and reduction of start rates. Ages 21 and above: increase former smokers by 38%. Decrease of restart rate to 30% of reference.	100% of entire population	Ages up to 20: increase never smokers 14% and reduction of start rates. Ages 21 and above: increase former smokers 8%. Decrease of restart rate to 80% of reference.	100% of entire population

+See Figures 1a-c, 2a-f and 3, Table 2 for results

++See Figures A4a-c, A5a-f and A6, Table A3 for results, in the appendix to this paper

RESULTS

Effect of interventions on future prevalence of current, former and never smokers

The smoking cessation intervention will cause an initially strong decrease in the prevalence of current smokers, mirrored by an increase in the prevalence of former smokers as compared to the reference scenario (Figure 1a-c). By definition the prevalence of never smokers is not affected by this intervention. In the first years after the intervention, the prevalence of current smokers decreases more quickly than in the reference scenario, yielding an increasing reduction in the prevalence of current smokers due to the intervention. After 15 years (year 2025), this reduction in the prevalence of current and former smokers becomes stable. In the smoking cessation scenario the prevalence of current smokers is estimated to fall to 14% in 2035, versus 20% in the reference scenario.

The smoking initiation intervention also causes a decrease in the prevalence of current smokers as compared to the reference scenario, but it is smaller than in the smoking cessation scenario. In the short-term this decrease is mirrored by a similar increase in the prevalence of never smokers and no change in the prevalence of former smokers (Figure 1a-c). The overall prevalence of current smokers decreases steadily and more rapidly than in the reference scenario, causing a major change in the age-distribution of current smokers over time (Figure 2a-f). Initially the reduction in smoking prevalence rates due to the intervention only occurs at younger ages. Increased projection time allows the effects to expand to older ages as the adolescents affected by the intervention reach adulthood and in the end old age.

Compared to the reference scenario, the population-wide smoking control policy causes an immediate decrease in the prevalence of current smokers, reflecting that the price increase is assumed to affect behavior virtually immediately. Evidently, this decrease is initially accompanied by a higher prevalence of former and never smokers, as in the model adults were assumed to quit and adolescents not to take up smoking in response to the price increase. Further, in the longer run the prevalence of former smokers becomes lower than in the reference scenario (Figure 1a-c), reflecting that less smoking initiation reduces smoking prevalence and in turn reduces former smoking prevalence. The population-wide smoking control policy affects the prevalence of current smokers in all age groups. Initially an increase of former smokers is seen at all ages, reflecting the massive number of individuals quitting due to the doubling of the price. With increasing projection time the prevalence of former smokers drops below their prevalence in the reference scenario. This effect starts at the youngest ages and with time expands to older ages (Figure 2a-f). This pattern is the net effect of two opposing effects. Firstly, an immediate increase in prevalence of former smokers due to the price increase, and secondly, a delayed opposite effect reflecting that less smoking initiation reduces current smoking prevalence and in turn reduces the prevalence of former smokers. This latter effect expands gradually to older ages.

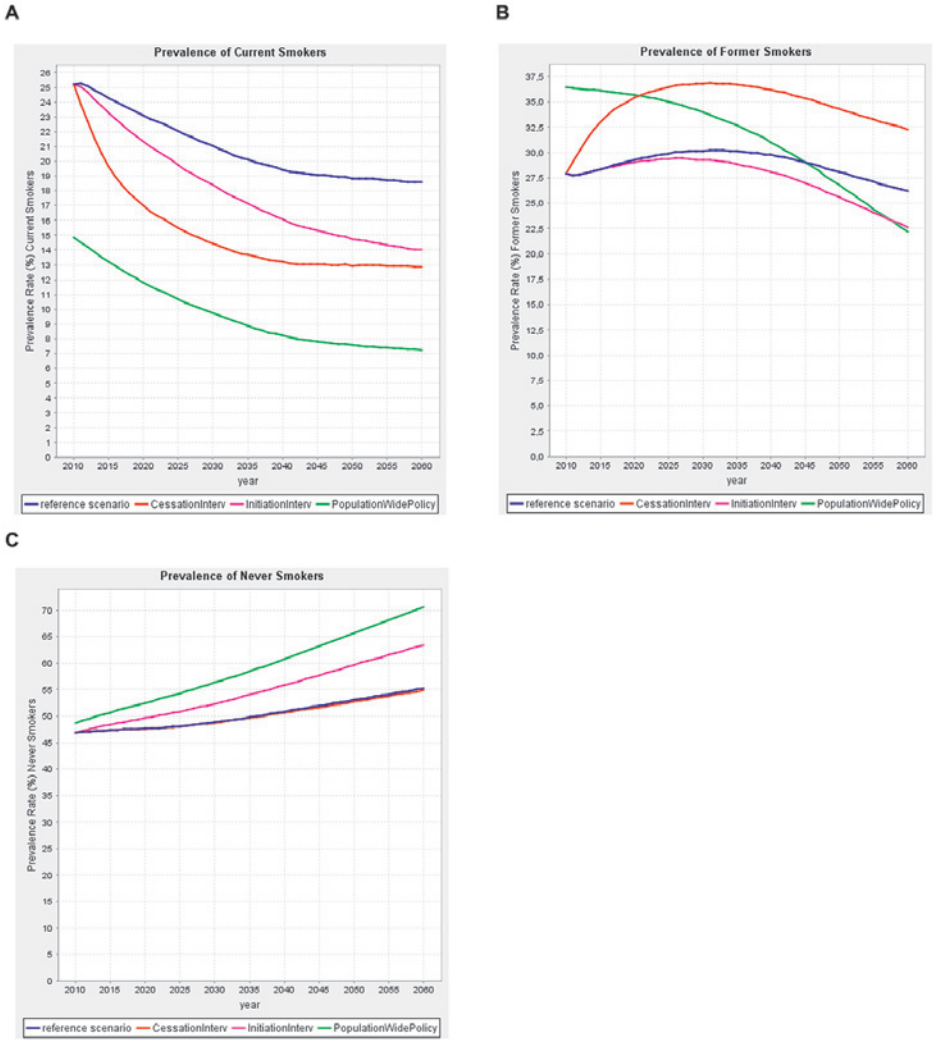

Figure 1: Smoking prevalence over time; Effects of each scenario in the Netherlands (maximum version, panels a-c)

The set of realistic scenario versions for each of the three types of interventions/policy models smaller effects on smoking exposure. This either reflects less dramatic interventions (e.g. smaller price increase), smaller effects of the interventions on the persons who participate (e.g. 20% reduction in start rates as compared to 50%) and/or a smaller percentage of the target population that participates (reach). This revealed similar patterns of smoking prevalence, though being less pronounced (Figures A4a-c and A5a-f, in the appendix to this paper).

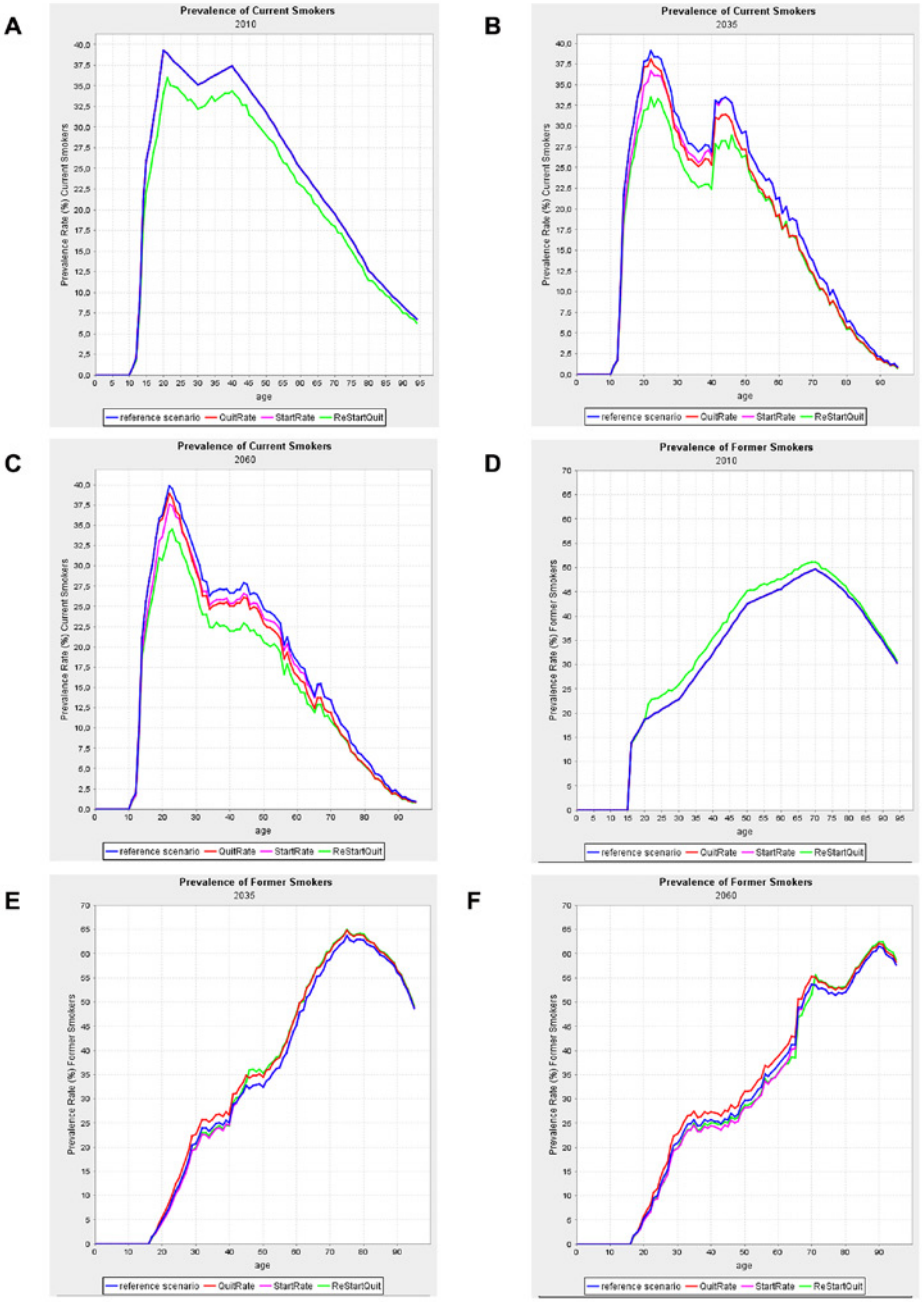

Figure 2: Smoking prevalence by age; Effects of each scenario in the Netherlands (maximum version, panels a-f)

Effect of interventions on future disease prevalence

Table 2 shows the effects of the maximum scenarios on the point prevalence of smoking-related diseases such as lung cancer, COPD, IHD as well as on the prevalence of those with at least one disease, i.e. diabetes, ischemic heart disease, stroke, lung cancer, oral cancer, esophageal cancer, colorectal cancer, breast cancer and COPD for the years 2035 and 2060. On the left we display the absolute baseline level and percentage and the difference due to the intervention in the prevalence of the respective diseases after 25 years, as compared to the reference. On the right we show results after 50 years, i.e. for the year 2060. These are two snapshots in time showing how the effects build up over 25 and 50 years, respectively. Figures showing the evolution over time in more detail are available from the authors on request.

The population-wide smoking control policy causes the largest reduction of the prevalence of lung cancer, COPD, IHD and of persons with at least one disease. By 2035 this intervention prevents about 67,000 COPD cases, 5,000 lung cancer cases, 54,000 IHD cases and about

Table 2: Effects of scenarios on point prevalence of diseases in the Netherlands (maximum version)

	Absolute Level and Reduction in Disease Prevalence as Compared to Reference Scenario							
	2010-2035				2010-2060			
	Lung Cancer	COPD	IHD	at least one disease*	Lung Cancer	COPD	IHD	at least one disease*
Absolute Baseline Prevalence 2010	12,863	211,798	508,596	1,483,769	12,863	211,798	508,596	1,483,769
change Scenario 1 (Cessation)	2,957	36,087	23,967	47,712	2,753	39,299	23,684	32,625
change Scenario 2 (Initiation)	3	0	94	118	534	6,167	10,880	17,465
change Scenario 3 (Population-Wide Policy)	5,044	66,952	54,071	92,796	5,006	72,550	63,161	79,467
	Percentage and Reduction in Disease Prevalence as Compared to Reference Scenario in Percentage Points							
	2010-2035				2010-2060			
	Lung Cancer	COPD	IHD	at least one disease*	Lung Cancer	COPD	IHD	at least one disease*
Baseline Prevalence 2010 in Percent	0.079	1.305	3.130	9.131	0.079	1.305	3.130	9.131
change Scenario 1 (Cessation)	0.018	0.219	0.153	0.314	0.018	0.260	0.179	0.287
change Scenario 2 (Initiation)	0.000	0.000	0.001	0.001	0.003	0.040	0.072	0.118
change Scenario 3 (Population-Wide Policy)	0.030	0.406	0.345	0.620	0.033	0.478	0.453	0.650

*out of: diabetes, ischemic heart disease, stroke, lung cancer, oral cancer, esophageal cancer, colorectal cancer, breast cancer, COPD

93,000 cases of persons with at least one disease. The smoking cessation intervention takes a middle position on the prevalence reduction for the listed diseases. The smoking initiation intervention builds up much slower since it will only exert its effects when those prevented from smoking would have otherwise become ill. Thus, even in 25 and 50 years time, the effects on disease prevalence are substantially smaller than in the other two scenarios.

The effects of the realistic scenarios on disease prevalence in 2035 and 2060 were similar in shape, but evidently smaller than in the maximum version. The exact results for the realistic scenario versions can be seen in Table A3 (in the appendix to this paper).

Effect of interventions on future deaths/lives saved

Figure 3 shows the difference in the excess number of deaths from all causes by calendar year due to each intervention, the baseline number of deaths being 125,650. The population-wide smoking control policy scenario prevents the most deaths. The effects of the interventions on the excess number of deaths as compared to the reference scenario in the population-wide smoking control policy and the smoking cessation intervention both first show an increase, followed by a reduction. This reflects two opposite effects. Firstly, fewer deaths occur, due to the lower prevalence of smoking, reducing the prevalence of smoking-related diseases. Secondly, more deaths occur in the longer run because the intervention keeps persons alive longer, yielding an on average older population. Simultaneously, this also translates into an increase in healthy life expectancy: HLE for men (women) for maximum scenarios in 2010 at

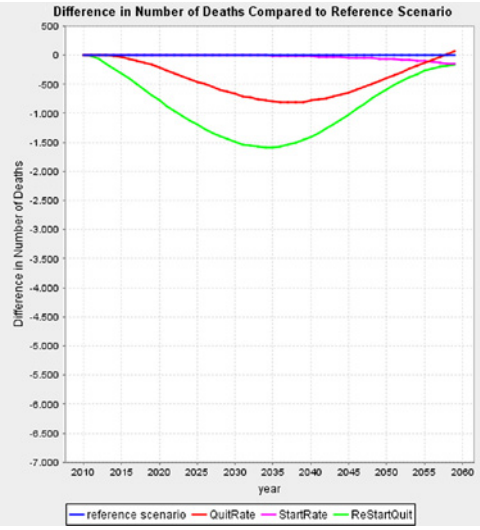

Figure 3: Difference in the number of deaths; Effects of each scenario in the Netherlands (maximum version)

baseline: 68.26 (71.45) years; in 2035 without intervention: 69.70 (71.90), with smoking cessation intervention: 70.25 (72.30), with smoking initiation intervention: 69.71 (71.91) and with population-wide policy: 70.79 (72.73). HLE for men (women) in 2060 without intervention: 70.22 (72.11), with smoking cessation intervention: 70.92 (72.67), with smoking initiation intervention: 70.41 (72.25) and with population-wide policy: 71.64 (73.32). Similar mortality patterns can be observed for the realistic scenario versions, displayed in Figure A6 (in the appendix to this paper).

DISCUSSION

Main findings

The comparison of the three types of interventions shows that the population-wide smoking control policy causes an instant exposure improvement, while also resulting in the largest decrease in the prevalence of current smokers, in disease prevalence and in the number of deaths. The smoking cessation scenario results in the next largest decrease. The reduction of smoking prevalence under the smoking initiation scenario builds up over time and will be highly effective in the future, while being least effective in the short run. Of course, the potential effects of the population-wide policy are the largest as this scenario, by definition, reaches the entire population, whereas the other scenarios only affect quitters or those who might take up smoking. However, given the goal of smoking eradication, it is crucial to keep the long-run benefits of the initiation intervention in mind, since here potential future smokers are kept from ever even taking up the habit.

The fact that the population-wide policy yields larger effects may be seen as support for Rose's claim that population strategies are often the most effective, in contrast to the cessation intervention which could be classified as a "high risk approach" according to his classification [7]. However, the gains of the population-wide scenario presented here can only be realized if sufficient smoking cessation services are available that enable smokers to successfully quit smoking.

The effects of the future reduction in smoking prevalence have implications in terms of health. All three intervention scenarios resulted in fewer excess prevalence cases of smoking-related diseases such as COPD, lung cancer and ischemic heart disease and fewer deaths after the intervention, though the level and timing of the effects differed. The population-wide smoking control policy showed the largest reduction in disease prevalence, followed by the smoking cessation scenario. On the other hand, we see virtually no effect of the initiation scenario until the end of the projection interval, because the group that does not take up smoking due to the intervention, will not yet have had the chance to develop the major

smoking-related diseases during most of the period, as it takes years until these adolescents enter the age ranges where incidence of these chronic diseases is substantial. In the long run the health effects of the smoking initiation scenario start to build up.

The population-wide smoking control policy also reaches the largest reduction in deaths, again followed by the cessation scenario. The effect of the population-wide smoking control policy and cessation intervention on the number of deaths first rises, then falls and in the end even completely disappears. With time the reduction in deaths due to the lower prevalence of smoking-related diseases, such as COPD, lung cancer and IHD is increasingly nullified because the intervention keeps persons alive longer, yielding an on average older population with a higher prevalence of non-smoking related diseases such as diabetes (data not shown) and dampening the reductions of prevalence of smoking-related diseases. This goes in line with estimates of (healthy) life expectancy, also calculated by the DYNAMO tool, which increase over the projection period, and where the improvement is bigger between 2010 and 2035 than between 2035 and 2060.

The differences in timing can be explained by the fact that these different types of interventions/policies target different exposure groups (current smokers vs. never/non smokers vs. entire population), and hence different age groups. For example, since the vast majority of smokers starts smoking before adulthood, interventions preventing persons from taking up the habit mainly target and affect these younger age groups. Cessation interventions, on the other hand, will mainly affect the adult population. Nationwide policy measures impacting population-wide smoking behavior such as a tax on tobacco affect both the young and the old. Age strongly affects the risks of the onset of chronic diseases, both associated and unassociated with smoking, and of death. Smoking-related diseases, such as COPD, lung cancer or IHD only start taking a substantial toll in adulthood and early old age, and within the smoking related diseases, the timing of the effects differs, partly because of variation in the incidence rates by age. Additionally, differences in timing can be explained by the effects of the interventions on mortality and hence on "surplus" aging caused by the intervention.

The dynamic modeling tool DYNAMO-HIA, with its ability to quantify the effects of interventions or policies on future risk factor prevalence and in turn on population health is a powerful instrument when the consequences of different tobacco control policies and interventions are to be assessed. Our findings not only show the different general patterns which interventions can produce but also illustrate how important it is that participation, i.e. the reach of an intervention, is as high as possible. Only then will interventions produce the desired effects on the population level. Such differences are illustrated well by our comparison of the maximum and the realistic scenario versions for the cessation and initiation interventions. This goes in line with the findings of other simulation models. Using the SIMSMOKE model it

was shown that there is only a visible population effect of individual interventions if as many smokers as possible attempt to quit and as many of them also make use of the array of available quitting support tools [23,24]. The RIVM Chronic Disease Model [25] showed comparable projections of the effects of various quit interventions on smoking prevalence in future years.

The present study modeled each intervention one by one. A combination of several interventions and policies affecting different target groups and covering different time horizons will yield better tobacco control outcomes than the implementation of just one intervention quantified in this study. However, in the situation of more interventions the effect of one intervention will depend on the effect of the second intervention, and vise versa. For instance, a smoking initiation intervention that is successful in preventing adolescents from taking up smoking will reduce the potential effects of a smoking cessation intervention among adults. On the other hand, the population-wide intervention might be more effective if those who are motivated to quit because of a price increase are reached by smoking cessation interventions. These interdependencies depend on the effectiveness and reach of the interventions involved, as well as on the demographic and epidemiological context. Given our purpose to disentangle and illustrate the effects of three types of interventions, we did not model combinations of intervention types.

Strengths and limitations

Some limitations of our analyses must be considered. While we were aiming at a realistic model, a model always remains only a simplified version of reality, here being a demonstration of stylized scenarios. Much more work can still be put into the development of actual and more elaborate scenarios. This is a simulation analysis synthesizing existing data and evidence on disease epidemiology, smoking exposure, effects of smoking exposure on diseases and effects of smoking interventions on smoking exposure, all by age and sex. DYNAMO-HIA compares the effects of interventions/policies, i.e. it quantifies a reference scenario and one or more intervention scenarios with a modified risk factor exposure. The goal is not to project future population health as such. For projecting future population health, accurate information on incidence, prevalence and excess mortality data (IPM) of the diseases included in the model are needed, while in reality those data are embedded with uncertainty. This is partly because of the presence of past trends which are not exactly known. For the DYNAMO-HIA database it was decided to include trend-free IPM data partly estimated using the DisModII software [26]. Such trend-free data are used as a neutral option, because of the lack of reliable information on trends. In view of the intended use of DYNAMO-HIA, i.e. comparing scenarios, this choice is not very significant as the same disease data are used both in the intervention and reference scenario(s). Therefore, we do not expect that this unavoidable compromise has an important effect on the outcomes of our study.

Additionally, smoking prevalence and quit and (re)start rates may be biased. Classifications of smoking exposure differ between adolescents and the adult population, as do the data sources. While for older ages non-smokers in the POLS study [9] were further distinguished into former and never smokers, below age 16 in the "Youth monitor" [10], a distinction was only made between non-smokers and smokers. A distinction of non-smokers into never and former smokers at these ages is less meaningful, as these adolescents will have smoked for only a short time anyway. Given that prevalence data of smokers from different sources did not indicate important inconsistencies, we do not expect that this has biased the results. Further, quit and (re)start rates at younger ages might be biased because at these ages flows into the non-smoking state due to quitting were not explicitly modeled, nor were restart rates. This yields an underestimation of the restart rates, but at the same time also an underestimation of the quit rates which have an opposite effect. Since the overall effect on the smoking prevalence was consistent, we do not expect bias. The only issue is that when changing the start rates in the "stop initiation scenario", the effect may be slightly underestimated given that we used "net" start rates. However, given that the higher start rates would have been nullified by quit rates, we again expect no bias.

A second limitation relates to the translation of the effects of interventions, as reported in the literature, into parameters of a dynamic tool such as DYNAMO-HIA. For example, if intervention studies report a reduction in the prevalence of smokers, additional assumptions are needed about the origin of the reduction: less initiation of smoking, increasing the prevalence of never smokers vs. more quitting, increasing the prevalence of former smokers. This translation was needed for the population-wide smoking control policy. We made our choices explicit in the paper. Assuming that most persons start smoking up to the age of 20, it is around this age when most uncertainty exists on whether the reduction in smokers reflects less starting or more quitting. Given that future health outcomes do not differ between former and never smokers at these ages, we do not expect that this affected our estimates. For older ages, mainly the expected effect of the price increase on restart rates is embedded with uncertainty. We expected that a price increase would also reduce the likelihood that future former smokers take up smoking again, and assumed a similar decrease in restart rates as in initial start rates. But other quantifications of the effect on restart rates may be equally defendable, and might yield different changes in future smoking exposure and health. At the most extreme, assuming no change in the restart rates would imply that the effect of this intervention on smoking prevalence at adult and older ages would be virtually absent during part of the projection period. While we do not consider this a plausible scenario, it indicates that future intervention studies should also evaluate the long-term effects on future smoking behavior.

A third limitation of our study is that the comparisons of the size of the effects partly depend on the exact quantification of each intervention scenario. Given that evidence from current evaluation studies is insufficient to set all the parameters in DYNAMO-HIA or any other modeling tool with certainty, this cannot be avoided. Next to a set of maximum scenarios we presented a set of realistic scenario versions, which indicated that the general patterns remained unchanged, only showing the lesser effects due to smaller effect size and reach. Due to the model's linear behavior all specific interventions or smoking control policies with effectiveness and reach specifications in-between these two versions will produce results between the realistic and maximum variant.

The research presented here shows the general patterns of three types of smoking interventions and illustrates the general use of DYNAMO-HIA. For each of the three types of interventions a wide range of smoking control or prevention services with varying effectiveness and reach can be chosen. The effect of each specific intervention will depend on its exact specifications and the current risk factor exposure and demographic and epidemiological context, which may differ from the Dutch situation. In particular, in populations with a different smoking pattern, reflecting a different stage in the smoking epidemic and/or a different mix of smoking control policies, the room for gains that can potentially be realized by different types of interventions may differ. DYNAMO-HIA can be used to quantify these effects as it easily allows for taking such factors into account.

The key strength of our study relates to using a dynamic multistate model that distinguishes separate smoking states in order to model the effects of the different interventions/policies.

Smoking affects a large range of diseases, each to a different extent and the RRs associated with smoking also depend on age and sex. Further, the different smoking-related diseases have different epidemiological patterns (time of onset, mortality). The health effects of different types of interventions depend on the effects of the intervention on future smoking exposure at different ages. Future smoking exposure, in turn, does not only depend on prevalence at baseline, and (re)start and quit rates, but also on selective mortality, as smoking is strongly associated with mortality. Using DYNAMO-HIA allowed us to assess how an intervention affects smoking exposure in future years and in different age groups, taking into account selective mortality, and to substitute morbidity and mortality in the extra years persons are alive because of the lower mortality due to the intervention. Other models like SIMSMOKE [24] use the Potential Impact Fraction (PIF) to model the effects of interventions on transitions, and hence do not contain selective mortality.

Also, DYNAMO-HIA allowed us to take into account the effect of smoking on various diseases, each having different excess risks, which vary by age. The effect of smoking exposure on

death was accounted for through the effect of smoking on incidence of the nine included diseases and through the RR of total mortality, which allows DYNAMO-HIA to take into account the effect of smoking on mortality through diseases not included in the model. Technical advantages of our software also include the fact that it requires relatively modest data input resulting in rich model output, while being freely accessible through a website.

Conclusion

The DYNAMO-HIA model showed that all smoking interventions will be effective in the long run, the population-wide strategy being most effective in both the short and long term. The quit smoking scenario evidently will be second-most effective in the short run, though in the long run the smoking initiation scenario will be almost as effective as the smoking cessation scenario. Even if interventions aimed at preventing the initiation of smoking take a long time to become manifest in terms of health effects, they need to be part of tobacco control measures as they keep in check the numbers of new smokers. A combination of interventions and policies with different time horizons reinforcing each other would be most optimal on the way to smoking eradication.

The dynamic modeling tool DYNAMO-HIA, with its ability to quantify information on the long term impact of interventions on population health, is a powerful instrument when the consequences of different tobacco control policies and interventions are to be assessed. We can directly compare the differences in the timing as well as in the relative sizes of the effects of the scenarios.

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APPENDIX FIGURES AND TABLE

(Please refer to the supporting information Figures S1, S2 and S3 of the original publication for figures in full color. Available at: http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0032363)

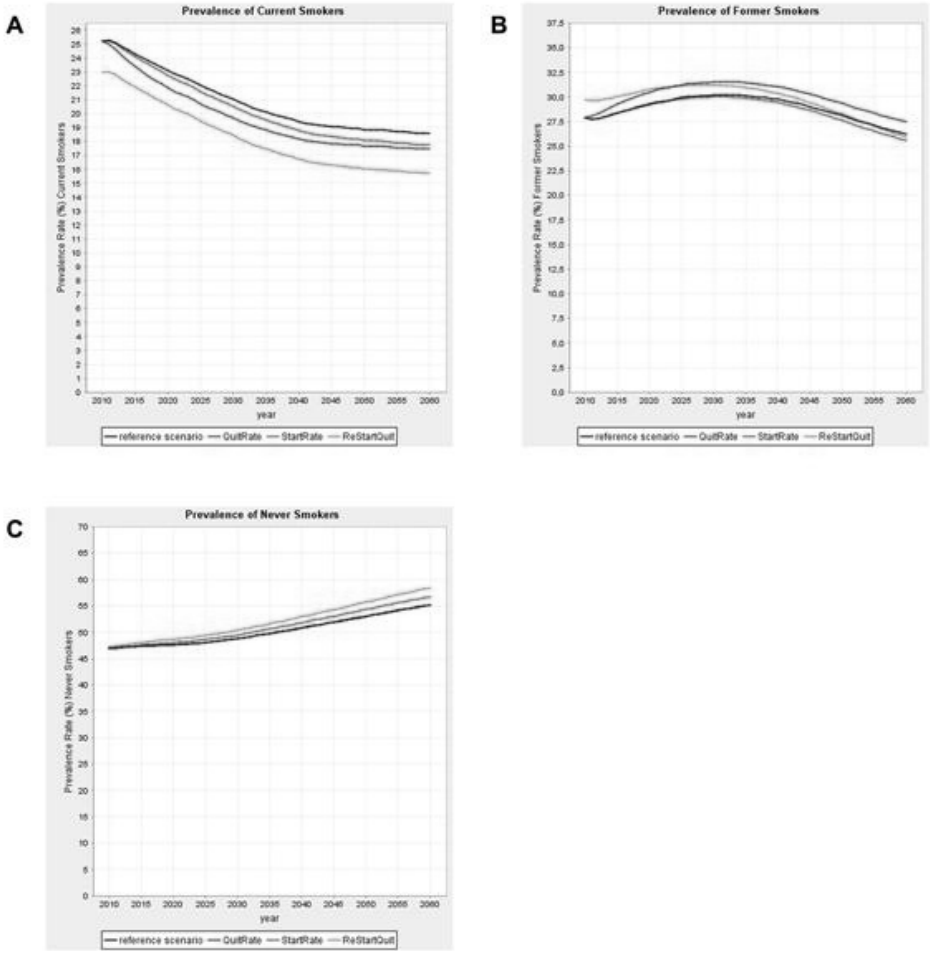

Figure A4: Smoking prevalence over time; Effects of each scenario in the Netherlands (realistic version, panels a-c)

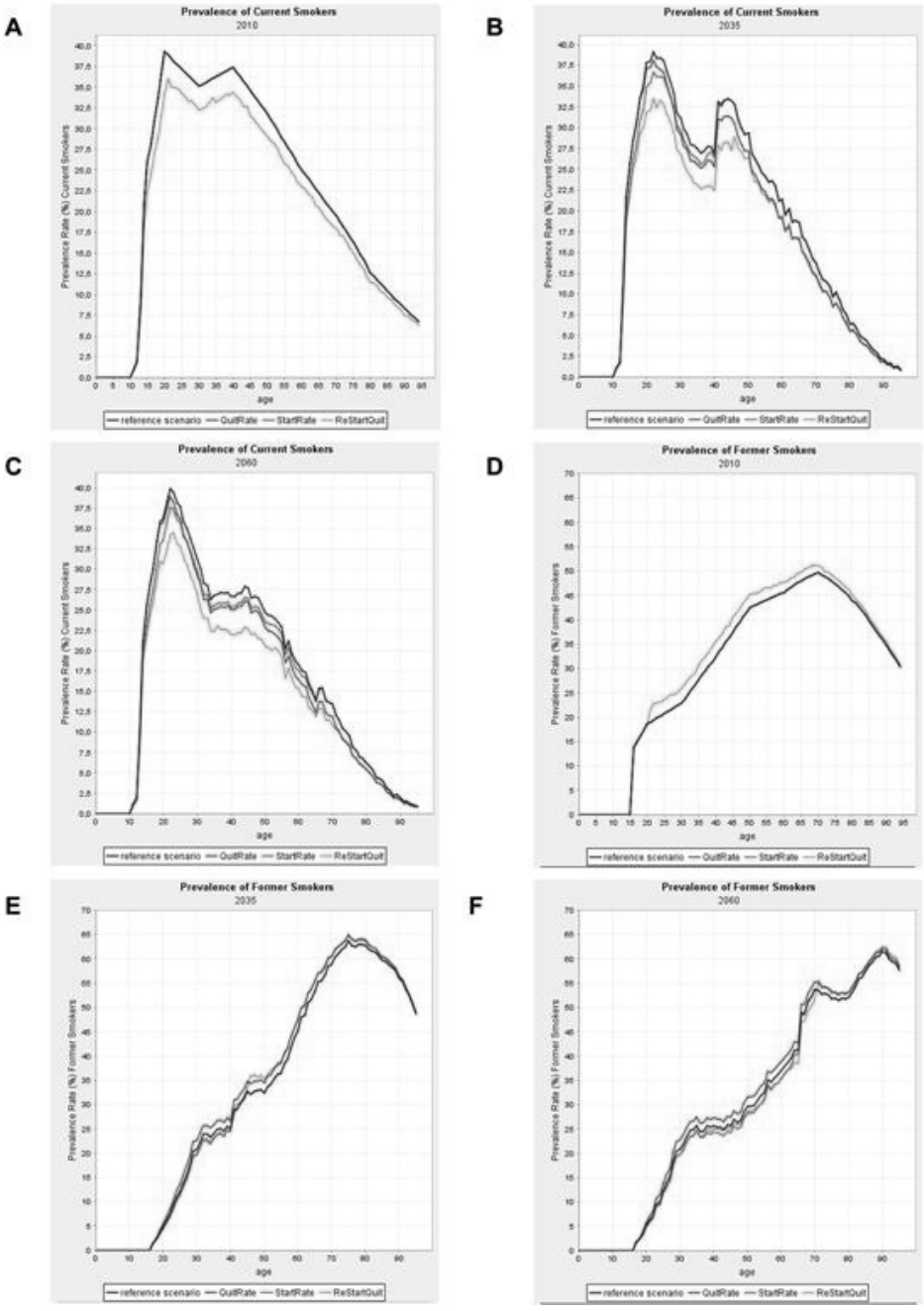

Figure A5: Smoking prevalence by age over time; Effects of each scenario in the Netherlands (realistic version, panels a-f)

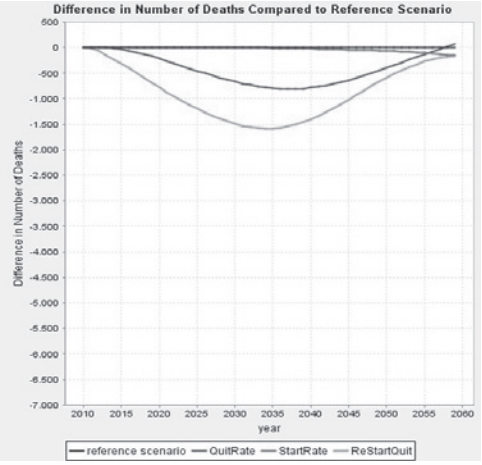

Figure A6: Difference in the number of deaths; Effects of each scenario in the Netherlands (realistic version)

Table A3: Effects of scenarios on point prevalence of diseases in the Netherlands (realistic version)

	Absolute Level and Reduction in Disease Prevalence as Compared to Reference Scenario							
	2010-2035				2010-2060			
	Lung Cancer	COPD	IHD	at least one disease	Lung Cancer	COPD	IHD	at least one disease
Absolute Baseline Prevalence 2010	12,863	211,798	508,596	1,483,769	12,863	211,798	508,596	1,483,769
change Scenario 1 (Cessation)	591	7,217	4,793	9,542	551	7,860	4,737	6,525
change Scenario 2 (Initiation)	1	0	19	23	101	1,159	2,064	3,304
change Scenario 3 (Population-Wide Policy)	1,149	15,076	11,744	20,263	1,236	17,796	15,691	20,980
	Percentage and Reduction in Disease Prevalence as Compared to Reference Scenario in Percentage Points							
	2010-2035				2010-2060			
	Lung Cancer	COPD	IHD	at least one disease	Lung Cancer	COPD	IHD	at least one disease
Baseline Prevalence 2010 in Percent	0.079	1.305	3.130	9.131	0.079	1.305	3.130	9.131
change Scenario 1 (Cessation)	0.004	0.044	0.031	0.063	0.004	0.052	0.036	0.058
change Scenario 2 (Initiation)	0.000	0.000	0.000	0.000	0.001	0.008	0.014	0.022
change Scenario 3 (Population-Wide Policy)	0.007	0.092	0.076	0.137	0.008	0.118	0.112	0.168

*out of: diabetes, ischemic heart disease, stroke, lung cancer, oral cancer, esophageal cancer, colorectal cancer, breast cancer, COPD

CHAPTER 5

Smoking and the potential for reduction of inequalities in mortality in Europe

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ABSTRACT

Socioeconomic inequalities in health and mortality remain a widely recognized problem. Countries with smaller inequalities in smoking have smaller inequalities in mortality, and smoking plays an important part in the explanation of inequalities in some countries.

We identify the potential for reducing inequalities in all-cause and smoking-related mortality in 19 European populations, by applying different scenarios of smoking exposure.

Smoking prevalence information and mortality data come from 19 European populations. Prevalence rates are mostly taken from National Health Surveys conducted around the year 2000. Mortality rates are based on country-specific longitudinal or cross-sectional datasets. Relative risks come from the Cancer Prevention Study II. Besides all-cause mortality we analyze several smoking-related cancers and COPD/asthma.

We use a newly-developed tool to quantify the changes in population health potentially resulting from modifying the population distribution of exposure to smoking. This tool is based on the epidemiological measure of the Population Attributable Fraction, and estimates the impact of scenario-based distributions of smoking on educational inequalities in mortality.

The potential reduction of relative inequality in all-cause mortality between those with high and low education amounts up to 26% for men and 32% for women. More than half of relative inequality may be reduced for some causes of death, often in countries of Northern Europe and in Britain. Patterns of potential reduction in inequality differ by country or region and sex, suggesting that the priority given to smoking as an entry-point for tackling health inequalities should differ between countries.

INTRODUCTION

Socioeconomic inequalities in health and mortality remain a widely recognized problem, and smoking plays an important part in the explanation of these inequalities in some countries [1-10]. It has also been shown that socioeconomic inequalities in smoking have increased in past decades due to the progression of countries through the stages of the smoking epidemic [2]. In a more advanced stage of the epidemic relatively more individuals with a lower socioeconomic status (SES) smoke compared to more higher-SES smokers in earlier stages [11,12]. Still, quantitative estimates of the impact of eliminating inequalities in smoking on inequalities in mortality are largely lacking. This is a serious barrier for effective policy-making, because it hinders both priority setting and the formulation of realistic quantitative targets for reducing health inequalities.

The aim of this analysis was to identify the potential of reducing inequalities in all-cause and smoking-related mortality in 19 European populations, by hypothetically modifying the exposure to smoking. In order to quantify the potential for inequality reduction we investigated four different scenarios. The first was a behavioral scenario in which we assumed smoking prevalence of current, former and never smokers for all socioeconomic subgroups to be at the level observed for the higher educated (Scenario 1 "upward leveling scenario"). The second scenario modeled a currently optimal situation, applying the smoking prevalence of the country with the least inequalities and a low prevalence of current smokers to all countries, France for men and Italy for women (Scenario 2, "current optimum scenario"). We also modeled the influence of effective tobacco control policies. A literature search identified two systematic reviews with evidence that interventions related to price effects are the most promising in reducing inequalities in smoking [13,14]. Thus, we based the last two scenarios on studies of tobacco price changes that have been shown to reduce social inequalities in smoking prevalence. In scenario 3a we increased the price of tobacco in each country to the theoretical maximum, i.e. the currently highest price in the EU ("maximum price scenario"). In scenario 3b we increased the tobacco price by a more realistic 20% in every country ("20% price scenario").

METHODS

Data

We used smoking prevalence and mortality data by age, sex, country and educational level. The European countries and regions included in the analysis were Finland, Sweden and Denmark in Northern Europe; England & Wales, Scotland, the Netherlands, Belgium, France, Switzerland and Austria in Western Europe; Barcelona, the Basque Country, Madrid, Turin

and Tuscany representing Southern Europe and the Czech Republic, Poland, Lithuania and Estonia representing Central and Eastern Europe. Prevalence rates were mostly taken from nationally representative Health Interview Surveys conducted around the year 2000. They were usually provided by national statistical offices, with the exception of Estonia, Finland and Lithuania for which the data came from the Finbalt Health Monitor, and Belgian data coming from the Scientific Institute of Public Health. The surveys were collected and harmonized as part of the Eurothine project [15]. For Austria information was taken from the European Community Household Panel (ECHP wave 7) (see Table A2.1 for smoking prevalence rates and Table A2.2 for more information on the sources (in the data summary in appendix II to this thesis)). Mortality rates were based on country-specific longitudinal or cross-sectional datasets with one to seven years of follow-up (Table A2.4 of appendix II to this thesis). Due to the different study designs and follow-up times, specific correction factors were used to obtain comparable average ages at death [16]. Relative risks by sex and smoking status came from the Cancer Prevention Study II [17] (presented in Table A2.5 of appendix II to this thesis).

We analyzed all-cause mortality and mortality from smoking-related causes of death (CoD). The latter were defined as having a Population Attributable Fraction (PAF) of mortality of 50% or more [18], namely cancer of the trachea, lung, bronchus and larynx (combined, called lung cancer for brevity) (ICD-10 codes C32-C34); cancer of lip, oral cavity and pharynx (combined) (C00-C14); esophageal cancer (C15); and chronic obstructive pulmonary disease (COPD) and asthma (combined) (J40-J47). Deaths from cancer of the larynx were grouped together with lung cancer because of small numbers and relative risks similar to those for lung cancer. Smoking prevalence and mortality data were stratified by "low" (International Standard Classification of Education (ISCED) 0-2), "middle" (ISCED 3-4) and "high" education (ISCED 5-6).

Description of the PAF method

We used the PAF method to assess the expected changes in mortality that would result from modifying the population distribution of exposure to a risk factor (Formula 1). The PAF is defined as the fraction of deaths attributable to a specific disease which would have been avoided if a modification of the prevalence of a specific risk factor had occurred [19,20]. We use the term PAF in a generalized sense, also including situations in which the prevalence of the risk factor is set to a level above zero and which would usually be described by the Population Impact Fraction.

Formula 1:
$$PAF = \frac{\sum_{i=1}^{n} P_i RR_i - \sum_{i=1}^{n} P_i' RR_i}{\sum_{i=1}^{n} P_i RR_i}$$

n = number of exposure categories (of smoking)
P_i = proportion of population currently in the ith exposure category
P'_i = proportion of population in the ith exposure category in the counterfactual (alternative) scenario
RR_i = relative mortality risk for the ith exposure category

The original methodology was adapted to estimate the impact of counterfactual distributions of specific risk factors on the overall level of mortality and on educational differences in mortality. The latter was achieved by stratifying the PAF calculation by educational group.

Differences between men and women in how educational status relates to health are substantial [21], and the impact of risk factors on mortality varies in different stages of the life course [22,23]. Thus, the analyses were stratified by sex and age by using sex- and age-specific prevalence and mortality rates and sex-specific relative risks for the impact of smoking on mortality. The effects on total mortality were determined independently through the relative risk of smoking on total mortality as opposed to adding the cause-specific effects. We present results for ages 30-79 that are based on the age-specific calculations, also including a European Average which is an arithmetic mean of the country-specific estimates. The effect on mortality is illustrated by the PAF which incorporates the effect of two factors: 1) the degree of social inequality in smoking and its changes brought about by the scenario and 2) the impact of smoking on mortality.

The potential reduction in relative inequality in mortality was expressed as a percentage change in the relative excess risk (RR-1), comparing the excess risk before and after the implementation of the scenario. In rare cases where the scenarios would lead to a mortality increase in lower educated groups, because of a reverse social gradient of smoking prevalence, we set this deterioration to zero because it is implausible that a policy intervention would aim at worsening health outcomes. We also calculated absolute inequalities by subtracting the number of deaths (per 100,000) among the high educated from the corresponding number of deaths among the low educated. The specific excel-based PAF tool used here has been described elsewhere [24].

We calculated confidence intervals (CIs) around the PAFs by using bootstrapping in R [25] (see appendix II to this thesis for more information).

Calculation of price scenarios

On the basis of our reviews a study by Siahpush et al. [26] was identified to provide the most suitable estimates of the price elasticity of smoking participation for different socioeconomic groups. They were expressed as elasticities for low-, medium- and high-income groups. As shown by DeCippa et al. [27] elasticities based on income levels were in the same order of magnitude as those based on education. Hence, we took the former elasticities and assumed them to be elasticities for those with a low (-0.32), medium (-0.04) and high (-0.02) level of education.

In order to model a maximum price increase in scenario 3a we increased the price of tobacco in the countries and regions included in our analysis to match the price of tobacco in Ireland, which currently has the highest tobacco price in the EU [28]. Simultaneously, we accounted for the pattern of real price levels within the EU as, all other things being equal, there ought to be greater scope to increase prices in those countries where real prices are relatively low. This was done by weighting the percentage price increases needed to reach the currently highest tobacco price in the EU by the GDP per inhabitant expressed in terms of the Purchasing Power Standard [29] (Table 1). We assumed that the reduction in current smokers would result in an increase in former smokers, while leaving the prevalence of never smokers unchanged. In Scenario 3b we applied the same method but increased the price of tobacco by a more realistic 20% in every country (additional information on definitions and computations related to this section can be found in the appendix to this paper).

While in scenario 1 the smoking prevalence remained unchanged for those with a high educational level, in scenarios 3a and 3b the price increase modified the smoking behavior of all socioeconomic groups. In scenario 2 the level of change depended on the difference of the smoking prevalence between the country in question and the country with the currently best tobacco epidemic situation.

Due to the multitude of results we limit ourselves to showing PAFs, reductions of relative and absolute inequality for all-cause mortality due to all four smoking scenarios, and displaying the results of scenario 1, (upward leveling) for all CoD. We chose scenario 1 as it illustrates the theoretical maximum of what can be achieved in terms of health gains when inequalities in smoking are eliminated. The complete results for all scenarios and all CoD can be found in the appendix to this paper. We also only show results contrasting the groups with a high and a low educational level.

Table 1: Tobacco price levels and GDP levels in the countries analyzed, EU27 = 100

	Tobacco Price Level	% price increase needed to reach highest price level in EU (currently Ireland)	GDP expressed in terms of the Purchasing Power Standard	% price increase needed to reach highest price level in EU (currently Ireland) adjusted for Purchasing Power Standard
Finland	110	97	113	**76**
Sweden	130	67	118	**55**
Denmark	117	85	121	**77**
UK	166	31	112	**15**
Netherlands	111	95	131	**102**
Belgium	108	101	116	**84**
France	133	63	108	**39**
Switzerland	104	109	145	**138**
Austria	97	124	124	**118**
Spain	73	197	103	**141**
Italy	104	109	104	**71**
Czech Rep	75	189	82	**87**
Poland	52	317	61	**100**
Lithuania	51	325	55	**84**
Estonia	73	197	64	**50**
Ireland	217		127	

Sources: [28,29]

RESULTS

Reduction of mortality

The impact of the scenarios on all-cause mortality is presented in Table 2 (see Tables A6a-A6d in the appendix to this paper for cause-specific results), showing the PAF in percent. The results are shown by country, grouped by European region, and by sex, with the scenarios in columns next to each other. In the last line of the tables the arithmetic mean of all countries is included.

According to scenario 1, all-cause mortality could be reduced by up to 13% among lower educated men in Poland, followed by men in the Czech Republic, Scotland and England & Wales with reductions above 10%. Changes among women were much smaller. In scenario 2 the largest mortality reductions were found in Denmark, both for men and for women. Large reductions above 10% were also observed for the Netherlands, Poland, Lithuania and Estonia for men and for Sweden, England & Wales, Scotland and the Netherlands for women. In scenario 3a the smallest, and non-significant, mortality reduction was observed in England & Wales and Scotland, as these were the countries with the lowest maximum price increase. Among men in Southern Europe, Belgium and Switzerland the maximum price scenario led

to a larger reduction when compared to scenario 1. This was also true for women in those countries and additionally in the Netherlands and Austria. In scenario 3b the only mortality reduction larger than for scenario 3a was observed in England & Wales and Scotland, because these were the only countries where the 20% tobacco price increase was larger than the 15% increase in the maximum price scenario.

Table 2: Population Attributable Fraction (%) of those with a low educational level for all-cause mortality due to four different smoking scenarios [a]

Population	1) Upward leveling scenario		2) Current optimum scenario		3a) Maximum price scenario		3b) 20% price scenario	
MEN	PAF (%)	95% CI	PAF (%)	95% CI	PAF (%)	95% CI	PAF (%)	95% CI
Finland	8.1	6.3-9.8	5.1	3.3-7.0	3.6	1.8-5.4	1.0	0.0-2.4
Sweden	8.0	6.4-9.7	3.6	2.0-5.1	1.8	0.3-3.2	0.6	0.0-1.8
Denmark	8.4	6.8-10.0	16.3	14.9-17.7	5.1	3.5-6.7	1.3	0.0-2.7
England & Wales	10.7	9.5-11.8	7.4	6.3-8.6	0.6	0.0-1.5	0.8	0.0-1.7
Scotland	11.1	9.6-12.7	9.1	7.5-10.7	0.7	0.0-1.9	0.9	0.0-2.1
Netherlands	5.5	4.1-6.9	13.2	12.0-14.5	5.1	3.7-6.5	1.0	0.0-2.1
Belgium	3.4	2.4-4.5	9.0	7.9-10.2	3.9	2.7-5.2	0.9	0.0-1.9
France	3.0	2.0-4.0	-	-	1.6	0.4-2.8	0.8	0.0-1.9
Switzerland	4.9	2.9-6.9	8.6	6.6-10.6	7.1	5.1-9.2	1.0	0.0-2.6
Austria	4.9	2.7-7.0	0.8	0.0-2.5	4.2	1.8-6.7	0.7	0.0-2.5
Barcelona	2.6	2.1-3.1	7.7	6.9-8.4	6.8	6.0-7.5	1.0	0.2-1.7
Basque Country	2.7	1.6-3.8	4.9	3.2-6.6	5.5	3.8-7.1	1.0	0.0-2.2
Madrid	2.4	2.0-2.9	7.6	6.8-8.4	6.6	5.7-7.4	0.9	0.2-1.7
Turin	1.7	1.4-1.9	5.0	4.6-5.3	2.8	2.4-3.2	0.8	0.4-1.1
Tuscany	1.6	1.3-1.9	5.0	4.6-5.4	2.8	2.4-3.2	0.8	0.4-1.2
Czech Republic	12.1	9.3-14.9	6.5	3.8-9.1	4.0	1.4-6.5	0.9	0.0-2.8
Poland	13.4	12.3-14.4	11.1	10.0-12.1	5.9	4.8-7.1	1.2	0.1-2.2
Lithuania	8.2	6.3-10.1	10.3	8.3-12.4	5.6	3.8-7.4	1.3	0.1-2.6
Estonia	8.4	5.8-11.0	13.8	10.9-16.7	3.5	0.5-6.4	1.4	0.0-3.9
European Average	7.1		8.4		3.9		1.0	
WOMEN								
Finland	3.5	2.6-4.4	3.0	2.1-4.0	1.3	0.3-2.2	0.4	0.0-1.3
Sweden	4.7	3.4-6.0	10.0	8.7-11.2	1.7	0.4-2.9	0.6	0.0-1.6
Denmark	3.8	2.9-4.7	17.5	16.4-18.5	3.6	2.3-4.8	0.9	0.0-1.9
England & Wales	6.0	5.0-6.9	12.5	11.7-13.4	0.5	0.0-1.1	0.6	0.0-1.3
Scotland	9.9	8.6-11.1	16.2	15.1-17.3	0.6	0.0-1.6	0.8	0.0-1.8
Netherlands	2.3	1.7-2.8	12.1	11.2-13.0	3.1	2.2-4.0	0.6	0.0-1.3
Belgium	0.9	0.5-1.2	6.0	4.9-7.0	1.9	0.8-3.0	0.5	0.0-1.3
France	0.9	0.6-1.1	1.1	0.6-1.5	0.7	0.1-1.4	0.4	0.0-0.9
Switzerland	0.8	0.5-1.2	5.4	4.4-6.4	3.4	2.4-4.4	0.5	0.0-1.2

Table 2: (Continued)

Population	1) Upward leveling scenario		2) Current optimum scenario		3a) Maximum price scenario		3b) 20% price scenario	
WOMEN	PAF (%)	95% CI	PAF (%)	95% CI	PAF (%)	95% CI	PAF (%)	95% CI
Austria	0.6	0.3-1.0	0.8	0.1-1.5	1.6	0.6-2.6	0.3	0.0-1.0
Barcelona	0.5	0.4-0.7	1.1	0.9-1.2	2.0	1.6-2.4	0.3	0.0-0.6
Basque Country	0.7	0.4-1.0	1.0	0.7-1.3	1.8	1.1-2.6	0.3	0.0-0.9
Madrid	0.4	0.3-0.5	0.8	0.7-1.0	1.7	1.4-2.1	0.2	0.0-0.5
Turin	0.2	0.2-0.3	-	-	1.1	0.8-1.3	0.3	0.1-0.5
Tuscany	0.3	0.2-0.3	-	-	1.1	0.8-1.3	0.3	0.1-0.5
Czech Republic	2.7	1.9-3.5	4.0	2.7-5.3	1.7	0.4-3.0	0.4	0.0-1.4
Poland	2.6	2.2-3.1	4.8	4.2-5.4	2.5	1.8-3.1	0.5	0.0-1.1
Lithuania	1.6	1.3-1.9	0.1	0.0-0.3	1.0	0.5-1.5	0.2	0.0-0.6
Estonia	3.1	1.5-4.7	3.4	1.6-5.2	1.3	0.0-3.0	0.5	0.0-2.0
European Average	2.8		6.5		1.7		0.5	

[a] Significant results are depicted in black. Depicted in grey are statistically non-significant results where the original confidence intervals included 0. However, in the table we set the lower bounds of these intervals to 0 as negative values would indicate a protective effect of a reduction of smoking, which is conceptually impossible

- Reference country, hence no change through scenario

We see that the proportional mortality decreases due to smoking-related CoD for the upward leveling scenario tended to be more substantial than those due to all-cause mortality, a result which is more striking for cancer of lip, oral cavity and pharynx (combined) for men, and for lung cancer among women (Table 3).

Reduction of relative and absolute inequality in mortality

Tables 4 and 5 show the potential reduction of relative inequality in all-cause mortality (in percent) between those with high and low education due to the four scenarios, and the inequality reduction in mortality from smoking-related CoD due to the upward leveling scenario, respectively. The results are shown by country and sex. In each table we first present the initial mortality rate ratios for those with low education, followed by the new scenario-specific rate ratios and the resulting reduction in inequality, first for men, then for women. See Tables A7a-A7d in the appendix to this paper for the full set of results. In order to present a more complete picture we also show reductions of absolute inequality in all-cause mortality in Figure 1, and in the smoking-related CoD in Figures A2a-A2d in the appendix to this paper.

The potential reduction of relative inequality in all-cause mortality in scenario 1 was largest for men in England and Wales (26%). Just as with the potential mortality reduction, decreases in inequality were much lower among women, with a maximum of 20% in Scotland. Scenario 2 resulted in the highest reductions among men in Poland, followed by England & Wales and

Table 3: Population Attributable Fraction (%) of those with a low educational level for different smoking-related CoD for the upward leveling scenario (Scenario 1) [a]

Population	Trachea, lung, bronchus and larynx cancer		Lip, oral cavity and pharynx cancer		Esophageal cancer		COPD/asthma	
MEN	PAF (%)	95% CI	PAF (%)	95% CI	PAF (%)	95% CI	PAF (%)	95% CI
Finland	19.3	13.8-24.7	24.2	20.8-27.6	14.2	11.4-16.9	7.9	3.7-12.0
Sweden	23.9	19.6-28.3	27.0	22.5-31.5	16.4	13.2-19.6	15.2	11.0-19.4
Denmark	19.0	15.6-22.4	21.7	18.7-24.6	13.9	11.5-16.2	12.6	9.2-15.9
England & Wales	29.9	27.1-32.8	[b]	[b]	21.1	19.1-23.0	21.5	19.3-23.8
Scotland	27.2	23.1-31.3	[c]	[c]	[c]	[c]	15.3	11.0-19.6
Netherlands	13.1	9.7-16.6	16.8	12.1-21.4	8.0	5.5-10.5	5.4	2.3-8.5
Belgium	6.9	4.1-9.8	11.6	8.5-14.7	3.4	1.5-5.3	3.0	0.9-5.1
France	6.0	2.7-9.3	8.1	3.8-12.5	3.3	0.8-5.9	2.3	0.0-5.5
Switzerland	13.0	7.6-18.5	15.0	9.8-20.1	9.3	5.5-13.0	7.6	2.8-12.5
Austria	10.9	3.7-18.1	9.3	3.2-15.5	10.2	4.7-15.8	14.4	7.7-21.1
Barcelona	5.5	4.1-6.9	8.7	6.7-10.7	4.6	3.4-5.8	1.2	0.8-1.6
Basque Country	6.3	3.3-9.4	10.2	6.7-13.7	3.8	1.6-6.0	0.9	0.0-2.6
Madrid	4.9	3.6-6.1	8.9	6.9-11.0	3.3	2.1-4.4	0.7	0.4-1.0
Turin	2.4	1.6-3.2	6.0	3.8-8.1	1.8	0.9-2.8	1.1	0.5-1.7
Tuscany	2.4	1.6-3.3	[b]	[b]	1.1	0.0-2.4	0.4	0.0-0.9
Czech Republic	34.2	27.1-41.3	[c]	[c]	[c]	[c]	30.5	23.8-37.3
Poland	31.6	29.2-34.0	[c]	[c]	[c]	[c]	19.6	17.0-22.1
Lithuania	18.9	13.1-24.6	21.3	17.3-25.2	12.3	8.8-15.7	9.7	5.2-14.2
Estonia	14.8	7.6-22.0	[c]	[c]	[c]	[c]	7.3	2.8-11.9
European Average	17.3		17.1		9.8		10.9	
WOMEN								
Finland	12.8	7.6-17.9	9.9	6.0-13.7	9.3	4.2-14.4	7.5	0.9-14.1
Sweden	20.4	15.1-25.6	15.4	10.8-20.1	16.6	11.2-22.0	9.3	4.8-13.8
Denmark	13.5	10.5-16.5	12.7	10.1-15.4	11.3	8.3-14.3	6.8	4.4-9.3
England & Wales	22.7	19.1-26.3	20.2	15.7-24.8	20.4	16.7-24.0	17.2	13.4-21.0
Scotland	32.8	29.1-36.4	[c]	[c]	[c]	[c]	25.9	21.9-29.9
Netherlands	10.0	7.3-12.7	7.4	3.6-11.3	5.0	1.7-8.4	2.1	0.4-3.8
Belgium	1.6	0.2-2.9	2.5	0.0-5.5	0.4	0.0-1.1	1.0	0.5-1.6
France	2.5	0.0-5.3	0.0	0.0-0.0	0.0	0.0-0.2	[b]	[b]
Switzerland	2.3	0.4-4.2	1.5	0.0-3.4	1.0	0.0-2.8	0.9	0.2-1.5
Austria	1.2	0.0-2.7	4.3	0.5-8.0	4.4	0.0-11.0	0.3	0.0-0.8
Barcelona	2.2	1.4-3.0	1.0	0.0-2.2	1.0	0.0-2.5	0.4	0.0-0.9
Basque Country	3.0	1.3-4.7	2.9	0.5-5.3	0.0	0.0-0.0	0.3	0.0-0.7
Madrid	1.0	0.4-1.6	1.2	0.0-2.6	[b]	[b]	0.5	0.0-1.1
Turin	1.1	0.3-1.8	1.3	0.0-3.0	0.0	0.0-0.0	0.3	0.0-0.8
Tuscany	0.9	0.1-1.7	1.3	0.0-3.3	0.0	0.0-0.0	0.0	0.0-0.0

Table 3: (Continued)

Population	Trachea, lung, bronchus and larynx cancer		Lip, oral cavity and pharynx cancer		Esophageal cancer		COPD/asthma	
WOMEN	PAF (%)	95% CI	PAF (%)	95% CI	PAF (%)	95% CI	PAF (%)	95% CI
Czech Republic	12.6	8.6-16.5	[c]	[c]	[c]	[c]	7.2	5.3-9.2
Poland	10.5	8.1-12.9	[c]	[c]	[c]	[c]	4.4	3.0-5.8
Lithuania	5.8	5.3-6.3	1.7	1.4-2.0	3.2	2.8-3.6	10.2	8.3-12.2
Estonia	9.6	0.1-19.0	[c]	[c]	[c]	[c]	6.3	0.0-16.5
European Average	10.1		6.6		6.0		6.2	

[a] Significant results are depicted in black. Depicted in grey are statistically non-significant results where the original confidence intervals included 0. However, in the table we set the lower bounds of these intervals to 0 as negative values would indicate a protective effect of a reduction of smoking, which is conceptually impossible

[b] no result available as there are no cause-specific deaths among those with the highest educational level

[c] Mortality information not available

Scotland. In women potential inequality reductions were above 20% in Sweden, Denmark, England & Wales, Scotland and the Netherlands. In scenario 3a inequality was most reduced among men in Spain, with marked inequality reductions for women in Denmark, the Netherlands, Switzerland, the Basque Country and Turin (Table 4).

The comparison of the four scenarios showed that among men the highest potential for inequality reductions would stem from Scenario 1 in the Nordic countries, in Western Europe except for Belgium and Switzerland and in Central and Eastern Europe. Scenario 3a would most benefit men in Spain. Among women Scenario 2 was the most successful one in parts of Northern and Western Europe, while it would worsen the situation in parts of Spain (Table 4).

Scenario 1 implies that educational inequality in mortality due to lung cancer could be maximally decreased by up to 56% for low-educated women in England & Wales, as well as by more than half for cancer of the lip, oral cavity and pharynx for men in Finland (58%) and Sweden (57%). In the case of esophageal cancer we observed a 53% potential reduction in inequality among English & Welsh men and more than 60% among women in Sweden and Denmark. The potential in inequality reduction in mortality due to COPD/asthma was highest among men in the Czech Republic (39%) and England & Wales (38%) and among women in Scotland (34%) (Table 5).

Figure 1 illustrates the reduction of absolute inequality in mortality between those with high and low education. This is the difference between the initial absolute inequalities and the absolute inequalities due to the different scenarios (absolute deaths per 100,000). Hence, if the number is positive, absolute inequalities declined due to the scenario. In scenario 1 the mortality among those with a high education does not change per definition, while it does

Table 4: Mortality RRs, scenario RRs and potential reduction in inequality in all-cause mortality (%) between those with high and low education due to four different smoking scenarios

			1) Upward leveling scenario				2) Current optimum scenario				3a) Maximum price scenario				3b) 20% price scenario			
	initial RR	initial RR	new RR	Ineq. Redu.	new RR	Ineq. Redu.	new RR	Ineq. Redu.	new RR	Ineq. Redu.	new RR	Ineq. Redu.	new RR	Ineq. Redu.	new RR	Ineq. Redu.	new RR	Ineq. Redu.
Population	M	W	M	M	W	W	M	M	W	W	M	M	W	W	M	M	W	W
Finland	1.95	1.77	1.79	17	1.71	8	1.88	8	1.72	7	1.88	7	1.75	3	1.93	2	1.76	1
Sweden	1.76	1.82	1.62	19	1.74	10	1.7	8	1.64	22	1.73	4	1.79	4	1.75	1	1.81	1
Denmark	1.71	1.66	1.57	20	1.6	9	1.63	12	1.49	27	1.63	12	1.61	9	1.69	3	1.65	2
England &Wales	1.69	1.62	1.51	26	1.52	16	1.58	15	1.42	32	1.68	1	1.61	1	1.67	2	1.61	2
Scotland	2.03	1.95	1.8	22	1.76	20	1.88	15	1.65	32	2.01	1	1.94	1	2.01	2	1.94	2
Netherlands	1.79	1.54	1.69	13	1.51	7	1.72	9	1.4	25	1.7	11	1.5	8	1.77	2	1.53	2
Belgium	1.76	1.56	1.7	8	1.54	2	1.74	1	1.47	16	1.69	9	1.53	5	1.74	2	1.55	1
France	2.2	1.61	2.14	6	1.59	2	-	-	1.59	3	2.17	3	1.6	2	2.19	1	1.6	1
Switzerland	2.04	1.53	1.94	10	1.52	2	1.99	5	1.46	13	1.9	13	1.48	9	2.02	2	1.52	1
Austria	1.86	1.51	1.77	11	1.5	2	1.87	0[c]	1.5	2	1.79	9	1.49	4	1.85	1	1.51	1
Barcelona	1.54	1.35	1.5	8	1.34	2	1.56	0[c]	1.36	0[c]	1.44	18	1.32	7	1.52	3	1.34	1
Basque C.	1.4	1.2	1.36	9	1.2	4	1.4	0[c]	1.2	4	1.32	18	1.18	10	1.38	3	1.2	2
Madrid	1.42	1.27	1.39	8	1.27	2	1.44	0[c]	1.29	0[c]	1.33	21	1.26	7	1.41	3	1.27	1
Turin	1.56	1.14	1.54	5	1.14	2	1.57	0[c]	-	-	1.52	7	1.13	8	1.55	2	1.14	2
Tuscany	1.64	1.28	1.61	4	1.28	1	1.65	0[c]	-	-	1.59	7	1.27	4	1.62	2	1.28	1
Czech Republic	2.86	2.19	2.52	19	2.14	5	2.68	10	2.11	7	2.75	6	2.16	3	2.84	1	2.19	1
Poland	2.79	2.03	2.42	21	1.97	5	2.51	16	1.93	9	2.63	9	1.98	5	2.76	2	2.02	1
Lithuania	2.34	2.14	2.15	14	2.11	3	2.22	9	2.14	0	2.21	9	2.12	2	2.31	2	2.14	0
Estonia	2.48	2.31	2.27	14	2.24	6	2.42	4	2.24	6	2.39	6	2.29	2	2.44	2	2.3	1

- Reference country, hence no change through scenario

[c] set to 0, no inequality reduction due to this scenario

Table 5: Mortality RRs, scenario RRs and potential reduction in inequality in mortality (%) between those with high and low education for different smoking-related CoD for the upward leveling scenario (Scenario 1)

	Trachea, lung, bronchus and larynx cancer						Lip, oral cavity and pharynx cancer						Esophageal Cancer						COPD/Asthma					
	initial RR	new RR	Ineq. Redu.	initial RR	new RR	Ineq. Redu.	initial RR	new RR	Ineq. Redu.	initial RR	new RR	Ineq. Redu.	initial RR	new RR	Ineq. Redu.	initial RR	new RR	Ineq. Redu.	initial RR	new RR	Ineq. Redu.	initial RR	new RR	Ineq. Redu.
Population	M	M	M	W	W	W	M	M	M	W	W	W	M	M	M	W	W	W	M	M	M	W	W	W
Finland	2.73	2.2	30	2.03	1.77	25	1.71	1.3	58	1.38	1.24	36	1.9	1.63	30	1.49	1.35	28	3.3	3.04	11	3.09	2.86	11
Sweden	2.01	1.53	48	2.19	1.75	38	1.91	1.39	57	1.7	1.44	38	1.72	1.44	39	1.38	1.15	61	3.06	2.6	23	3.23	2.93	13
Denmark	1.86	1.5	41	2.47	2.14	23	2.56	2	36	1.67	1.46	32	1.82	1.57	31	1.21	1.07	66	3.01	2.64	19	2.87	2.67	11
England &Wales	3.46	2.42	42	1.67	1.29	56	[a]	[a]	[a]	0.81	0.65	0[d]	1.67	1.32	53	2.62	2.09	33	2.33	1.83	38	3.26	2.7	25
Scotland	3.72	2.71	37	3.66	2.46	45	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	3.54	3	21	4.24	3.14	34
Netherlands	2.62	2.27	21	1.86	1.67	22	2.07	1.73	32	1.49	1.38	23	1.77	1.63	18	1.17	1.11	35	3.83	3.62	7	5.04	4.93	3
Belgium	2.27	2.11	12	1.56	1.53	4	2.12	1.87	22	2.15	2.1	5	1.3	1.23	21	1.69	1.68	1	3.09	2.99	4	2.04	2.02	2
France	2.38	2.23	10	1.18	1.15	17	3.45	3.17	12	2.49	2.49	0	5.79	5.6	4	0.64	0.64	0	5.56	5.43	3	[a]	[a]	[a]
Switzerland	2.78	2.42	20	1.75	1.71	5	3.58	3.05	21	1.77	1.75	4	2.15	1.95	17	0.98	0.97	0[d]	4.21	3.89	10	3.03	3.01	1
Austria	2.4	2.14	19	1.49	1.47	4	2.6	2.36	15	2.09	2	8	1.86	1.67	22	0.74	0.71	0[d]	3.64	3.11	20	3.12	3.11	0
Barcelona	1.58	1.49	15	0.89	0.87	0[d]	2.03	1.86	17	0.87	0.86	0[d]	2.11	2.02	9	1.23	1.21	5	2.47	2.44	2	1.5	1.5	1
Basque C.	1.45	1.36	21	0.74	0.72	0[d]	2.38	2.14	18	1.15	1.11	23	1.48	1.43	12	0.48	0.48	0	1.84	1.83	2	2.48	2.47	1
Madrid	1.68	1.59	12	0.72	0.71	0[d]	1.88	1.72	19	2.32	2.29	2	1.85	1.79	7	[a]	[a]	[a]	2.4	2.38	1	2.83	2.82	1
Turin	2.38	2.32	4	1.01	1	0[d]	2.83	2.66	9	1.6	1.58	4	1.68	1.65	5	1.29	1.29	0	2.43	2.4	2	1.02	1.02	12
Tuscany	2.7	2.64	4	1.01	1	0[d]	[a]	[a]	[a]	1.16	1.15	9	0.87	0.86	0[d]	1.25	1.25	0	2.26	2.25	1	0.68	0.68	0
Czech Rep.	4.42	2.9	44	1.7	1.48	31	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	4.75	3.3	39	2.22	2.06	13
Poland	3.6	2.46	44	1.37	1.23	39	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	8.38	6.74	22	2.51	2.4	7
Lithuania	3.47	2.82	27	1.63	1.54	15	5.83	4.59	26	1.77	1.74	4	4.84	4.25	16	2.63	2.54	5	7.15	6.46	11	5.1	4.58	13
Estonia	3.04	2.59	22	1.95	1.76	20	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	3.69	3.42	10	3.36	3.14	9

[a] no result available as there are no cause-specific deaths among those with the highest educational level

[b] Mortality information not available

[d] set to 0, no inequality reduction due to reverse social gradient in smoking

in the other scenarios (mortality rates not shown). Even though there might be no decrease in relative inequality in some countries and scenarios, there might still be one in absolute inequality. This can be seen for all-cause mortality among men in Southern Europe in scenario 2. For instance, while relative inequalities increase among men in Barcelona (Table 4), absolute inequalities decrease by 18 per 100,000 (Figure 1, upper panel).

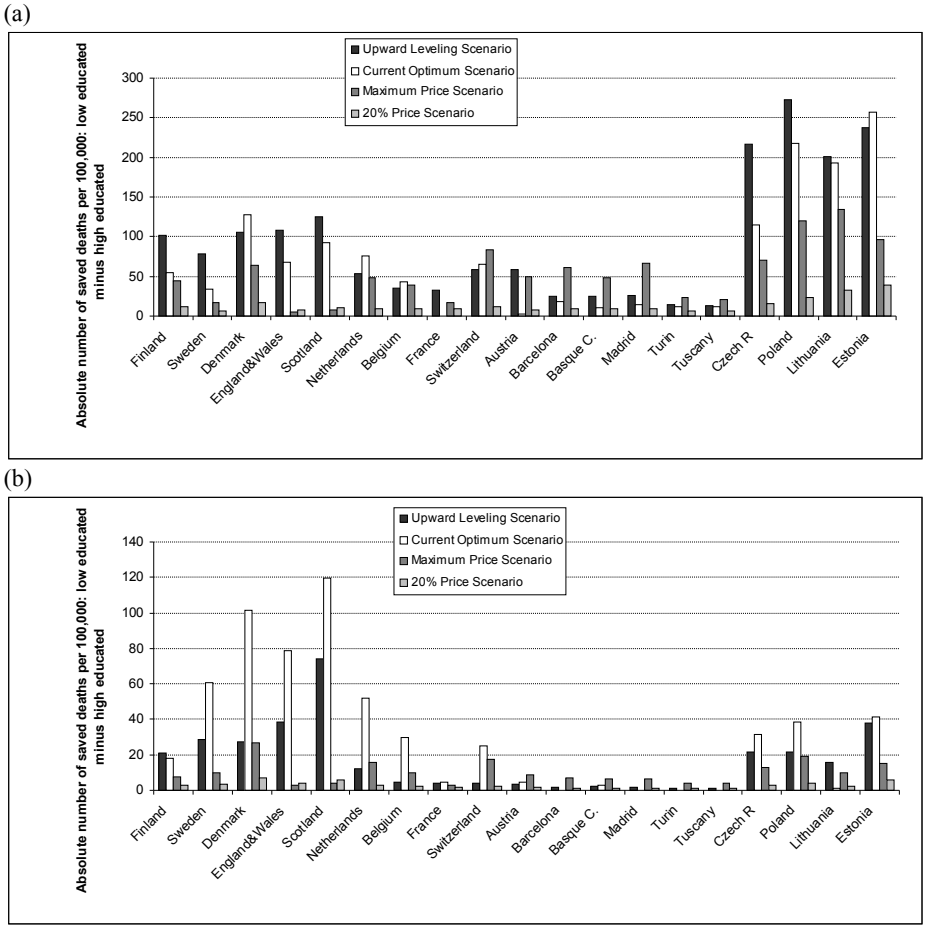

Figure 1: Change in absolute inequalities due to four different smoking scenarios: all-cause mortality, men in upper panel (a), women in lower panel (b) (To allow for additional clarity, axes for men and women are scaled differently)

Note: Reference country in Scenario 2: France for men, Italy for women, hence no change through scenario
Negative inequality reduction in Scenario 2 set to zero for women in Barcelona and Madrid

DISCUSSION

We calculated the effect of a change in the socioeconomic distribution of smoking on mortality and on socioeconomic inequalities in all-cause mortality and mortality related to smoking. The potential reduction of relative inequality in all-cause mortality between those with high and low education amounted up to 26% for men (scenario 1) and 32% for women (scenario 2). More than half of the relative inequality could be reduced for some causes of death related to smoking, often in the Nordic countries and England & Wales. While some scenarios resulted in no relative inequality reductions, there could still be a reduction in absolute inequality. The patterns of potential reduction in inequality differed by country or region, and sex.

Data and model limitations

The main advantage of the PAF approach is that it can combine data from different sources, while a regression necessarily measures the risk exposure and the outcome in the same sample. In many situations country-specific data on both exposure and impact are not available. Moreover relative risks from large studies (as used here) might be more accurate than those from small national surveys.

The mortality data came from different countries in which practices of data collection may differ, thus influencing comparability. The direction and the magnitude of this bias are not easy to assess and may fluctuate between countries. We accounted for the differences in study designs and follow-up times by using a correction factor [16] and hence do not expect our conclusions to change due to such a bias. For France the study population excluded those born outside of the country, in Switzerland all foreign nationals irrespective of place of birth were excluded. Hence, this might have resulted in a more homogenous population leading to an underestimation of inequalities in mortality.

The prevalence of smoking can be compared across sources only if it is measured in a very similar way. In all cases, smoking status was self-reported and refered to smoking in general. In most countries the respondents were classified as current regular smokers, current occasional smokers, ex-smokers or never smokers, while in some there was no distinction between regular or occasional smokers. As we combined regular and occasional smokers in our analyses there is no bias resulting from the formulation of the survey question.

In the following we discuss specific assumptions inherent to the PAF methodology. First, the relative risk used in the calculations should accurately reflect the causal effect of smoking on mortality [30]. With the causal effect of smoking being undisputed we feel safe to apply the PAF approach. Further, the relative risks were assumed to be the same for all countries [19]. This assumption was necessary for practical reasons, as there are no high-quality literature

reviews on the impact of risk factors for each country. There is an increasing body of evidence stating that, when the metric of exposure is comparable, the relative risks are similar across populations in different world regions [31]. Additionally, the relative risks were assumed to be the same for all educational groups. Whether a relative risk for smoking can be regarded as a biological constant or whether the impact of smoking differs between socioeconomic groups is still an open question, [32] but there is no systematic evidence on how the impact of this risk factor would differ by socioeconomic group. Higher relative risks for those with a lower socioeconomic status would result in an even higher potential for reducing inequalities.

Second, in the scenarios we did not specify the time dimension of the proposed changes. The implicit time frame is that we can only expect to see the reductions in mortality after persons who have been moved from one exposure group to another also have acquired the mortality risk of the new group [33]. In the case of lung cancer this may take as long as 20 years. Related to this is also the possible limitation that we used smoking prevalence data which might not reflect a sufficiently long time-lag between smoking and CoD like lung cancer or COPD. For countries which are far advanced in the smoking epidemic this might mean that some potential for inequality reduction is overestimated as social differences in smoking behavior have been increasing over time, especially among women. Hence, in a sensitivity analysis we used historical smoking prevalence rates from the early 1980s for England [34] and France [35] (results not shown). It demonstrated that for all-cause mortality in the upward leveling scenario the potential inequality reduction remained almost the same for English men and declined from 16% to 8% for women. The respective changes for France were 6% to 1% for men and 2% to no inequality reduction for women. This illustrates the sex-specific progression of countries through the stages of the smoking epidemic with England being more advanced than France, and men being more advanced than women.

Third, since the evidence of the effect of tobacco price increases on different SES groups encompasses a wide range of estimates [14,36] we also did a sensitivity analysis of the elasticity levels we used in this paper. It showed that if we assumed that those with a low education were only half as responsive, i.e. their elasticity of smoking participation was -0.16 instead of -0.32, the PAF and the potential inequality reduction would also decline by 50% (results not shown).

Lastly, we chose to include CoD for which it had been shown that smoking causes at least 50% of their deaths, in order to focus on those diseases that are for their most part caused by smoking as opposed to other risk factors. However, there are many more CoD related to smoking which we did not include in our analyses (e.g. cancer of the stomach, liver, pancreas, bladder, or ischemic heart disease and stroke [37]). While some CoD like cancers are usually clearly identifiable and easily coded within the ICD-Code system, other CoD like COPD might

be less clear-cut [38] and some underreporting or misreporting might occur due to variability in coding practices between countries [39]. When defining our variable for COPD/asthma we chose to use a broader definition including chronic bronchitis, emphysema, and asthma (J40-J47). This broad definition might at least partly guard against the fact that deaths of individuals with COPD are often attributed to other CoD [40].

We only show results contrasting the high and the low educated. The resulting potential reductions in mortality and inequality do not include those reductions experienced by the population subgroup with a medium level of education. All-cause results including the mid-educated can be found in the final report of the Euro-GBD-SE project [41].

Interpretation and comparison with other studies

The upward leveling scenario shows the theoretical maximum of what can be achieved in terms of health gains when inequalities in smoking are eliminated. It can also be viewed as a way of depicting of how advanced a country is within the stages of the smoking epidemic. A country which is far advanced in this transition will have high potential reductions in relative inequality, as it is those with a low level of education where most smokers will be found [1]. The other scenarios provide more of a realistic picture of what can actually be achieved.

As the relationship between smoking and specific smoking-related diseases and mortality is much stronger than that between smoking and all-cause mortality, potential reductions in mortality and inequality are much larger for those CoD explicitly related to smoking. Inequalities can be reduced substantially albeit not entirely.

Even though policies and scenarios are usually not sex-specific, for the interpretation of the results it is important to keep in mind that the relative risks are not the same for men and women and that their proportional relationships differ across causes of death. Further, depending on the stage of the smoking epidemic which does not just vary by country/region but also by sex, the scenario-induced change of the smoking distribution can result in opposite effects for men and women in different age groups. The impact of the different stages of the smoking epidemic and hence the effect of a reverse social gradient of smoking prevalence can also be observed among women of Southern Europe where scenario 1 would currently not decrease much of the inequalities in mortality.

Based on the Whitehall II longitudinal cohort study it was shown that leveling smoking behavior of those with low SES to that of those with high SES could reduce inequalities in all-cause mortality in England by 32% [42]. In Finland these numbers would be 28% for men and 22% for women, among those with the lowest education [43]. Another Finnish study based on indirect estimation of smoking-attributable mortality through lung cancer death

rates, quantified the contribution of smoking to inequalities in mortality at 29% among men and at 11% among women in the period 2001-2005 [44]. These results are slightly higher than our estimates of 26% and 16% for men and women in England and Wales and 17% for men and 8% for women in Finland.

Soerjomataram et al. [45] analyzed the potential reduction in inequalities of lung cancer incidence by modeling the effects of smoking policies. Their conclusion was that if there was a continuous price increase of 10% annually in England and Wales, inequalities in mortality could be decreased by 86% among men and by 74% among women by the year 2050. Given that the one-time price increases in our price scenarios are 15% and 20% only, and are not necessarily exhausting the possibilities of further increases, these authors' conclusion might be closer to our scenarios 1 and 2 which eliminate much more smoking inequalities in England and Wales. Hence, the results of both approaches can be seen as comparable, with ours being a conservative estimate of about 50% of inequality reduction in lung cancer mortality in scenarios 1 and 2.

Conclusion

Although the scenarios presented here were not able to fully eliminate social inequalities in mortality between those with a low and a high educational level they were still able to, in some cases, reduce inequality by a substantial amount. The patterns of potential reduction in inequality differed by population and sex, suggesting that the priority given to smoking as an entry-point for tackling health inequalities should differ between countries and possibly by sex. Reducing educational inequalities in smoking would be the most effective strategy in the Central and Eastern European region (particularly among men) and in the Nordic countries and Britain. Whereas in the South the strategy of increasing the price of tobacco would be more successful. Still, as some countries in Southern and Central and Eastern Europe, and especially women, have not yet fully passed through the stages of the smoking epidemic inequalities are likely to still rise. Further, it is crucial to keep in mind that reductions of relative and absolute inequalities might not point in the same direction, and that policies and interventions aimed at reducing the prevalence of smoking do not automatically also reduce inequalities in smoking or smoking-related mortality.

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APPENDIX: ADDITIONAL INFORMATION ON THE CALCULATION OF PRICE SCENARIOS

Price elasticity measures the average proportional reduction in demand when the price of a commodity increases. In our case the price is negatively associated with smoking prevalence, and those with a lower level of education are more responsive to price increases.

Eurostat defines its Purchasing Power Standard (PPS) in the following way: The PPS is an artificial currency unit. Theoretically, one PPS can buy the same amount of goods and services in each country. However, price differences across borders mean that different amounts of national currency units are needed for the same goods and services depending on the country. PPS are derived by dividing any economic aggregate of a country in national currency by its respective purchasing power parities (PPP). PPS is the technical term used by Eurostat for the common currency in which national accounts aggregates are expressed when adjusted for price level differences using PPPs. Thus, PPPs can be interpreted as the exchange rate of the PPS against the Euro.

Information on PPS and PPP retrieved from (accessed August 2013): http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Glossary:Purchasing_power_standard_(PPS)

Calculation example for obtaining new smoking prevalence in Finland in Scenario 3a:
In Finland where the price of tobacco would have to be increased by 76% in the maximum price scenario (see Table 1) we calculate the reduction in the prevalence of current smokers in the following way: for those with a low level of education we arrive at -0.32 (elasticity)*0.76 (price increase) = -0.243, resulting in a reduction of the smoking prevalence by 24.3% for every age group of those with a low educational level. For those with a medium level of education this leads to -0.04*0.76 = -0.030, a reduction of the initial smoking prevalence by 3%. For those with high education we get -0.02*0.76 = -0.015, a reduction by 1.5%.

APPENDIX TABLES AND FIGURES

Table A6a: Population Attributable Fraction (%) of those with a low educational level due to different smoking scenarios [a]

Cause-specific mortality: Trachea, Lung, Bronchus, Larynx Cancer								
Population	1) Upward leveling scenario		2) Current optimum scenario		3a) Maximum price scenario		3b) 20% price scenario	
MEN	PAF (%)	95% CI	PAF (%)	95% CI	PAF (%)	95% CI	PAF (%)	95% CI
Finland	19.3	13.8-24.7	18.5	13.3-23.7	9.7	3.9-15.5	2.5	0.0-7.0
Sweden	23.9	19.6-28.3	11.9	7.6-16.2	5.4	1.0-9.7	2.0	0.0-5.4
Denmark	19.0	15.6-22.4	41.4	39.1-43.8	11.8	8.2-15.4	3.1	0.0-6.1
England & Wales	29.9	27.1-32.8	24.1	21.2-26.9	1.5	0.0-4.0	2.0	0.0-4.7
Scotland	27.2	23.1-31.3	27.8	23.6-31.9	1.7	0.0-5.2	2.3	0.0-6.0
Netherlands	13.1	9.7-16.6	35.8	33.3-38.3	12.6	9.2-16.0	2.5	0.0-5.3
Belgium	6.9	4.1-9.8	26.9	24.1-29.7	10.1	6.6-13.6	2.4	0.0-5.2
France	6.0	2.7-9.3	-	-	4.9	1.0-8.9	2.5	0.0-6.1
Switzerland	13.0	7.6-18.5	25.9	20.9-30.8	19.0	13.5-24.5	2.7	0.0-7.1
Austria	10.9	3.7-18.1	2.4	0.0-8.2	12.8	4.6-21.0	2.2	0.0-8.0
Barcelona	5.5	4.1-6.9	23.1	21.1-25.0	18.0	16.0-20.1	2.6	0.5-4.6
Basque Country	6.3	3.3-9.4	15.8	11.6-20.1	15.7	11.3-20.0	2.7	0.0-6.2
Madrid	4.9	3.6-6.1	23.2	21.2-25.2	17.6	15.4-19.7	2.5	0.4-4.6
Turin	2.4	1.6-3.2	16.8	15.8-17.9	7.9	6.7-9.2	2.2	1.0-3.4
Tuscany	2.4	1.6-3.3	17.2	16.0-18.3	7.9	6.7-9.1	2.2	1.1-3.3
Czech Republic	34.2	27.1-41.3	20.1	12.1-28.2	10.9	2.8-19.1	2.5	0.0-8.6
Poland	31.6	29.2-34.0	31.7	29.4-34.0	14.1	11.1-17.1	2.8	0.1-5.6
Lithuania	18.9	13.1-24.6	28.0	21.9-34.2	13.6	8.0-19.3	3.2	0.0-7.0
Estonia	14.8	7.6-22.0	37.5	31.0-44.0	7.9	0.0-16.0	3.1	0.0-10.2
European Average	17.3		24.6		10.1		2.5	
WOMEN								
Finland	12.8	7.6-17.9	13.7	8.2-19.2	6.0	0.5-11.4	2.3	0.0-7.1
Sweden	20.4	15.1-25.6	43.0	39.2-46.8	7.4	1.8-13.0	2.7	0.0-7.1
Denmark	13.5	10.5-16.5	58.9	57.3-60.5	12.2	8.7-15.8	3.2	0.1-6.3
England & Wales	22.7	19.1-26.3	51.2	48.9-53.4	1.8	0.0-4.6	2.4	0.0-5.4
Scotland	32.8	29.1-36.4	58.4	56.2-60.6	2.0	0.0-5.4	2.7	0.0-6.3
Netherlands	10.0	7.3-12.7	47.9	46.0-49.8	12.9	9.9-15.9	2.5	0.0-5.1
Belgium	1.6	0.2-2.9	29.7	26.7-32.7	9.7	5.7-13.7	2.3	0.0-5.5
France	2.5	0.0-5.3	4.7	1.2-8.2	4.4	0.0-8.7	2.2	0.0-6.0
Switzerland	2.3	0.4-4.2	27.6	23.7-31.5	18.2	13.7-22.7	2.6	0.0-6.2
Austria	1.2	0.0-2.7	5.4	0.4-10.5	10.9	3.4-18.3	1.8	0.0-7.0
Barcelona	2.2	1.4-3.0	4.5	3.0-5.9	14.3	11.5-17.1	2.0	0.0-4.5

Table A6a: (Continued)

Cause-specific mortality: Trachea, Lung, Bronchus, Larynx Cancer								
Population	1) Upward leveling scenario		2) Current optimum scenario		3a) Maximum price scenario		3b) 20% price scenario	
WOMEN	PAF (%)	95% CI	PAF (%)	95% CI	PAF (%)	95% CI	PAF (%)	95% CI
Basque Country	3.0	1.3-4.7	4.3	1.7-6.8	13.2	8.7-17.6	2.3	0.0-5.8
Madrid	1.0	0.4-1.6	2.0	0.8-3.2	12.5	9.1-15.9	1.8	0.0-4.3
Turin	1.1	0.3-1.8	-	-	7.1	5.5-8.7	2.0	0.6-3.4
Tuscany	0.9	0.1-1.7	-	-	7.4	5.8-8.9	2.1	0.7-3.5
Czech Republic	12.6	8.6-16.5	21.5	14.1-29.0	9.3	1.2-17.3	2.1	0.0-8.5
Poland	10.5	8.1-12.9	25.5	23.0-27.9	13.0	9.5-16.4	2.6	0.0-5.4
Lithuania	5.8	5.3-6.3	0.1	0.0-0.1	6.6	1.4-11.9	1.6	0.0-5.2
Estonia	9.6	0.1-19.0	14.0	4.0-23.9	6.1	0.0-15.6	2.4	0.0-11.2
European Average	10.1		27.0		8.8		2.3	

[a] Significant results are depicted in black. Depicted in grey are statistically non-significant results where the original confidence intervals included 0. However, in the table we set the lower bounds of these intervals to 0 as negative values would indicate a protective effect of a reduction of smoking, which is conceptually impossible

- Reference country, hence no change through scenario

Table A6b: Population Attributable Fraction (%) of those with a low educational level due to different smoking scenarios [a]

Cause-specific mortality: Lip, Oral Cavity, Pharynx Cancer								
Population	1) Upward leveling scenario		2) Current optimum scenario		3a) Maximum price scenario		3b) 20% price scenario	
MEN	PAF (%)	95% CI	PAF (%)	95% CI	PAF (%)	95% CI	PAF (%)	95% CI
Finland	24.2	20.8-27.6	13.0	9.2-16.8	11.4	7.8-15.1	3.0	0.0-6.0
Sweden	27.0	22.5-31.5	5.7	2.0-9.4	6.7	2.1-11.3	2.4	0.0-6.1
Denmark	21.7	18.7-24.6	33.6	30.9-36.2	13.8	10.6-17.0	3.6	0.6-6.6
England & Wales	34.6	30.9-38.3	13.2	8.8-17.5	2.1	0.0-5.1	2.8	0.0-6.0
Scotland	c	c	c	c	c	c	c	c
Netherlands	16.8	12.1-21.4	28.2	23.5-33.0	15.4	12.1-18.7	3.0	0.0-6.0
Belgium	11.6	8.5-14.7	20.1	17.2-23.0	12.9	9.8-16.0	3.1	0.1-6.0
France	8.1	3.8-12.5	-	-	5.6	1.7-9.4	2.9	0.0-6.3
Switzerland	15.0	9.8-20.1	21.0	16.1-25.9	22.3	17.5-27.2	3.2	0.0-7.5
Austria	9.3	3.2-15.5	2.7	0.0-7.6	16.4	9.3-23.6	2.8	0.0-8.0
Barcelona	8.7	6.7-10.7	20.4	18.3-22.4	22.3	20.2-24.3	3.2	0.9-5.4
Basque Country	10.2	6.7-13.7	13.8	9.9-17.7	18.4	14.8-22.0	3.2	0.0-6.6
Madrid	8.9	6.9-11.0	19.6	17.7-21.5	21.8	19.9-23.7	3.1	1.0-5.2
Turin	6.0	3.8-8.1	10.0	8.5-11.4	10.1	9.1-11.1	2.9	1.8-3.9
Tuscany	6.6	2.5-10.6	10.5	8.3-12.6	9.9	8.7-11.0	2.8	1.7-3.8
Czech Republic	c	c	c	c	c	c	c	c

Table A6b: (Continued)

Cause-specific mortality: Lip, Oral Cavity, Pharynx Cancer								
Population	1) Upward leveling scenario		2) Current optimum scenario		3a) Maximum price scenario		3b) 20% price scenario	
MEN	PAF (%)	95% CI	PAF (%)	95% CI	PAF (%)	95% CI	PAF (%)	95% CI
Poland	[c]	[c]	[c]	[c]	[c]	[c]	[c]	[c]
Lithuania	21.3	17.3-25.2	27.0	23.1-30.8	15.6	11.5-19.6	3.7	0.2-7.3
Estonia	[c]	[c]	[c]	[c]	[c]	[c]	[c]	[c]
European Average	17.1		17.5		12.8		3.0	
WOMEN								
Finland	9.9	6.0-13.7	10.2	6.5-13.8	3.7	0.2-7.2	1.5	0.0-4.5
Sweden	15.4	10.8-20.1	30.6	27.4-33.8	5.2	1.3-9.1	1.9	0.0-4.9
Denmark	12.7	10.1-15.4	44.4	42.4-46.3	9.6	6.9-12.3	2.5	0.2-4.8
England & Wales	20.2	15.7-24.8	32.9	28.3-37.6	1.5	0.0-3.5	1.9	0.0-4.1
Scotland	[c]	[c]	[c]	[c]	[c]	[c]	[c]	[c]
Netherlands	7.4	3.6-11.3	35.4	33.3-37.6	9.2	6.5-11.8	1.8	0.0-4.0
Belgium	2.5	0.0-5.5	20.5	17.5-23.5	7.0	3.3-10.6	1.7	0.0-4.6
France	0.0	0.0-0.0	2.5	0.0-5.6	2.9	0.0-6.1	1.5	0.0-4.1
Switzerland	1.5	0.0-3.4	18.6	15.9-21.3	12.3	9.3-15.3	1.8	0.0-4.1
Austria	4.3	0.5-8.0	4.4	0.7-8.1	7.8	3.4-12.2	1.3	0.0-4.3
Barcelona	1.0	0.0-2.2	2.1	0.0-4.6	6.9	4.4-9.4	1.0	0.0-2.4
Basque Country	2.9	0.5-5.3	4.2	0.7-7.7	8.7	5.4-11.9	1.5	0.0-3.9
Madrid	1.2	0.0-2.6	2.4	0.0-5.4	7.4	4.7-10.1	1.1	0.0-2.4
Turin	1.3	0.0-3.0	-	-	4.3	3.1-5.5	1.2	0.4-2.1
Tuscany	1.3	0.0-3.3	-	-	5.0	3.6-6.3	1.4	0.5-2.3
Czech Republic	[c]	[c]	[c]	[c]	[c]	[c]	[c]	[c]
Poland	[c]	[c]	[c]	[c]	[c]	[c]	[c]	[c]
Lithuania	1.7	1.4-2.0	0.0	0.0-0.0	3.2	0.2-6.3	0.8	0.0-2.8
Estonia	[c]	[c]	[c]	[c]	[c]	[c]	[c]	[c]
European Average	6.6		18.4		6.2		1.6	

[a] Significant results are depicted in black. Depicted in grey are statistically non-significant results where the original confidence intervals included 0. However, in the table we set the lower bounds of these intervals to 0 as negative values would indicate a protective effect of a reduction of smoking, which is conceptually impossible

- Reference country, hence no change through scenario

[c] Mortality information not available

Table A6c: Population Attributable Fraction (%) of those with a low educational level due to different smoking scenarios [a]

Cause-specific mortality: Esophageal Cancer								
Population	1) Upward leveling scenario		2) Current optimum scenario		3a) Maximum price scenario		3b) 20% price scenario	
MEN	PAF (%)	95% CI	PAF (%)	95% CI	PAF (%)	95% CI	PAF (%)	95% CI
Finland	14.2	11.4-16.9	13.3	10.2-16.3	4.2	1.2-7.1	1.1	0.0-3.6
Sweden	16.4	13.2-19.6	14.2	11.0-17.4	2.1	0.0-4.7	0.8	0.0-3.0
Denmark	13.9	11.5-16.2	30.6	28.6-32.5	5.5	3.1-7.9	1.4	0.0-3.3
England & Wales	21.1	19.1-23.0	23.1	20.7-25.5	0.6	0.0-2.1	0.8	0.0-2.3
Scotland	c	c	c	c	c	c	c	c
Netherlands	8.0	5.5-10.5	30.6	28.1-33.1	5.4	3.3-7.4	1.1	0.0-2.6
Belgium	3.4	1.5-5.3	22.2	20.4-24.1	4.5	2.5-6.6	1.1	0.0-2.6
France	3.3	0.8-5.9	-	-	2.0	0.0-4.9	1.0	0.0-3.5
Switzerland	9.3	5.5-13.0	18.9	15.3-22.5	8.4	4.4-12.3	1.2	0.0-3.8
Austria	10.2	4.7-15.8	4.9	0.0-10.0	5.1	0.3-10.0	0.9	0.0-4.5
Barcelona	4.6	3.4-5.8	18.7	17.3-20.1	8.3	6.8-9.9	1.2	0.0-2.5
Basque Country	3.8	1.6-6.0	10.9	8.0-13.8	7.0	4.1-9.8	1.2	0.0-3.3
Madrid	3.3	2.1-4.4	19.3	17.8-20.9	8.0	6.3-9.7	1.1	0.0-2.6
Turin	1.8	0.9-2.8	15.4	13.8-17.0	3.2	2.4-4.0	0.9	0.2-1.6
Tuscany	1.1	0.0-2.4	16.2	14.1-18.3	3.1	2.2-4.1	0.9	0.1-1.7
Czech Republic	c	c	c	c	c	c	c	c
Poland	c	c	c	c	c	c	c	c
Lithuania	12.3	8.8-15.7	17.6	13.6-21.6	6.5	2.9-10.1	1.5	0.0-4.2
Estonia	c	c	c	c	c	c	c	c
European Average	9.8		18.9		4.6		1.1	
WOMEN								
Finland	9.3	4.2-14.4	9.6	4.3-15.0	4.8	0.0-9.9	1.9	0.0-6.6
Sweden	16.6	11.2-22.0	36.8	33.4-40.2	6.6	2.0-11.1	2.4	0.0-6.0
Denmark	11.3	8.3-14.3	53.1	51.1-55.1	11.6	8.1-15.0	3.0	0.0-6.0
England & Wales	20.4	16.7-24.0	44.0	41.5-46.4	1.7	0.0-4.3	2.2	0.0-5.1
Scotland	c	c	c	c	c	c	c	c
Netherlands	5.0	1.7-8.4	43.0	40.3-45.7	11.1	7.1-15.0	2.2	0.0-5.2
Belgium	0.4	0.0-1.1	24.0	21.6-26.5	8.4	5.5-11.3	2.0	0.0-4.1
France	0.0	0.0-0.2	2.8	0.0-6.2	3.4	0.0-7.6	1.8	0.0-5.2
Switzerland	1.0	0.0-2.8	23.1	19.5-26.8	15.0	10.9-19.2	2.2	0.0-5.5
Austria	4.4	0.0-11.0	2.9	0.0-6.7	8.4	1.9-14.9	1.4	0.0-5.6
Barcelona	1.0	0.0-2.5	2.0	0.0-4.9	10.7	7.1-14.3	1.5	0.0-3.7
Basque Country	0.0	0.0-0.0	0.0	0.0-1.2	9.8	5.8-13.9	1.7	0.0-4.7
Madrid	0.8	0.0-2.0	1.6	0.0-4.1	10.9	7.7-14.2	1.6	0.0-3.6
Turin	0.0	0.0-0.0	-	-	5.4	3.3-7.4	1.5	0.2-2.8
Tuscany	0.0	0.0-0.0	-	-	4.9	2.8-7.0	1.4	0.0-2.8
Czech Republic	c	c	c	c	c	c	c	c

Table A6c: (Continued)

Cause-specific mortality: Esophageal Cancer								
Population	1) Upward leveling scenario		2) Current optimum scenario		3a) Maximum price scenario		3b) 20% price scenario	
WOMEN	PAF (%)	95% CI	PAF (%)	95% CI	PAF (%)	95% CI	PAF (%)	95% CI
Poland	[c]	[c]	[c]	[c]	[c]	[c]	[c]	[c]
Lithuania	3.2	2.8-3.6	0.0	0.0-0.0	4.9	0.9-9.0	1.2	0.0-3.9
Estonia	[c]	[c]	[c]	[c]	[c]	[c]	[c]	[c]
European Average	6.0		21.9		7.6		1.9	

[a] Significant results are depicted in black. Depicted in grey are statistically non-significant results where the original confidence intervals included 0. However, in the table we set the lower bounds of these intervals to 0 as negative values would indicate a protective effect of a reduction of smoking, which is conceptually impossible

- Reference country, hence no change through scenario

[c] Mortality information not available

Table A6d: Population Attributable Fraction (%) of those with a low educational level due to different smoking scenarios [a]

Cause-specific mortality: COPD/asthma								
Population	1) Upward leveling scenario		2) Current optimum scenario		3a) Maximum price scenario		3b) 20% price scenario	
MEN	PAF (%)	95% CI	PAF (%)	95% CI	PAF (%)	95% CI	PAF (%)	95% CI
Finland	7.9	3.7-12.0	16.6	11.5-21.8	4.2	0.0-9.8	1.1	0.0-6.0
Sweden	15.2	11.0-19.4	19.7	15.8-23.5	1.9	0.0-5.1	0.7	0.0-3.4
Denmark	12.6	9.2-15.9	38.2	35.9-40.4	5.5	2.1-8.8	1.4	0.0-3.9
England & Wales	21.5	19.3-23.8	27.9	25.8-29.9	0.6	0.0-2.2	0.8	0.0-2.5
Scotland	15.3	11.0-19.6	29.0	25.5-32.5	0.7	0.0-3.0	0.9	0.0-3.3
Netherlands	5.4	2.3-8.5	38.0	35.7-40.2	5.0	1.8-8.3	1.0	0.0-3.2
Belgium	3.0	0.9-5.1	28.5	26.4-30.6	4.0	1.6-6.5	1.0	0.0-2.8
France	2.3	0.0-5.5	-	-	1.9	0.0-5.3	1.0	0.0-4.0
Switzerland	7.6	2.8-12.5	23.5	18.7-28.4	8.1	2.9-13.4	1.2	0.0-4.7
Austria	14.4	7.7-21.1	5.6	0.0-11.9	4.8	0.0-10.7	0.8	0.0-5.4
Barcelona	1.2	0.8-1.6	23.2	21.4-24.9	6.6	4.4-8.7	0.9	0.0-2.5
Basque Country	0.9	0.0-2.6	13.8	8.5-19.1	6.1	1.2-10.9	1.1	0.0-4.4
Madrid	0.7	0.4-1.0	23.5	21.7-25.3	6.3	3.9-8.6	0.9	0.0-2.5
Turin	1.1	0.5-1.7	19.8	18.6-21.0	3.0	1.9-4.2	0.9	0.0-1.8
Tuscany	0.4	0.0-0.9	20.5	19.3-21.8	2.9	1.7-4.2	0.8	0.0-1.8
Czech Republic	30.5	23.8-37.3	16.6	9.2-23.9	4.6	0.0-10.6	1.0	0.0-6.0
Poland	19.6	17.0-22.1	27.5	25.3-29.7	5.7	3.0-8.4	1.1	0.0-3.1
Lithuania	9.7	5.2-14.2	18.8	12.7-24.9	6.5	1.7-11.3	1.6	0.0-4.9
Estonia	7.3	2.8-11.9	30.9	24.4-37.4	3.7	0.0-11.1	1.5	0.0-8.1
European Average	10.9		24.1		4.2		1.1	

Table A6d: (Continued)

Cause-specific mortality: COPD/asthma								
Population	1) Upward leveling scenario		2) Current optimum scenario		3a) Maximum price scenario		3b) 20% price scenario	
WOMEN	PAF (%)	95% CI	PAF (%)	95% CI	PAF (%)	95% CI	PAF (%)	95% CI
Finland	7.5	0.9-14.1	9.6	2.5-16.6	3.8	0.0-10.2	1.5	0.0-7.5
Sweden	9.3	4.8-13.8	45.7	42.0-49.4	4.6	0.0-9.5	1.7	0.0-5.6
Denmark	6.8	4.4-9.3	61.7	60.1-63.3	8.1	4.2-12.1	2.1	0.0-5.2
England & Wales	17.2	13.4-21.0	56.0	54.0-58.0	1.1	0.0-3.7	1.5	0.0-4.3
Scotland	25.9	21.9-29.9	60.6	58.3-62.9	1.3	0.0-4.3	1.7	0.0-4.8
Netherlands	2.1	0.4-3.8	54.6	52.3-56.9	7.5	3.2-11.7	1.5	0.0-4.5
Belgium	1.0	0.5-1.6	33.5	30.3-36.6	5.4	2.2-8.7	1.3	0.0-3.8
France	0.0	0.0-0.0	0.6	0.0-1.6	2.4	0.0-7.4	1.2	0.0-5.8
Switzerland	0.9	0.2-1.5	29.0	24.8-33.3	11.3	6.2-16.3	1.6	0.0-5.3
Austria	0.3	0.0-0.8	3.9	0.3-7.6	5.7	0.0-12.5	1.0	0.0-6.1
Barcelona	0.4	0.0-0.9	1.0	0.0-2.2	5.8	2.7-8.9	0.8	0.0-3.1
Basque Country	0.3	0.0-0.7	0.4	0.0-1.2	6.1	0.1-12.0	1.1	0.0-5.7
Madrid	0.5	0.0-1.1	1.3	0.0-2.7	5.0	1.9-8.1	0.7	0.0-3.0
Turin	0.3	0.0-0.8	-	-	3.8	1.6-6.0	1.1	0.0-2.7
Tuscany	0.0	0.0-0.0	-	-	3.6	1.3-5.9	1.0	0.0-2.6
Czech Republic	7.2	5.3-9.2	16.3	9.9-22.7	5.3	0.0-12.7	1.2	0.0-7.6
Poland	4.4	3.0-5.8	16.2	14.0-18.4	7.4	3.5-11.2	1.5	0.0-4.3
Lithuania	10.2	8.3-12.2	0.0	0.0-0.3	4.6	0.5-8.6	1.1	0.0-4.1
Estonia	6.3	0.0-16.5	9.9	0.0-21.1	4.1	0.0-14.4	1.7	0.0-11.5
European Average	6.2		26.6		5.1		1.4	

[a] Significant results are depicted in black. Depicted in grey are statistically non-significant results where the original confidence intervals included 0. However, in the table we set the lower bounds of these intervals to 0 as negative values would indicate a protective effect of a reduction of smoking, which is conceptually impossible

- Reference country, hence no change through scenario

Table A7a: Mortality RRs, scenario RRs and potential reduction in inequality in mortality (%) between those with high and low education due to different smoking scenarios

Cause-specific mortality: Trachea, Lung, Bronchus, Larynx Cancer																		
			1) Upward leveling scenario				2) Current optimum scenario				3a) Maximum price scenario				3b) 20% price scenario			
	initial RR	initial RR	new RR	Ineq. Redu.	new RR	Ineq. Redu.	new RR	Ineq. Redu.	new RR	Ineq. Redu.	new RR	Ineq. Redu.	new RR	Ineq. Redu.	new RR	Ineq. Redu.	new RR	Ineq. Redu.
Population	M	W	M	M	W	W	M	M	W	W	M	M	W	W	M	M	W	W
Finland	2.73	2.03	2.2	30	1.77	25	2.38	20	1.75	27	2.47	15	1.91	11	2.66	4	1.99	4
Sweden	2.01	2.19	1.53	48	1.75	38	1.79	22	1.25	79	1.9	10	2.04	13	1.97	4	2.14	5
Denmark	1.86	2.47	1.5	41	2.14	23	1.62	28	1.34	77	1.65	24	2.18	20	1.8	6	2.39	5
England &Wales	3.46	1.67	2.42	42	1.29	56	2.7	31	0.84	0[e]	3.41	2	1.65	4	3.39	3	1.64	6
Scotland	3.72	3.66	2.71	37	2.46	45	2.87	31	1.54	80	3.66	2	3.59	3	3.64	3	3.57	4
Netherlands	2.62	1.86	2.27	21	1.67	22	2.33	17	1.17	81	2.3	20	1.63	27	2.55	4	1.82	5
Belgium	2.27	1.56	2.11	12	1.53	4	2.24	3	1.11	80	2.05	17	1.41	26	2.22	4	1.52	6
France	2.38	1.18	2.23	10	1.15	17	-	-	1.12	31	2.27	8	1.13	28	2.32	4	1.15	14
Switzerland	2.78	1.75	2.42	20	1.71	5	2.56	12	1.32	58	2.28	28	1.45	40	2.71	4	1.7	6
Austria	2.4	1.49	2.14	19	1.47	4	2.42	0[c]	1.41	16	2.1	21	1.34	32	2.35	4	1.47	5
Barcelona	1.58	0.89	1.49	15	0.87	0[d]	1.62	0[c]	0.94	0[d]	1.31	47	0.77	0[d]	1.54	7	0.87	0[d]
Basque C.	1.45	0.74	1.36	21	0.72	0[d]	1.44	1	0.73	0[d]	1.23	48	0.65	0[d]	1.41	8	0.73	0[d]
Madrid	1.68	0.72	1.59	12	0.71	0[d]	1.72	0[c]	0.83	0[d]	1.4	42	0.64	0[d]	1.64	6	0.71	0[d]
Turin	2.38	1.01	2.32	4	1	0[d]	2.42	0[c]	-	-	2.2	13	0.94	0[d]	2.33	4	0.99	0[d]
Tuscany	2.7	1.01	2.64	4	1	0[d]	2.77	0[c]	-	-	2.5	12	0.94	0[d]	2.65	3	0.99	0[d]
Czech Republic	4.42	1.7	2.9	44	1.48	31	3.54	26	1.33	52	3.95	14	1.55	22	4.31	3	1.66	5
Poland	3.6	1.37	2.46	44	1.23	39	2.56	40	1.03	93	3.1	19	1.2	45	3.5	4	1.34	9
Lithuania	3.47	1.63	2.82	27	1.54	15	2.95	21	1.63	0	3.02	18	1.53	16	3.37	4	1.61	4
Estonia	3.04	1.95	2.59	22	1.76	20	2.84	10	1.68	29	2.81	11	1.84	12	2.95	4	1.9	5

- Reference country, hence no change through scenario

[c] set to 0, no inequality reduction due to this scenario

[d] set to 0, no inequality reduction due to reverse social gradient in smoking

[e] set to 0, scenario causes reversal of social gradient in smoking

Table A7b: Mortality RRs, scenario RRs and potential reduction in inequality in mortality (%) between those with high and low education due to different smoking scenarios

Cause-specific mortality: Lip, Oral Cavity, Pharynx Cancer																		
			1) Upward leveling scenario				2) Current optimum scenario				3a) Maximum price scenario				3b) 20% price scenario			
	initial RR	initial RR	new RR	Ineq. Redu.	new RR	Ineq. Redu.	new RR	Ineq. Redu.	new RR	Ineq. Redu.	new RR	Ineq. Redu.	new RR	Ineq. Redu.	new RR	Ineq. Redu.	new RR	Ineq. Redu.
Population	M	W	M	M	W	W	M	M	W	W	M	M	W	W	M	M	W	W
Finland	1.71	1.38	1.3	58	1.24	36	1.51	28	1.24	37	1.53	26	1.33	13	1.67	7	1.36	5
Sweden	1.91	1.7	1.39	57	1.44	38	1.8	12	1.18	74	1.78	14	1.62	12	1.86	5	1.67	4
Denmark	2.56	1.67	2	36	1.46	32	2.31	16	1.14	79	2.22	22	1.52	23	2.47	6	1.63	6
England &Wales	[a]	0.81	[a]	[a]	0.65	0[d]	[a]	[a]	0.55	[a]	[a]	[a]	0.8	0[d]	[a]	[a]	0.8	0[d]
Scotland	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]
Netherlands	2.07	1.49	1.73	32	1.38	23	1.71	34	1.03	94	1.77	28	1.36	26	2.01	6	1.47	5
Belgium	2.12	2.15	1.87	22	2.1	5	2.08	3	1.74	36	1.86	23	2.01	12	2.06	6	2.12	3
France	3.45	2.49	3.17	12	2.49	0	-	-	2.47	1	3.26	7	2.42	4	3.35	4	2.46	2
Switzerland	3.58	1.77	3.05	21	1.75	4	3.41	7	1.51	33	2.82	30	1.57	27	3.47	4	1.74	4
Austria	2.6	2.09	2.36	15	2	8	2.69	0[c]	2	8	2.19	25	1.94	14	2.53	4	2.06	2
Barcelona	2.03	0.87	1.86	17	0.86	0[d]	2.09	0[c]	0.96	0[d]	1.6	42	0.82	0[d]	1.97	6	0.86	0[d]
Basque C.	2.38	1.15	2.14	18	1.11	23	2.39	0[c]	1.1	33	1.97	30	1.05	64	2.31	5	1.13	11
Madrid	1.88	2.32	1.72	19	2.29	2	1.95	0[c]	2.85	0[c]	1.49	44	2.17	11	1.83	6	2.3	2
Turin	2.83	1.6	2.66	9	1.58	4	2.9	0[c]	-	-	2.56	15	1.54	11	2.75	4	1.58	3
Tuscany	[a]	1.16	[a]	[a]	1.15	9	[a]	[a]	-	-	[a]	[a]	1.11	34	[a]	[a]	1.14	9
Czech Republic	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]
Poland	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]
Lithuania	5.83	1.77	4.59	26	1.74	4	5.07	16	1.77	0	4.97	18	1.72	7	5.63	4	1.76	2
Estonia	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]

- Reference country, hence no change through scenario

[a] no result available as there are no cause-specific deaths among those with the highest educational level

[b] Mortality information not available

[c] set to 0, no inequality reduction due to this scenario

[d] set to 0, no inequality reduction due to reverse social gradient in smoking

Table A7c: Mortality RRs, scenario RRs and potential reduction in inequality in mortality (%) between those with high and low education due to different smoking scenarios

Cause-specific mortality: Esophageal Cancer																		
			1) Upward leveling scenario				2) Current optimum scenario				3a) Maximum price scenario				3b) 20% price scenario			
	initial RR	initial RR	new RR	Ineq. Redu.	new RR	Ineq. Redu.	new RR	Ineq. Redu.	new RR	Ineq. Redu.	new RR	Ineq. Redu.	new RR	Ineq. Redu.	new RR	Ineq. Redu.	new RR	Ineq. Redu.
Population	M	W	M	M	W	W	M	M	W	W	M	M	W	W	M	M	W	W
Finland	1.9	1.49	1.63	30	1.35	28	1.79	12	1.35	29	1.82	9	1.42	14	1.88	2	1.46	5
Sweden	1.72	1.38	1.44	39	1.15	61	1.53	27	0.87	0[e]	1.69	5	1.29	23	1.71	2	1.34	8
Denmark	1.82	1.21	1.57	31	1.07	66	1.66	19	0.72	0[e]	1.72	12	1.07	65	1.8	3	1.17	17
England &Wales	1.67	2.62	1.32	53	2.09	33	1.32	53	1.51	69	1.66	2	2.58	3	1.65	2	2.56	4
Scotland	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]
Netherlands	1.77	1.17	1.63	18	1.11	35	1.53	30	0.76	0[e]	1.68	12	1.04	74	1.75	2	1.14	14
Belgium	1.3	1.69	1.23	21	1.68	1	1.27	8	1.29	57	1.24	19	1.55	20	1.28	4	1.65	5
France	5.79	0.64	5.6	4	0.64	0	-	-	0.63	0[d]	5.68	2	0.62	0[d]	5.73	1	0.63	0[d]
Switzerland	2.15	0.98	1.95	17	0.97	0[d]	2.02	12	0.79	0[d]	1.98	15	0.84	0[d]	2.13	2	0.96	0[d]
Austria	1.86	0.74	1.67	22	0.71	0[d]	1.86	0	0.72	0[d]	1.77	10	0.68	0[d]	1.84	2	0.73	0[d]
Barcelona	2.11	1.23	2.02	9	1.21	5	2.13	0[c]	1.3	0[c]	1.94	15	1.1	55	2.09	2	1.21	8
Basque C.	1.48	0.48	1.43	12	0.48	0	1.49	0[c]	0.49	0[c]	1.38	20	0.44	0[d]	1.47	4	0.47	0[d]
Madrid	1.85	[a]	1.79	7	[a]	[a]	1.87	0[c]	[a]	[a]	1.71	17	[a]	[a]	1.83	2	[a]	[a]
Turin	1.68	1.29	1.65	5	1.29	0	1.7	0[c]	-	-	1.63	8	1.23	22	1.67	2	1.28	6
Tuscany	0.87	1.25	0.86	0[d]	1.25	0	0.86	0[d]	-	-	0.84	0[d]	1.2	22	0.86	0[d]	1.24	6
Czech Republic	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]
Poland	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]
Lithuania	4.84	2.63	4.25	16	2.54	5	4.33	13	2.63	0	4.54	8	2.5	8	4.77	2	2.6	2
Estonia	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]

- Reference country, hence no change through scenario

[a] no result available as there are no cause-specific deaths among those with the highest educational level

[b] Mortality information not available

[c] set to 0, no inequality reduction due to this scenario

[d] set to 0, no inequality reduction due to reverse social gradient in smoking

[e] set to 0, scenario causes reversal of social gradient in smoking

Table A7d: Mortality RRs, scenario RRs and potential reduction in inequality in mortality (%) between those with high and low education due to different smoking scenarios

Cause-specific mortality: COPD/asthma																		
			1) Upward leveling scenario				2) Current optimum scenario				3a) Maximum price scenario				3b) 20% price scenario			
	initial RR	initial RR	new RR	Ineq. Redu.	new RR	Ineq. Redu.	new RR	Ineq. Redu.	new RR	Ineq. Redu.	new RR	Ineq. Redu.	new RR	Ineq. Redu.	new RR	Ineq. Redu.	new RR	Ineq. Redu.
Population	M	W	M	M	W	W	M	M	W	W	M	M	W	W	M	M	W	W
Finland	3.3	3.09	3.04	11	2.86	11	3.2	4	2.8	14	3.17	6	2.98	5	3.27	2	3.05	2
Sweden	3.06	3.23	2.6	23	2.93	13	2.64	21	1.75	66	3	3	3.09	6	3.04	1	3.18	2
Denmark	3.01	2.87	2.64	19	2.67	11	2.71	15	1.6	68	2.86	8	2.64	12	2.97	2	2.81	3
England &Wales	2.33	3.26	1.83	38	2.7	25	1.8	40	1.51	77	2.32	1	3.22	2	2.32	1	3.21	2
Scotland	3.54	4.24	3	21	3.14	34	2.99	22	1.83	74	3.52	1	4.18	2	3.51	1	4.17	2
Netherlands	3.83	5.04	3.62	7	4.93	3	3.62	7	2.97	51	3.64	7	4.68	9	3.79	1	4.97	2
Belgium	3.09	2.04	2.99	4	2.02	2	3.03	2	1.37	64	2.97	6	1.94	10	3.06	1	2.02	2
France	5.56	[a]	5.43	3	[a]	[a]	-	-	[a]	[a]	5.46	2	[a]	[a]	5.51	1	[a]	[a]
Switzerland	4.21	3.03	3.89	10	3.01	1	3.92	9	2.26	38	3.88	10	2.71	16	4.16	2	2.99	2
Austria	3.64	3.12	3.11	20	3.11	0	3.48	6	2.99	6	3.47	6	2.95	8	3.61	1	3.09	1
Barcelona	2.47	1.5	2.44	2	1.5	1	2.55	0[c]	1.53	0[c]	2.32	10	1.42	16	2.45	1	1.49	2
Basque C.	1.84	2.48	1.83	2	2.47	1	1.86	0[c]	2.46	1	1.74	13	2.34	9	1.82	2	2.45	2
Madrid	2.4	2.83	2.38	1	2.82	1	2.47	0[c]	3	0[c]	2.26	10	2.7	7	2.38	1	2.81	1
Turin	2.43	1.02	2.4	2	1.02	0	2.46	0[c]	-	-	2.36	5	0.99	0[d]	2.41	1	1.01	44
Tuscany	2.26	0.68	2.25	1	0.68	0	2.28	0[c]	-	-	2.2	5	0.66	0[d]	2.24	1	0.67	0[d]
Czech Rep.	4.75	2.22	3.3	39	2.06	13	3.98	21	1.86	30	4.55	6	2.1	9	4.71	1	2.19	2
Poland	8.38	2.51	6.74	22	2.4	7	6.72	23	2.11	26	7.92	6	2.34	12	8.29	1	2.48	2
Lithuania	7.15	5.1	6.46	11	4.58	13	6.5	11	5.1	0	6.7	7	4.88	5	7.04	2	5.05	1
Estonia	3.69	3.36	3.42	10	3.14	9	3.77	0[c]	3.02	14	3.56	5	3.22	6	3.63	2	3.3	2

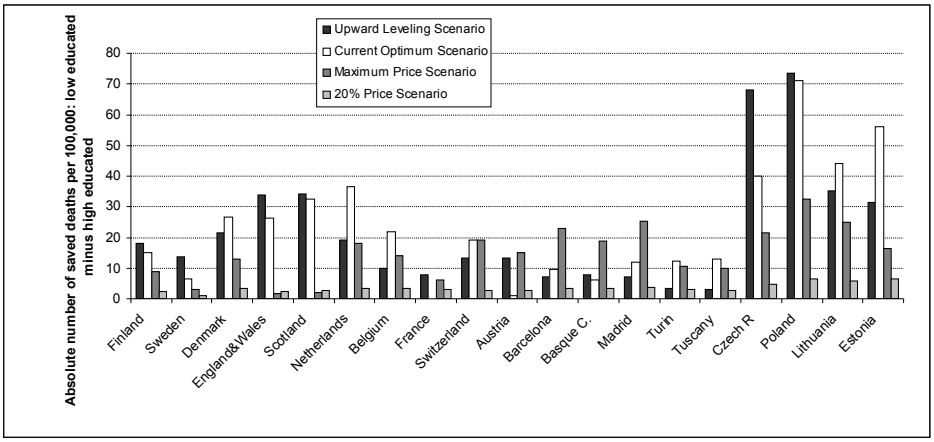
- Reference country, hence no change through scenario

[a] no result available as there are no cause-specific deaths among those with the highest educational level

[c] set to 0, no inequality reduction due to this scenario

[d] set to 0, no inequality reduction due to reverse social gradient in smoking

(a)



(b)

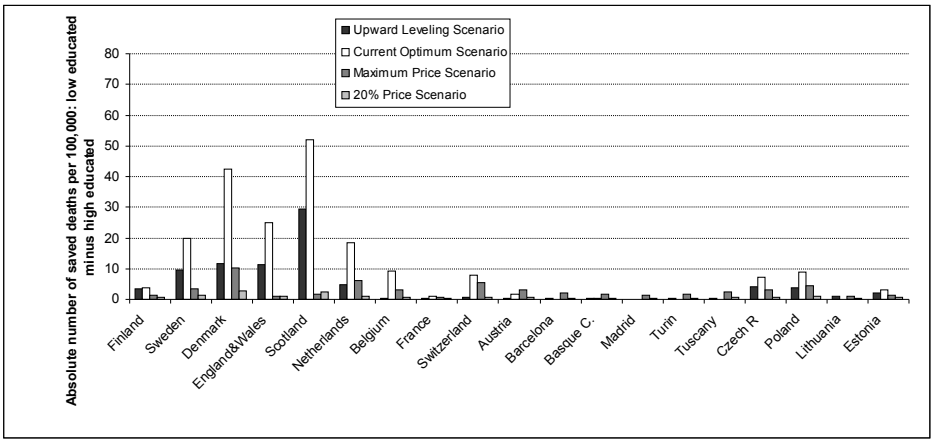
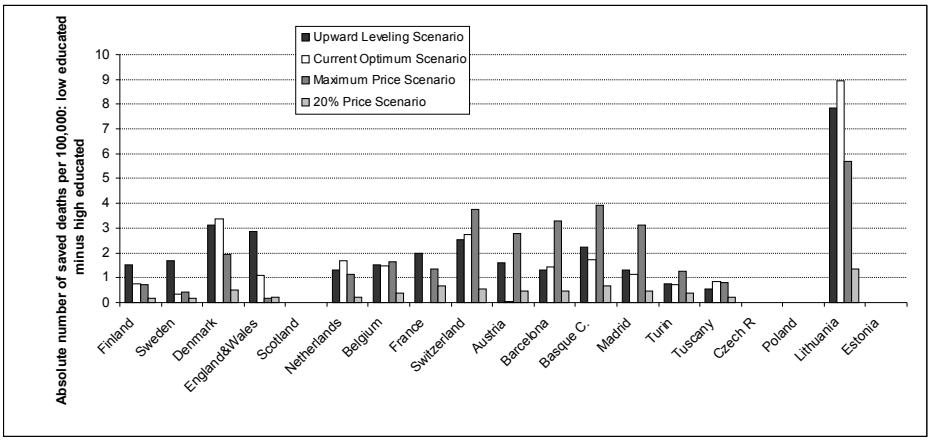


Figure A2a: Change in absolute inequalities due to four different smoking scenarios: Cause-specific mortality: Trachea, Lung, Bronchus, Larynx Cancer, men in upper panel (a), women in lower panel (b)
Note: Reference country in Scenario 2: France for men, Italy for women, hence no change through scenario
Negative inequality reduction in Scenario 2 set to zero for women in Barcelona and Madrid

(a)



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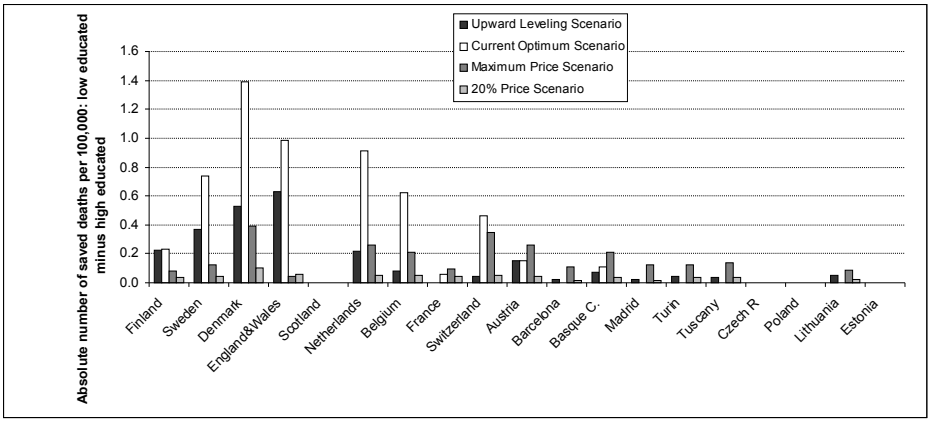
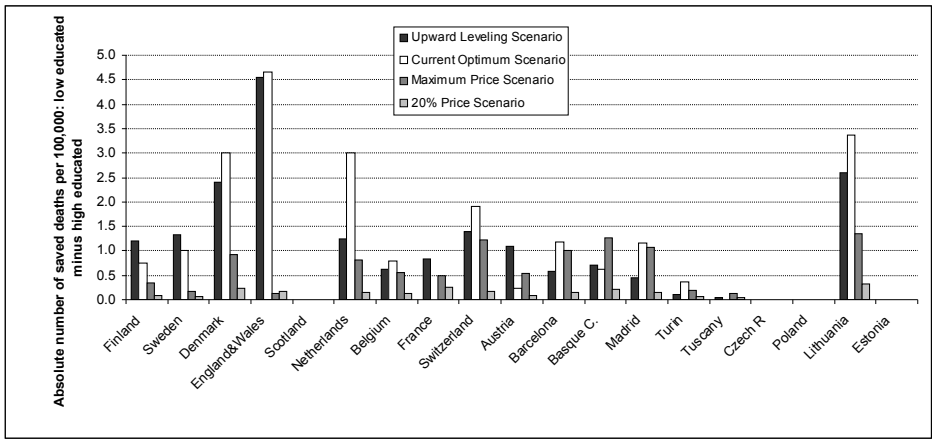


Figure A2b: Change in absolute inequalities due to four different smoking scenarios: Cause-specific mortality: Lip, Oral Cavity, Pharynx Cancer, men in upper panel (a), women in lower panel (b) (To allow for additional clarity, axes for men and women are scaled differently)
Note: Reference country in Scenario 2: France for men, Italy for women, hence no change through scenario
Mortality information not available for Scotland, the Czech Republic, Poland and Estonia
Negative inequality reduction in Scenario 2 set to zero for women in Barcelona and Madrid

(a)



(b)

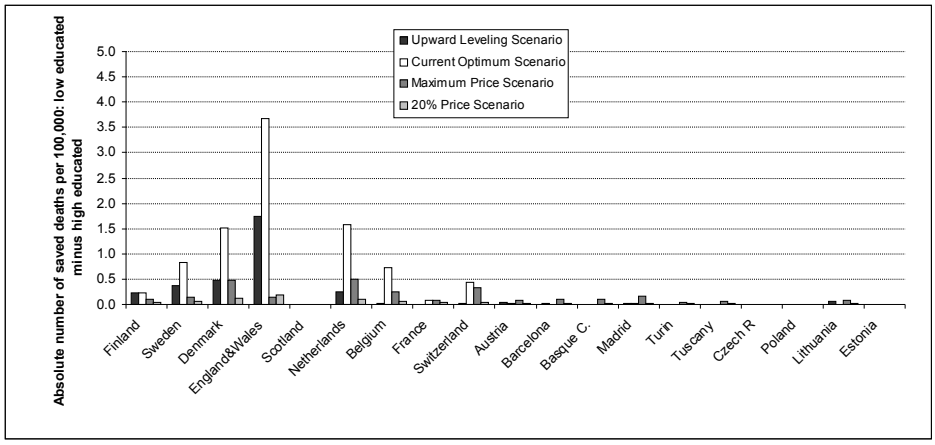
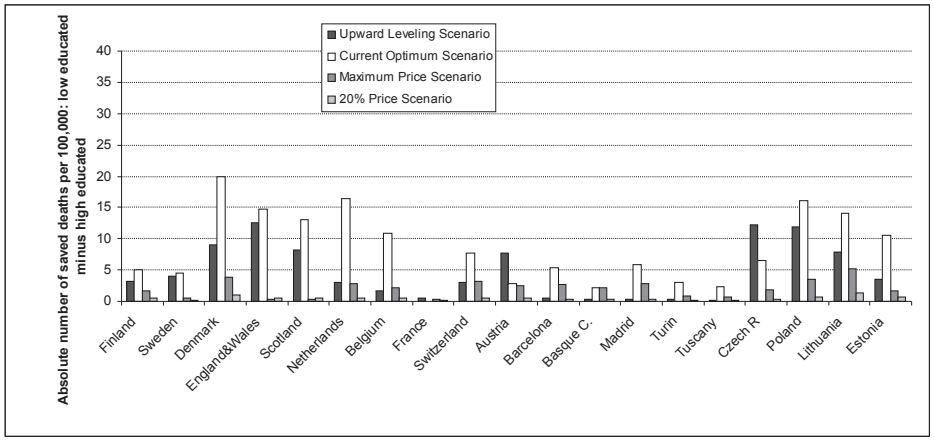


Figure A2c: Change in absolute inequalities due to four different smoking scenarios: Cause-specific mortality: Esophageal Cancer, men in upper panel (a), women in lower panel (b) Note: Reference country in Scenario 2: France for men, Italy for women, hence no change through scenario Mortality information not available for Scotland, the Czech Republic, Poland and Estonia Negative inequality reduction in Scenario 2 set to zero for women in Barcelona and Basque Country and for men in Tuscany

(a)



(b)

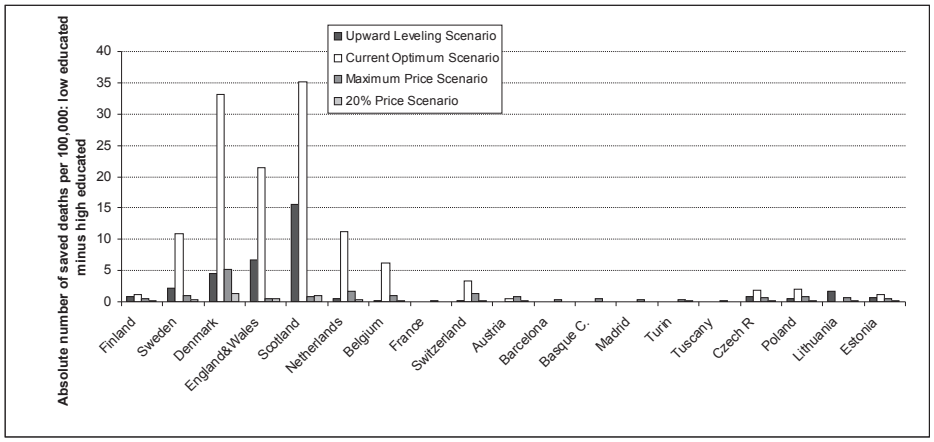


Figure A2d: Change in absolute inequalities due to four different smoking scenarios: Cause-specific mortality: COPD/asthma, men in upper panel, women in lower panel
Note: Reference country in Scenario 2: France for men, Italy for women, hence no change through scenario
Negative inequality reduction in Scenario 2 set to zero for women in Barcelona and Madrid

CHAPTER 6

General Discussion

This thesis presents a collection of papers on the quantification of inequalities, and policies and interventions related to smoking. This final chapter summarizes and discusses the answers to the study questions asked at the outset.

MAIN FINDINGS

Answers to study questions

1) Do patterns of smoking prevalence and patterns of smoking inequalities by educational level vary across different data sources?

Chapter 2 showed that patterns of smoking prevalence and patterns of smoking inequalities by educational level measured in Western European countries around the year 2000 varied across data sources. Hence, smoking inequalities depended on the survey used. The prevalence of ever and current smoking tended to be lower in the European Community Household Panel (ECHP) than in the National Health Interview Surveys (NHIS) and the Eurobarometer (EB), being highest in the latter. The pattern of educational inequalities in ever and current smoking also differed significantly between surveys. Statistically significant differences between surveys were found mainly in Spain, Portugal, Italy and Greece, where prevalence ratios based on the EB often deviated from those in the other two surveys. A comparison with lung cancer mortality data suggested that the NHISs provide the most reliable source of information on smoking inequalities by educational level.

2) What is the magnitude of smoking-related inequalities in mortality in Europe?

Chapter 3 documented the magnitude of smoking-related inequalities in mortality in Europe in the early 2000s, providing estimates of relative and absolute educational inequalities in mortality from lung cancer, upper aero-digestive cancers and Chronic Obstructive Pulmonary Disease (COPD)/asthma. Among men, relative inequalities in mortality from the three smoking-related causes of death combined were largest in the Czech Republic and Hungary and smallest in Spain, Sweden and Denmark. Among women these inequalities were largest in Scotland and Norway and smallest in Italy and Spain. They were often larger among men, and tended to be larger for COPD and asthma than for lung and upper aero-digestive cancers. Looking at specific age groups, relative inequalities in mortality from these conditions were often larger among younger individuals, particularly among women, suggesting a possible further widening of inequalities in mortality in the coming decades. The combined contribution of these diseases to inequality in all-cause mortality varied between 13% and 32% among men, and between -5% and 30% among women.

3) What are the potential health gains and health inequality reductions due to different tobacco control policies and interventions?

Chapters 4 and 5 discussed the potential health gains and inequality reductions due to different tobacco control policies and interventions. Dynamic quantification of three basic tobacco control intervention types illustrated potential health gains in the Netherlands. These intervention types were 1) promoting smoking cessation, 2) preventing smoking initiation and 3) targeting potential quitters and starters simultaneously. All three intervention scenarios resulted in fewer excess prevalence cases of smoking-related diseases such as COPD, lung cancer and ischemic heart disease (IHD), and fewer deaths after the intervention, though the magnitude and timing of the effects differed. It was shown that all smoking interventions will be effective in the long run. The combined strategy is most effective in both the short and long term. The smoking cessation scenario is second-most effective in the short run, though in the long run the smoking initiation scenario will become almost as effective. Interventions aimed at preventing the initiation of smoking need a long time horizon to become manifest in terms of health effects. The outcomes strongly depend on the groups targeted by the intervention.

We applied three additional smoking intervention scenarios to 19 European populations. In the first, smoking prevalence for all socioeconomic subgroups was changed to the level observed for the higher educated in the same country. In the second, smoking prevalence for all socioeconomic subgroups was changed to the level observed in the country with the smallest inequalities and a low prevalence of current smokers. In the third, the price of tobacco in every country was increased to the currently highest level in the EU, and also by a more realistic 20%. These intervention scenarios showed that the patterns of potential reduction in inequality differed by country or region and sex. The potential reduction of relative inequality in all-cause mortality between those with high and low education amounted up to 26% for men (scenario 1) in England & Wales and 32% for women (scenario 2) in England & Wales and Scotland. More than half of the relative inequality could be eliminated for smoking-related causes of death like lung cancer, lip, oral cavity and pharynx cancer, esophageal cancer and COPD/asthma, often in the Nordic countries and in Britain.

METHODOLOGICAL LIMITATIONS

Data considerations

We showed that patterns of smoking prevalence and of smoking inequalities varied across different data sources, even if survey questions were similar and the data was collected around the same point in time. We demonstrated that the NHIS data collection was more

reliable than other data sources and we therefore used this data as part of the modeling tool input for our scenario analyses of potential health gains and inequality reductions. However, some possible limitations still have to be considered. We investigated whether patterns of smoking prevalence and smoking inequalities by educational level differed across three major European surveys. The comparison could have been even more extensive if we had been able to evaluate other surveys along with the NHIS, the ECHP and the EB. However, while there were other international surveys collected around the year 2000, they either did not include questions on smoking or the variable was not measured in the way needed for the analysis, i.e. in categories of current, former and never smokers. While the Survey of Health, Aging, and Retirement in Europe (SHARE) [1] did include appropriate smoking information we chose not to use this survey as it only contains respondents who are 50 years old or older, whereas our analyses included all those aged 25 and above.

A more complete picture of the pattern of smoking inequalities across Europe would have emerged if our comparison had also included countries of Central and Eastern Europe. Since these were only available in the NHIS for the time around the year 2000, this information could not be compared with results from other surveys. We present some of these NHIS results in table 1 below. Although our analysis points out the reliability of estimates based on a collection of harmonized NHIS and detracts some of the value from international surveys like the ECHP and EB, the validity of country-specific NHIS data also has to be scrutinized. After an initial comparison of country-specific inequalities in smoking prevalence rates and in lung cancer mortality we chose not to trust the smoking data of the Hungarian NHIS. While smoking prevalence was roughly identical among those with low, medium and high education and also did not differ considerably between age groups (especially among men), mortality from lung cancer showed high levels of educational inequalities (see chapter 3). The smoking prevalence patterns also did not correspond to those in the neighboring countries of Central and Eastern Europe (see chapter 5).

The mortality data that was used to show the magnitude of smoking-related mortality inequalities and potential inequality reductions was based on population censuses and vital registries, and also made use of regional data due to lack of national information (Italy and Spain). Most datasets were longitudinal and census-linked, except for unlinked cross-sectional data from the Czech Republic, Estonia, Hungary and Poland, and data from Barcelona and Madrid, which were cross-sectional with a linkage between vital registries and population censuses. Due to the different study designs and follow-up times, specific correction factors were used to remove the bias due to classifying deaths by age at baseline, instead of age at death [2]. It has been shown that social inequalities in mortality may be biased in cross-sectional studies when compared to longitudinal studies because of possible numerator/denominator bias [3]. The direction and the magnitude of this bias are not eas-

ily assessed and may differ between countries. A Lithuanian study reported overestimation of educational inequalities in cross-sectional studies. However, this study also showed that despite some over-estimation of mortality rate ratios in the lowest education category, census-unlinked estimates reflect the same pattern of relative mortality inequality as the census-linked estimates [4]. Further, national data from Spain and Italy also show smaller inequalities in all-cause mortality in these two countries, suggesting that any bias due to use of regional data is limited [5,6].

This thesis includes analyses of all-cause and of smoking-related mortality, represented by several causes of death (CoD) like lung cancer (ICD-Code 10: C33-C34), upper aero-digestive cancers (cancers of lip, oral cavity, pharynx, esophagus, larynx; ICD-Code 10: C00-C15, C32), COPD/asthma (ICD-Code 10: J40-J47), and IHD (ICD-Code 10: I20-I25). While some CoD, such as cancers, are usually clearly identifiable and easily coded within the ICD-Code system, other CoD, such as COPD, might be less clear-cut [7], and underreporting or misreporting might occur, creating scope for variability in certification and coding practices between countries [8,9]. When defining our variable for COPD/asthma for analyses in chapters 3 and 5, which only included mortality data pertaining to COPD, we chose to use a broader definition including chronic bronchitis, emphysema, and asthma (COPD & related conditions: ICD-Code 10: J40-J47). This broad definition might at least partly guard against the fact that deaths of individuals with COPD are often attributed to other CoD causing underestimation of deaths due to COPD [10]. Input for the DYNAMO-HIA tool, on the other hand, required not only cause-specific mortality and its correct identification, but also incidence and prevalence. In the case of COPD this information came from General Practice (GP) Registries, and was made consistent with the DisMod II software [11]. Asthma cases were excluded from this analysis [12].

Timing considerations

In chapters 4 and 5 we quantified the impact of changes in the prevalence of smoking on (inequalities in) mortality. Because of the nature of smoking and how it affects morbidity and mortality several issues arise that are related to the time-lag between smoking, disease incidence and disease mortality, and also to how tobacco control interventions can change smoking prevalence and affect health outcomes over time. Smoking-induced effects related to lung cancer or COPD will e.g. need at least 20 years to manifest themselves [13,14,15,16]. This implies that current lung cancer or COPD mortality rates mirror smoking behavior that dates some 20 years back, or that current smoking behavior will only be fully translated into mortality rates some 20 years from today. Within the DYNAMO-HIA tool the problem of possible inconsistency between the inputs, i.e. incidence, prevalence and (excess) mortality (IPM) collected around the same point in time was resolved by using DisMod II software [11] to arrive at consistent country and disease-specific IPM data.

We can also only expect to see a reduction in mortality after persons who used to be smokers and then become non-smokers acquire the mortality risk of the new group [17]. This is why the DYNAMO-HIA tool differentiates the relative risks of former smokers by time since quitting. A further consideration is the interplay of time between tobacco control interventions and changes in smoking. In the DYNAMO-HIA tool the development of risk factor exposure after the implementation of a policy is explicitly quantified and can be followed over time. In this way the changing impact of smoking on disease prevalence and mortality can be also be illustrated.

In the PAF tool the time dimension of the proposed changes is not specified. The implicit time frame is that we can only expect to see reductions in mortality after persons who have been moved from one exposure group to another have acquired the mortality risk of that new group. Further, while it can be viewed as an advantage that the PAF tool can incorporate data on risk factor exposure and mortality from different data sources, this might lead to inconsistencies if smoking prevalence data relates to a point in time that does not allow a sufficiently long time-lag between smoking and CoD like lung cancer or COPD. In chapter 5 this would lead to most problems in countries where social differences in smoking have been changing especially fast in the past few decades. For example, if smoking inequalities have been increasing very fast, with relatively more and more smokers among those with a lower education, the current potential for inequality reduction is probably overestimated. This might be especially true among women [18,19]. Finally, as there is no explicit time frame, the policy-induced potential inequality reductions as estimated with the PAF tool should not be assumed to be immediate.

Modeling considerations

Models and scenarios are often not able to present all complexities of the real world. While the formulation of models and stylized scenarios necessarily requires a simplification of reality we still aimed at formulating realistic models. In this thesis we presented applications of two different tools for the modeling of potential health gains and potential inequality reductions related to tobacco control interventions and policies. There are certain limitations common to both tools.

A particular challenge in both the DYNAMO-HIA tool as well as the PAF tool was finding appropriate estimates of the consequences of interventions and tobacco control policies that could be translated into input parameters of a model. Evidence of, for example, the effect of tobacco price increases on total populations or on those in different socioeconomic groups encompasses a wide range of estimates [20,21,22]. Hence, when applying both modeling tools we also included sensitivity analyses assuming different effect levels.

If intervention studies reported a reduction in the prevalence of smokers, additional assumptions were needed about the origin of the reduction: less initiation of smoking, increasing the prevalence of never smokers, or more quitting, increasing the prevalence of former smokers. The price scenario was implemented in a similar way in both tools, using price elasticities of smoking participation found through literature reviews. For adults these were translated into reductions of the prevalence of current smokers and increases in former smokers in both tools, and in DYNAMO-HIA also into an increase of never smokers among those up to age 20. Whereas the PAF tool only allows for a change in risk factor prevalence, DYNAMO-HIA also requires an adjustment in transition rates between risk factors states when a lasting policy effect is modeled. Therefore, additional assumptions had to be made. Assuming that most persons start smoking below the age of 20, it is around this age when most uncertainty existed on whether the reduction in smokers reflects less starting or more quitting. Given that future health outcomes do not differ between former and never smokers at these young ages, we do not expect that this affected our estimates. For older ages, it was mainly the expected effect of the price increase on restart rates that was surrounded by uncertainty. We expected that a price increase would also reduce the likelihood that future former smokers take up smoking again, and assumed a similar decrease in restart rates as in initial start rates. However, other quantifications of the effect on restart rates may be equally defensible, and might yield different changes in future smoking exposure and health. At the most extreme, assuming no change in the restart rates would have implied that the effect of this intervention on smoking prevalence at adult and older ages would have been virtually absent during part of the projection period.

Uncertainty considerations

The DYNAMO-HIA tool does not provide confidence intervals around its outputs. Still, probabilistic sensitivity analysis (PSA) techniques can be used to estimate the uncertainty around model outcomes which stems from uncertainty of the data input [23,24]. However, a PSA is demanding in terms of data requirements and computational resources and was therefore impossible to implement as a standard option in the tool and within the time frame of our study. In order to allow for future use of such methods, the DYNAMO-HIA tool can be run in batch mode, allowing the experienced user to automatize the procedures necessary for such analyses.

Confidence intervals for the outcomes of the PAF tool were calculated using bootstrapping implemented in the statistical program R [25]. The procedure consisted of constructing replicas by drawing numbers from the Poisson distribution with the observed numbers as parameters. Recalculating the PAF using the replica numbers lead to a distribution around the point estimate from which the 2.5 and the 97.5 percentile were taken to represent the CI. We assumed the relative risks of the effect of the particular risk factors on mortality not

to be subject to sampling variation. We focused on the largest source of uncertainty which was the prevalence of the risk factors. In the particular analyses presented here it were the country-specific numbers of current, former and never smokers at the outset which were the driving force of the magnitude of the CIs.

INTERPRETATION OF FINDINGS

Comparison of findings between studies

The strength of this thesis is its comparative approach within each paper, and we will now add a comparison between chapters. Table 1 presents the main results of the studies next to each other. In the first two columns each country's patterns and levels of inequalities in smoking can be compared with its inequalities in lung cancer. In the second two columns the inequality contributions of smoking-related causes of death to inequalities in all-cause mortality are contrasted with the potential inequality reductions in all-cause mortality in an upward leveling scenario in which everyone has the smoking prevalence of the higher-educated. We do not necessarily expect a close correspondence between columns 1 or 2 and columns 3 or 4, as values in columns 3 and 4 are also influenced by the magnitude of inequalities in exposure to determinants other than smoking.

As seen in the first two columns of Table 1 and in Figure 1, the direction of educational inequalities among current smokers matched the direction of educational inequalities in lung cancer, the cause of death closest related to smoking, with a correlation coefficient of 0.79. It was still 0.61 even with the outlier (men in the Czech Republic) excluded. Among men, the inequalities were always above one, meaning that there were more smokers and more deaths due to lung cancer among those with a lower level of education. Among women in Italy both inequalities were reversed.

Among men, the combined contribution of inequalities in lung cancer, upper aero-digestive cancer and COPD to inequality in all-cause mortality varied between 13% in Sweden and Estonia and 32% in Italy. The contributions were particularly large in Southern Europe and parts of Western Europe (England & Wales, Scotland, the Netherlands and Belgium) and lowest in the Nordic countries and Central and Eastern Europe. Among women, those contributions varied between -5% in Spain and 30% in Denmark. They were highest in Denmark, Scotland and the Netherlands and smallest in Eastern Europe, France and Austria, and even reversed in Southern Europe (Table 1, column 3).

For both men and women, the potential inequality reduction in all-cause mortality in an upward leveling scenario, in which the low educated are assumed to have the smoking

Table 1: Comparison of results from Chapters 2, 3 and 5

European Region	Country	(1) Inequalities in Smoking based on NHIS (PR with CIs), Chapter 2	(2) Inequalities in Lung Cancer Mortality (RII with CIs), Chapter 3	(3) Inequality Contribution of Smoking-related CoD to Inequalities in All-cause Mortality (%), Chapter 3	(4) Potential Inequality Reduction in All-cause Mortality in Smoking Upward-leveling Scenario (%), Chapter 5
	MEN				
Nordic	Finland	1.42 (1.31-1.53)	4.05 (3.59-4.57)	14.8	17
	Sweden	1.48 (1.28-1.70)	2.20 (2.02-2.40)	13.1	19
	Denmark	1.44 (1.35-1.53)	2.08 (1.89-2.28)	20.7	20
West	England & Wales	1.56 (1.42-1.71)	4.78 (3.24-7.06)	30.2	26
	Scotland	*	6.00 (3.63-9.91)	27.4	22
	Netherlands	1.63 (1.51-1.76)	3.51 (2.61-4.73)	29.7	13
	Belgium	1.48 (1.38-1.59)	3.56 (3.16-4.00)	26.5	8
	France	1.21 (1.11-1.32)**	2.55 (1.87-3.48)	20.9	6
	Switzerland	1.20 (1.11-1.31)**	3.50 (3.14-3.90)	23.5	10
	Austria	1.18 (1.00-1.41)***	2.46 (2.04-2.98)	22.3	11
South	Spain	1.29 (1.22-1.36)	1.82 (1.65-2.00)	26.3	8, 9, and 8#
	Italy	1.27 (1.24-1.31)	3.61 (2.91-4.48)	32.2	5, 4##
Central/East	Czech Republic	2.25 (1.79-2.81)**	8.41 (7.74-9.13)	19.1	19
	Poland	*	2.72 (2.61-2.82)	19.6	21
	Lithuania	1.33 (1.25-1.42)**	3.84 (3.39-4.35)	17.9	14
	Estonia	1.16 (1.06-1.28)**	3.03 (2.58-3.56)	13.3	14
	WOMEN				
Nordic	Finland	1.61 (1.45-1.78)	3.36 (2.71-4.16)	9.9	8
	Sweden	1.55 (1.37-1.76)	2.45 (2.21-2.70)	17.3	10
	Denmark	1.39 (1.30-1.49)	3.11 (2.77-3.50)	30.0	9
West	England & Wales	1.62 (1.49-1.76)	2.98 (1.76-5.05)	21.9	16
	Scotland	*	6.14 (3.39-11.13)	29.4	20
	Netherlands	1.58 (1.44-1.72)	3.15 (1.94-5.11)	23.1	7
	Belgium	1.42 (1.29-1.55)	1.95 (1.57-2.43)	12.8	2
	France	1.06 (0.96-1.17)**	1.09 (0.56-2.13)	4.7	2
	Switzerland	1.15 (1.06-1.24)**	1.91 (1.62-2.26)	16.5	2
	Austria	1.03 (0.84-1.26)***	1.22 (0.88-1.69)	6.6	2
South	Spain	1.03 (0.96-1.11)	0.56 (0.45-0.70)	-4.8	2, 4, and 2#
	Italy	0.91 (0.88-0.95)	0.87 (0.61-1.25)	-1.5	2, 1##
Central/East	Czech Republic	1.51 (1.18-1.94)**	1.75 (1.51-2.02)	6.1	5
	Poland	*	1.01 (0.93-1.09)	3.5	5
	Lithuania	1.15 (0.99-1.34)**	1.68 (1.19-2.36)	4.2	3
	Estonia	1.26 (1.08-1.46)**	1.43 (0.97-2.10)	2.6	6

(Notes to this table are on the following page)

* no suitable individual-level data for PR calculation available
** additional data which was not part of the survey comparison in chapter 2
*** PR based on ECHP
# Barcelona, Basque Country, Madrid respectively; ##Turin, Tuscany respectively
Source: Chapters 2, 3, 5; Additional NHIS data France: Enquête Décennale Santé 2002, Switzerland: Swiss Health Survey 2002; Czech Republic: Sample Survey of the Health Status of the Czech Population 2002, Lithuania and Estonia: Finbalt Health Monitor 2002/2004

prevalence of the higher educated (column 4), was particularly high in England & Wales and Scotland. The association between the two indicators was also positive (0.54, Figure 2), even if it was less strongly positive than that between the inequalities in smoking and lung cancer mortality.

The direct contrast of the results of various chapters in Table 1 largely confirms their correspondence, but it also points to some discrepancies. For example, among women in Spain smoking is equally prevalent among the lower and the higher educated, whereas mortality from lung cancer is higher among the higher educated. This is likely to be due to the time-lag between smoking and lung cancer mortality as inequalities in lung cancer mortality still reflect the higher prevalence of smoking among higher educated women a few decades ago [19,26].

Some other discrepancies are seen when we contrast the contribution of the inequalities in smoking-related CoD to the inequalities in all-cause mortality with the potential inequality reduction in all-cause mortality when removing socioeconomic inequalities in smoking (columns 3 and 4 in Table 1). In some cases, like e.g. among Belgian men, the high inequality contribution of smoking-related CoD to inequality in all-cause mortality coupled with large inequalities in smoking and lung cancer mortality would lead us to expect a higher potential inequality reduction in column 4. This unexpectedly small inequality reduction can possibly be explained by a general difference in the calculation of the outcomes in columns 3 and 4. While the numbers in column 3 were calculated based on mortality information of overall populations of those 30-74 years old, the outcomes of the PAF tool are showing results for those between the ages 30-79, the latter being the sum of age-group specific calculations based on risk factor prevalence and mortality in different age groups (30-44, 45-59, 60-69 and 70-79). These can vary significantly over the life course. We recalculated some of the results of the PAF tool using all-age smoking prevalence and mortality rates (not shown). This lead to a potential all-cause mortality inequality reduction of about 24% (vs. 8% in the age-specific version) among men in Belgium, 14% (vs. 6%) among those in France, or 25% (vs. 17%) among Finish men. They were all higher than the estimates based on age-specific information, albeit to a different degree. This points to the country-specific complexities of the educational distribution of current, former and never smokers in the total population

and within specific age groups, and to how this distribution can influence particular scenario results.

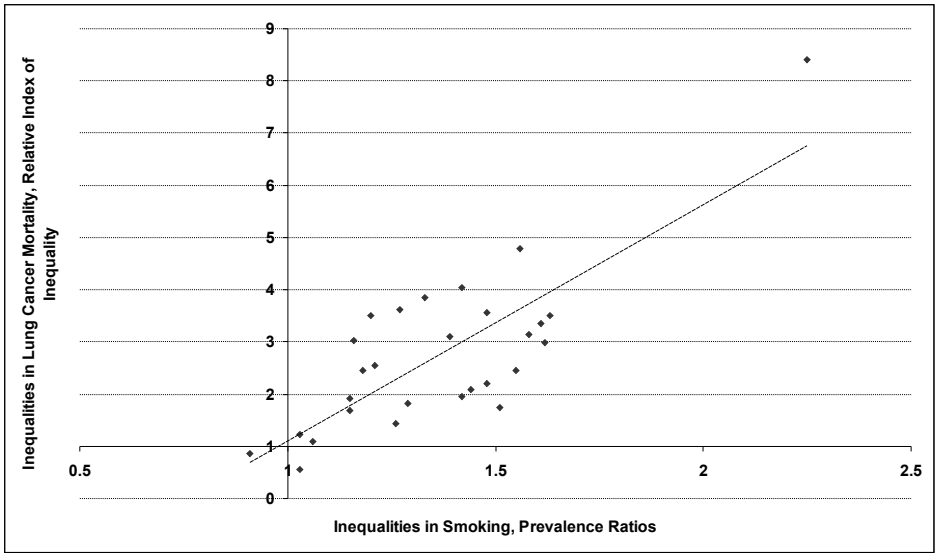


Figure 1: Association between inequalities in smoking and inequalities in lung cancer

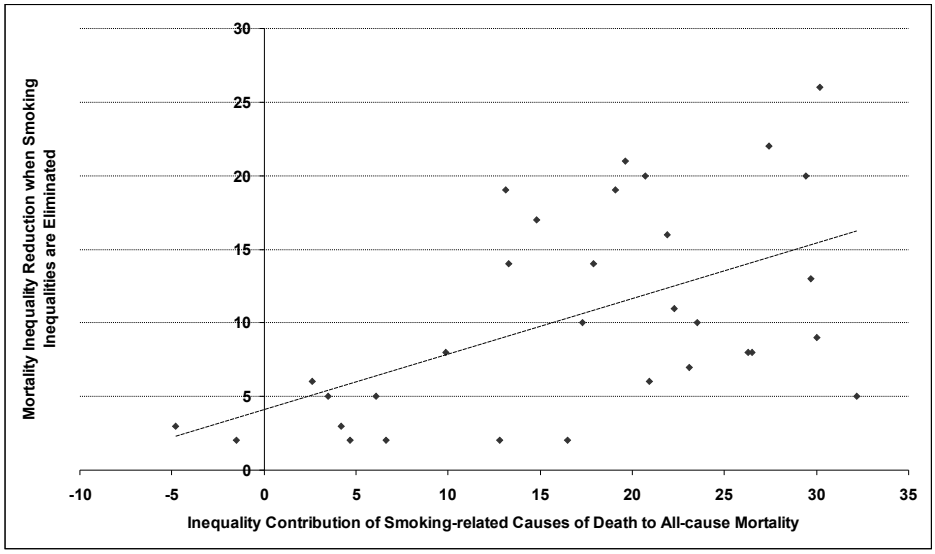


Figure 2: Association between the inequality contribution of smoking-related CoD to inequalities in all-cause mortality and the potential inequality reduction in all-cause mortality when smoking inequalities are eliminated

In a final comparison we can also contrast the results of the price policy scenarios obtained by the two different tools. As one of its outputs the DYNAMO-HIA tool calculated the difference in the absolute number of deaths as compared to the reference scenario. In the case of a maximum price increase in the Netherlands, the model showed that over time the overall number of saved deaths will be increasing in the first 25 years of the projection period, and will then decrease in the 25 years to follow. This reflects two opposite effects. Firstly, fewer deaths occur, due to the lower prevalence of smoking, reducing the prevalence of smoking-related diseases. Secondly, more deaths occur in the longer run because the intervention keeps persons alive longer, yielding an on average older population. The maximum number of saved deaths in this particular scenario when compared to the baseline will be 7,000 around the year 2035.

The PAF tool allowed for the calculation of a sex- and educational level-specific mortality rate per 100,000 person-years at baseline and after the implementation of e.g. the maximum price scenario. After the extrapolation of the number of saved deaths to all educational levels and to the entire Dutch population we arrived at approximately 6,100 saved deaths. This corresponds to the number of deaths which is reached about 17 and 32 years into the projection period of DYNAMO-HIA, given the U-shape of the number of saved deaths over time (as shown in chapter 4). This comparison gives us an approximation of the time frame which is only implicit in the PAF tool. These numbers also correspond to results obtained through the application of the Netherlands SimSmoke Tobacco Control Policy Simulation Model [27]. Although we used DYNAMO-HIA to estimate potential health gains in the Netherlands only, the general pattern of how the impact of three widely used tobacco control interventions evolves over time was demonstrated and might also be translated to other countries if these have a similar pattern of current risk factor exposure and a comparable demographic and epidemiological context.

Progression through the stages of the smoking epidemic

Given the undisputed association between smoking and mortality [28,29,30], smoking does not only make an important contribution as a major cause of morbidity and mortality, but educational inequalities in smoking also translate into inequalities in all-cause and smoking-related mortality. Depending on the stage of the smoking epidemic a country is in, tobacco use makes an important contribution to the explanation of such inequalities. Some countries with smaller inequalities in smoking have smaller inequalities in mortality [31,32,33,34]. Literature examining the trend in the educational gradient in smoking between 1985 and 2000 revealed that in most European countries the educational differences in smoking converge towards the pattern observed in the Northern European countries [19]. This implies that an increasingly selective group of Europeans from the lower socioeconomic strata will be affected by smoking-related diseases in the next few decades and that this will translate

into inequalities in mortality. Analyses monitoring this process and investigating whether the expected trends were indeed realized have thus to be undertaken and updated on a regular basis.

In our analyses we found that relative inequalities in mortality from lung and upper aero-digestive cancer and from COPD/asthma, for which smoking causes at least 50% of all deaths [35], were often larger in younger age groups and particularly among women. This suggests a possible further widening of inequalities in mortality in the coming decades, as women keep moving through the stages of the smoking epidemic. We found that among younger women in Spain and Italy relative inequalities in lung cancer mortality are reversing from a positive to a negative association between education and this CoD when compared to the earlier decade [36]. When comparing the two countries, which are both in a relatively early stage of the smoking epidemic, younger women in Italy seemed much further progressed than in Spain, displaying much higher inequalities within the younger age group. This pattern was also true when examining all three smoking-related CoD combined. We also saw indications of a progression of the smoking epidemic in Central and Eastern European countries. Our analysis further illustrated that for women in countries where the smoking epidemic set in slightly earlier than in the South, but still later than in the North, inequalities in lung cancer mortality have been increasing, being a trend that has been driven by younger women. This is not only true for France, as previously shown [37], but also for Austria. For the group of the Nordic countries we found that among men relative inequalities were often higher in Norway and Finland compared to Sweden and Denmark, without inequalities in survey-reported smoking being a clear explanation.

In further analyses we also showed the inequality contribution of the three major smoking-related CoD to inequalities in all-cause mortality. Among men the contributions were particularly large in Southern Europe and parts of Western Europe (England & Wales, Scotland, the Netherlands and Belgium) and lowest in the Nordic countries and Central and Eastern Europe. Among women they were highest in Denmark, Scotland and Norway and smallest in Eastern Europe, France and Austria, and even reversed in Southern Europe.

PAF tool-based results of the potential inequality reduction in all-cause mortality when socio-economic inequalities in smoking are eliminated showed the highest potential among men in England & Wales and Scotland and in the Nordic Countries. The potential was also high in the Czech Republic and Poland. Among women, the highest reduction potential could also be seen in England & Wales and Scotland, followed by the Nordic countries. Potential for inequality reduction was lower in other Western European countries, in the South and in the Central and Eastern part of Europe.

These results further illustrate the advanced position of England & Wales and Scotland in the smoking epidemic and also some of the effects of stringent tobacco control policies which were especially prominent in the UK in the last decades of the past century [38]. While the smoking epidemic might be viewed as an initially autonomous phenomenon which countries enter and then move through in different phases, at least in the later stages this process is also shaped by tobacco control efforts [39]. It is likely that smoking would not be declining as predicted by the theory of the smoking epidemic if no tobacco control policies were in place. However, the interpretation of negative associations between the level of tobacco control policy implementation and smoking prevalence also has to allow for a "reverse" explanation. It is also possible that countries that are further advanced in the smoking epidemic and therefore have a lower smoking prevalence are also those countries in which populations are most supportive of tobacco control policies [40].

The importance of smoking as a policy entry point

The Euro-GBD-SE study [41] analyzed several risk factors in addition to smoking (overweight, physical inactivity, diabetes mellitus, fruit and vegetable consumption, social participation, income, economic activity, occupational status). The final report shows that in Europe for men smoking remains the single most important risk factor contributing to educational inequalities in mortality. While it is also important for women, for them it is surpassed by obesity. As shown in our analyses for men in England & Wales the contribution of inequalities in smoking-related CoD to inequalities in all-cause mortality was 30%, and the potential inequality reduction in all-cause mortality through leveling the prevalence of smoking to that of the high educated amounted to 26%. Broadly similar findings on the role of smoking in generating inequalities in mortality in England & Wales have been reported elsewhere. The Whitehall II longitudinal cohort study showed that leveling smoking behavior of those with low socioeconomic status (SES) to that of those with high SES would reduce inequalities in all-cause mortality in England by 32% [42]. Through the use of indirect estimation [43], based on estimating smoking-related mortality from data on lung cancer, Iha et al. [44] showed that smoking-attributed mortality accounted for as much as 59% of the absolute difference between social strata in total male mortality rates in England & Wales. Although the contribution of smoking to inequalities in mortality is smaller in other countries, these findings clearly illustrate the importance of tackling smoking and inequalities in smoking through tobacco policies and interventions.

As mentioned earlier, smoking trends are neither entirely autonomous nor do they solely depend on policies and interventions implemented in a country. The apparent current "success" of e.g. women in Southern Europe who exhibit low and even reversed smoking inequalities, low overall mortality and low or reversed levels of mortality inequalities is not due to any tobacco control policy but to their early stage in the smoking epidemic. This means that their

"success" is not one that can easily be copied in other countries by implementing similar health policies. It is likely to deteriorate as these women also move through the stages of the epidemic. Hence, it might not only be in countries with high mortality and inequality levels where policies and interventions might have the largest potential for improvement, but also in countries where current potential is small. Without appropriate intervention latecomers of the smoking epidemic will probably follow down the path of those preceding them.

Upstream vs. downstream risk factors

The pressing need for tackling smoking and inequalities in smoking remains, though there are scholars who rightly argue that in order to eliminate, or at least significantly diminish inequalities in morbidity and mortality it is the more upstream, i.e. social determinants that have to be confronted rather than the more downstream risk factors like smoking or other individually-based behaviors [45,46]. According to the fundamental cause theory of Link and Phelan growing and persisting inequalities in health in developed countries during a time of improvement in levels of overall health during the 20th century can be explained because those with a higher socioeconomic status tend to make better use of key resources that lower SES individuals lack, be it knowledge, money, power, prestige, or beneficial social connections [47,48,49]. Therefore, socioeconomic inequalities are likely to persist over time even if the mediators, i.e. downstream risk factors, between low socioeconomic status and mortality change. Hence, it is the social context and the more fundamental causes of particular social conditions that have to be taken into account when fighting inequalities in morbidity and mortality. While this is a valid approach to conceptualize health inequalities, it at the same time could underestimate the importance of smoking as an entry point for health policy and divert attention away from the smoking epidemic [45,46]. Ideally, policies and interventions geared towards improving health levels and diminishing health inequalities should take both the distal and the proximal factors into account [50].

Independently of the exact level of importance which is attributed to smoking as an entry point to tackle inequalities in health, it is an interesting question what would happen to inequalities if smoking as a mediator was eliminated. Studies of inequalities in mortality among life-long non-smokers suggest that the inequality gap left may be filled by inequalities caused by a different risk factor, e.g. obesity. Importantly, health inequalities caused by obesity rather than smoking are likely to be smaller, because obesity is a weaker determinant of mortality than smoking [51,52,53].

IMPLICATIONS AND RECOMMENDATIONS FOR POLICY AND RESEARCH

Equity aspects of tobacco price policies

Results of the DYNAMO-HIA modeling exercise (chapter 4) showed that a population-wide price policy will be most effective in terms of absolute health gains in both the short and long term, when compared to other intervention types. Further, studies demonstrate that those with lower education are likely to be most affected by price increases, which will theoretically decrease inequalities when prices go up [21,22]. However, before recommending tobacco price increases as the most effective way to decrease smoking prevalence and inequalities in smoking without any reservations, it is important to realize that even if such policies might reduce inequalities, they could be detrimental from a wider equity perspective. This is because an increase in price will further deteriorate the financial position, and may ultimately decrease the overall wellbeing of those who already are at the bottom of the social ladder, if they do not want or are not able to quit smoking [54]. Therefore, before policy makers choose which policy or intervention to implement, the underlying country-specific redistribution mechanisms should be analyzed. This is not to argue that tobacco prices should not be increased if such an analysis showed that they would be a regressive measure. The price policy should rather be coupled with strong efforts to provide outreaching smoking cessation support services which are free at the point of access.

Policies geared towards tobacco supply vs. demand

The scenario applications in this thesis show that even with the tobacco price policy which we showed to be most effective in terms of size and timing of overall health effects, ample room for further improvements still remains. Further, even if more than half of the relative inequality could be removed for some smoking-related causes of death a substantial part of it would continue to exist. Each intervention scenario and policy was modeled separately. A combination of several of them would naturally yield even better outcomes than the implementation of just one of the interventions quantified here.

In the situation of more interventions the effect of one intervention would depend on the effect of the second intervention, and vice versa. For instance, a smoking initiation intervention that is successful in preventing adolescents from taking up smoking will reduce the potential effects of a smoking cessation intervention among adults. On the other hand, the price policy might be more effective if those who are motivated to quit because of a price increase are reached by smoking cessation interventions. These interdependencies depend on the effectiveness and reach of the interventions involved, as well as on the demographic and epidemiological context, and on how each of them affects different socioeconomic groups within a population.

Unfortunately, even a full implementation of the Tobacco Control Scale (TCS) has been shown to not eradicate smoking entirely. The TCS quantifies the country-specific impact of those tobacco control policies [55,56], which have been described by the World Bank [57] as those that should be prioritized in a comprehensive tobacco control package. The following measures are considered essential:

1) price increases through higher taxes on cigarettes and other tobacco products
2) bans/restrictions on smoking in public and work places
3) better consumer information, including public information campaigns, media coverage, and publicizing research findings
4) comprehensive bans on the advertising and promotion of all tobacco products, logos and brand names
5) large, direct health warning labels on cigarette boxes and other tobacco products
6) treatment to help dependent smokers stop, including increased access to medications

The TCS is obviously geared more towards the demand side than towards controlling the tobacco industry itself. As shown by Schaap [39,58], if all European countries had fully implemented the policies listed above by 2005, scoring the maximum of 100 points on the TCS, there would be 3.4 million less smokers in 2035, but smoking would remain a serious health problem.

If the ultimate goal is to eliminate inequalities in smoking, i.e. eliminate smoking as a cause of inequalities, it might not, or not only, be policies and interventions geared towards reducing the demand for tobacco, but policies geared towards curbing the supply of tobacco that are needed. Education reduces demand but is unlikely to prevent smoking entirely. In order to truly decrease all adverse health effects caused by smoking the long run policy goal should be to eradicate smoking completely. The Framework Convention on Tobacco Control (FCTC) has imposed a set of requirements in order to enhance tobacco control practice, clearly acknowledging the need for supply-side controls. The requirements include a move from occasional surveys to surveillance systems, from information and education to changing social and cultural norms, a move from demand-side awareness to supply-side controls, and one from isolated quit programs to a more integrated approach to health services [59].

Suggestions by those propagating an endgame against tobacco by tackling its supply side include e.g. moving distribution to a public non-profit tobacco marketing agency, introducing tobacco sale quotas which would decrease over time, reducing the nicotine content of cigarettes, or plainly prohibiting tobacco sales [60,61,62,63,64].

Future policy considerations and recommendations

We showed that there is a continuing need for tobacco control policies, and specifically for such policies which take into account socioeconomic position. These should lead to a reduction of smoking in lower socioeconomic groups, while not decreasing the overall well-being of those already worse off. A well-balanced tobacco control package should include different interventions which complement each other. Much more focus should be placed on ways to curb the supply side of the tobacco market with the ultimate goal of eradicating smoking. When deciding on which policies to implement policy makers should take into account the current position of their country within the smoking epidemic in order to better identify which population groups are most likely to benefit from specific interventions. The DYNAMO-HIA and the PAF tool can help finding the most effective policy mix for a specific country. Given the time-lag between tobacco control policies and their manifestation in terms of health and equality gains policy makers must be willing to plan for the long run.

Future research considerations and recommendations

As the need for tobacco control policies which take into account socioeconomic position continues, so does the need for data to monitor their effectiveness. Clearly, more efforts are needed to improve data collection of overall smoking prevalence and of its patterns by socioeconomic status. These should comprise sample sizes allowing for a meaningful analysis of population subgroups and coordinated efforts between countries to ensure comparability of outcomes and control variables, especially when measuring educational attainment or any other indicator of socioeconomic status. If survey data comes from individual countries and is not part of an international survey, data collection should be frequent and at similar points in time in different countries. Countries should coordinate their efforts. In addition to surveillance systems of smoking trends, the development of smoking-related mortality and inequalities should also continue to be monitored closely.

When measuring smoking status, a distinction should be made between current, former and never smokers. Distinguishing between occasional and regular former and current smokers should also be possible, just like differentiating between different tobacco products (cigarettes, pipes and cigars). Ideally, we would also recommend a measure of the amount smoked. Finally, information about when a person took up and quit smoking would allow for even more differentiated analyses about the duration of an individual's smoking habit, or the time since quitting. Based on the review of smoking surveys in chapter 2 these recommendations were used in order to formulate the survey question of the health module in the 7th wave of the European Social Survey [65].

In order to further improve the efforts to quantify smoking-related policies and inequalities we recommend that modeling software, like the PAF tool, should be extended to include an

explicit time dimension and to allow for dynamic analyses. On the other hand, the data base of the DYNAMO-HIA tool should be expanded to allow for risk factor scenario analyses by socioeconomic status. Our PAF-based results should also be further validated through the use of indirect estimation based on estimating smoking-related mortality from data on lung cancer [34,43].

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SUMMARY

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Worldwide, about six million deaths occurred due to smoking in the year 2010 alone. Smoking is the largest avoidable health risk in Europe. As it is a socially patterned behavior, its disease burden not only differs by sex, but also by socioeconomic status (SES). Even though the numbers of smokers have decreased since the implementation of the WHO Framework Convention on Tobacco Control (FCTC), smoking-related mortality remains high as there is a considerable lag between smoking and the incidence and mortality from e.g. lung cancer or Chronic Obstructive Pulmonary Disease (COPD). Therefore, the need remains to 1) monitor trends in smoking prevalence, smoking inequalities and in the resulting magnitude of inequalities in smoking-related mortality, and to 2) quantify health gains and potential inequality reductions due to different tobacco control policies and interventions. This in turn requires improved and internationally harmonized data collection efforts.

The initial rise in cigarette consumption in Western countries took place during World War II. The growth of mass consumer marketing made cigarettes the most widely advertised consumer product. By the mid 1950s the dangers of smoking were becoming public through epidemiological studies, being followed by the stepwise implementation of tobacco control policies.

The spread of smoking can best be described in terms of an epidemic and its stages. Every country is at a specific stage, reflected by its smoking prevalence levels by sex and socioeconomic status. In a more advanced stage of the smoking epidemic relatively more individuals with a lower SES smoke compared to more higher-SES smokers in earlier stages, with women lagging behind men in this progression. Men in countries of Northern Europe are furthest advanced in the smoking epidemic while women in Southern Europe entered it last. This implies that an increasingly selective group of Europeans from the lower socioeconomic strata will be affected by smoking-related diseases in the next few decades and that this will translate into inequalities in mortality.

A number of surveys could potentially be used to analyze the level of inequalities in smoking. Because such inequalities are usually evaluated on the basis of a single source of information, we investigated whether patterns of inequalities in smoking prevalence differed across three major European surveys (chapter 2). We showed that smoking prevalence, as well as socioeconomic inequalities, differed by data source. Significant differences between surveys were found mainly in Spain, Portugal, Italy and Greece. Our results suggested that for the investigation of smoking levels and inequalities across Europe a harmonized set of National Health Interview Surveys is a more reliable source of information than other international

surveys. This raises the concern that when undertaking comparative analyses of prevalence and inequalities of other risk factors results might also differ depending on the data source.

As patterns of smoking prevalence change over time, updates on the development of smoking-related mortality inequalities are needed. We provided estimates of educational inequalities in mortality from lung cancer, upper aero-digestive cancers and COPD/asthma across Europe, and assessed the contribution of these smoking-related diseases to inequalities in all-cause mortality (chapter 3). Among men, relative inequalities in mortality from the three smoking-related causes of death combined were largest in the Czech Republic and Hungary and smallest in Spain, Sweden and Denmark. Among women, these inequalities were largest in Scotland and Norway and smallest in Italy and Spain. They were often larger among men, and tended to be larger for COPD/asthma than for lung and upper aero-digestive cancers. Looking at specific age groups, relative inequalities in mortality from these conditions were often larger among younger individuals, particularly among women, suggesting a possible further widening of inequalities in mortality in the coming decades, as they keep moving through the stages of the smoking epidemic. The combined contribution of these diseases to inequality in all-cause mortality varied between 13% and 32% among men, and between -5% and 30% among women.

Tobacco control encompasses a wide array of different measures which can affect smoking prevalence and health outcomes in different ways. The most basic intervention types are 1) smoking cessation interventions, 2) preventing smoking initiation, and 3) implementation of a policy affecting quitters and starters simultaneously. The possibility for dynamic quantification of such different interventions is essential for comparing the timing and size of their effects. We developed a software tool, DYNAMO-HIA, which allowed for a quantitative comparison of the health impact of different policy scenarios in the Netherlands (chapter 4). All three intervention scenarios resulted in fewer excess prevalence cases of smoking-related diseases such as COPD, lung cancer and ischemic heart disease (IHD) and in fewer deaths, though the magnitude and timing of the effects differed. It was shown that all smoking interventions will be effective in the long run. The combined strategy is most effective in both the short and long term. The smoking cessation scenario is second-most effective in the short run, though in the long run the smoking initiation scenario will become almost as effective. Interventions aimed at preventing the initiation of smoking need a long time horizon to become manifest in terms of health effects. The outcomes strongly depend on the groups targeted by the intervention.

In order to not only assess average health gains due to implementation of tobacco control but to also analyze the impact on potential inequality reductions, we applied three additional smoking intervention scenarios (chapter 5). In the first one, smoking prevalence for all socio-

economic subgroups was changed to the level observed for the higher educated in the same country. In the second, smoking prevalence for all socioeconomic subgroups was changed to the level observed in the country with the smallest inequalities and a low prevalence of current smokers. In the third, the price of tobacco in every country was increased either to the currently highest level in the EU, or by 20%. We used a newly-developed excel-based application, the PAF tool, to quantify the changes in population health potentially resulting from modifying the population distribution of exposure to smoking. These intervention scenarios showed that the patterns of potential reduction in inequality differed by country or region and sex, suggesting that the priority given to smoking as an entry-point for tackling health inequalities should differ between countries. The potential reduction of relative inequality in all-cause mortality between those with high and low education amounted up to 26% for men (Scenario 1) and 32% for women (Scenario 2), both in England & Wales and also among women in Scotland. More than half of the relative inequality could be eliminated for smoking-related causes of death like lung cancer, lip, oral cavity and pharynx cancer, esophageal cancer and COPD/asthma, often in countries of Northern Europe and in Britain.

We showed that there is a continuing need for tobacco control policies, and specifically for such policies which take into account socioeconomic position. These should lead to a reduction of smoking in lower socioeconomic groups, while not decreasing the overall well-being of those already worse off. A well-balanced tobacco control package should include different interventions which complement each other and it should also stress the need for data collection in order to monitor their effectiveness. Much more focus should be placed on ways to curb the supply side of the tobacco market with the ultimate goal of eradicating smoking. When deciding on which policies to implement, policy makers should take into account the current position of their country within the smoking epidemic in order to better identify which population groups are most likely to benefit from specific interventions. The DYNAMO-HIA and the PAF tool can help finding the most effective policy mix for a specific country. Given the time-lag between tobacco control policies and their manifestation in terms of health and equality gains policy makers must be willing to plan for the long run.

SAMENVATTING

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Wereldwijd konden alleen al in het jaar 2010 ongeveer zes miljoen sterfgevallen aan roken toegeschreven worden. Roken is het belangrijkste vermijdbare gezondheidsrisico in Europa. Omdat rookgedrag verschilt tussen sociale groepen, verschillen ook de gevolgen van roken niet alleen per geslacht, maar ook per sociaaleconomische status (SES). Ondanks dat het aantal rokers afgenomen is sinds de invoering van de *Framework Convention on Tobacco Control (FCTC)* van de WHO, blijft aan roken gerelateerde sterfte hoog, omdat er een aanzienlijke *lag time* tussen roken en incidentie en sterfte aan bijvoorbeeld longkanker of chronisch obstructieve longziekte (COPD) is. Daarom blijft de noodzaak bestaan om 1) de trends in rookprevalentie, ongelijkheid in roken en de grootte van de ongelijkheid in aan roken gerelateerde sterfte te monitoren, en 2) de gezondheidswinst en potentiële afname in ongelijkheid door anti-tabaksbeleid en interventies te kwantificeren. Daartoe is verbeterde en internationaal geharmoniseerde dataverzameling essentieel.

De eerste toename in tabaksconsumptie in Westerse landen vond plaats tijdens de 2e Wereldoorlog. Door toename van grootschalige marketing werden sigaretten het meest geadverteerde consumentenproduct. Halverwege de jaren '50 werden door epidemiologisch onderzoek de risico's van roken bekender, wat gevolgd werd door stapsgewijze implementatie van anti-tabaksbeleid.

De verspreiding van roken kan het best beschreven worden in termen van een epidemie en bijbehorende stadia. Ieder land is in een bepaald stadium, wat weerspiegeld wordt in de prevalentie per geslacht en SES groep. In een verder gevorderd stadium van de epidemie roken mensen met een lagere sociaaleconomische status vaker dan mensen met een hogere sociaaleconomische status in een eerder stadium, waarbij vrouwen in deze progressie achterop lopen op mannen. De epidemie is het verst gevorderd bij mannen in Noord Europa en het minst gevorderd bij Zuid Europese vrouwen. Dit houdt in dat in de komende paar decennia een toenemende groep Europeanen uit de lagere sociaaleconomische klasse getroffen zullen worden door aan roken gerelateerde ziektes, en dat dit zich zal vertalen in ongelijkheid in sterfte.

Een aantal onderzoeken kunnen potentieel gebruikt worden om het niveau van ongelijkheid in roken te analyseren. Omdat zulke ongelijkheid meestal op basis van één bron van informatie geëvalueerd wordt, hebben wij onderzocht of patronen in ongelijkheid in roken verschilden tussen drie grote Europese studies (hoofdstuk 2). We toonden aan dat zowel prevalentie in roken als sociaaleconomische ongelijkheid verschilden per data bron. Significante verschillen tussen studies werden met name waargenomen in Spanje, Portugal, Italië en Griekenland. Onze resultaten suggereerden dat voor het bestuderen van niveaus

en ongelijkheid in roken in Europa een geharmoniseerde set van *National Health Interview Surveys* een betrouwbaarder informatiebron is dan andere internationale studies. Dit roept de vraag op of de resultaten van vergelijkende analyses naar prevalentie en ongelijkheid van andere risicofactoren ook verschillen per data bron.

Updates over de ontwikkeling van aan roken gerelateerde ongelijkheid in sterfte zijn noodzakelijk naarmate de rookepidemie zich ontwikkelt. Wij hebben de ongelijkheid tussen opleidingsniveaus in sterfte aan longkanker, kanker van luchtwegen en maag-darmkanaal en COPD/astma in Europa geschat, en hebben de bijdrage van deze aan roken gerelateerde ziekten aan de ongelijkheid in sterfte aan alle oorzaken berekend (hoofdstuk 3). Bij mannen was de relatieve ongelijkheid in sterfte aan deze drie gecombineerde oorzaken het grootst in Tsjechië en Hongarije, en het kleinst in Spanje, Zweden en Denemarken. Bij vrouwen was deze ongelijkheid het grootst in Schotland en Noorwegen en het kleinst in Italië en Spanje. Ongelijkheid in sterfte was vaak groter bij mannen en was meestal groter voor COPD/astma dan voor longkanker en kanker van luchtwegen en maag-darmkanaal. Leeftijdsspecifiek gezien, was de relatieve ongelijkheid in de sterfte aan deze oorzaken vaak groter in jonge dan in oude leeftijdsgroepen, met name bij vrouwen, wat suggereert dat de ongelijkheid in sterfte de komende decennia verder zal toenemen, naarmate zij de opeenvolgende stadia van de rookepidemie doormaken. De totale bijdrage van deze ziektes aan ongelijkheid in sterfte aan alle oorzaken varieerde tussen de 13% en 32% bij mannen, en tussen de -5% en 30% bij vrouwen.

Anti-tabaksbeleid omvat een wijd spectrum van verschillende methoden die de prevalentie van roken en gezondheidsuitkomsten op verschillende manieren kunnen beïnvloeden. De meest basale types interventie zijn 1) stoppen met roken interventies, 2) het voorkomen van het beginnen met roken, en 3) implementatie van beleid die stoppers en starters tegelijkertijd beïnvloeden. Om de timing en de grootte van de effecten van de verschillende interventies te vergelijken, is het essentieel om zulke verschillende interventies dynamisch te kwantificeren. We hebben een softwareprogramma ontwikkeld, *DYNAMO-HIA* genaamd, waarmee de gezondheidsimpact van verschillende beleidsscenario's in Nederland op een kwantitatieve manier vergeleken kan worden (hoofdstuk 4). Alle drie de interventiescenario's resulteerden in een lagere prevalentie van aan roken gerelateerde ziekten zoals COPD, longkanker en ischemische hartziekte, en minder sterfgevallen, hoewel de grootte en de timing van de effecten verschilde. We toonden aan dat alle rookinterventies op de lange termijn effectief zullen zijn. De gecombineerde strategie is op zowel korte- als lange termijn het meest effectief. Het stoppen met roken scenario is op korte termijn het op één na effectiefst, hoewel op lange termijn het beginnen met roken scenario bijna even effectief zal zijn. Gezondheidseffecten van interventies die gericht zijn op het voorkomen van het beginnen met

roken komen pas na lange tijd aan het licht. De effecten hangen sterk samen met de groepen waarop de interventie zich richt.

Om niet alleen de gemiddelde gezondheidswinst van anti-tabaksbeleid, maar ook de impact op potentiële afname in ongelijkheid te analyseren, hebben we drie extra rookinterventies-cenario's toegepast (hoofdstuk 5). In het eerste scenario werd de prevalentie van roken voor alle sociaaleconomische subgroepen veranderd tot het niveau van de hoger opgeleiden in hetzelfde land. In het tweede scenario werd de prevalentie van roken voor alle sociaal-economische groepen veranderd in het niveau dat waargenomen werd in het land met de laagste ongelijkheid en een laag percentage huidige rokers. In het derde scenario werd de prijs van tabak in ieder land verhoogd tot het huidig hoogste niveau in de EU, of met 20%. We gebruikten een nieuw-ontwikkelde applicatie in Excel, de *PAF-tool*, om de veranderingen in volksgezondheid te kwantificeren die potentieel kunnen voortkomen uit het aanpassen van de bevolkingsverdeling in de blootstelling aan roken. Deze interventiescenario's toonden aan dat de patronen in potentiële afname in ongelijkheid verschilden tussen landen of regio's en geslacht, wat suggereert dat het belang van roken bij het aanpakken van gezondheids-verschillen zou moeten verschillen tussen landen. De potentiële afname van relatieve onge-lijkheid in sterfte aan alle oorzaken tussen mensen met een laag en hoog opleidingsniveau loopt op tot 26% voor mannen (Scenario 1) en 32% voor vrouwen (Scenario 2), allebei in Engeland & Wales en ook voor vrouwen in Schotland. Meer dan de helft van de relatieve ongelijkheid in aan roken gerelateerde sterfteoorzaken, zoals long-, lip-, mondholte-, farynx-, en slokdarmkanker en COPD/ astma, zou kunnen worden geëlimineerd, vooral in Noord Europese landen en in Groot-Brittannië.

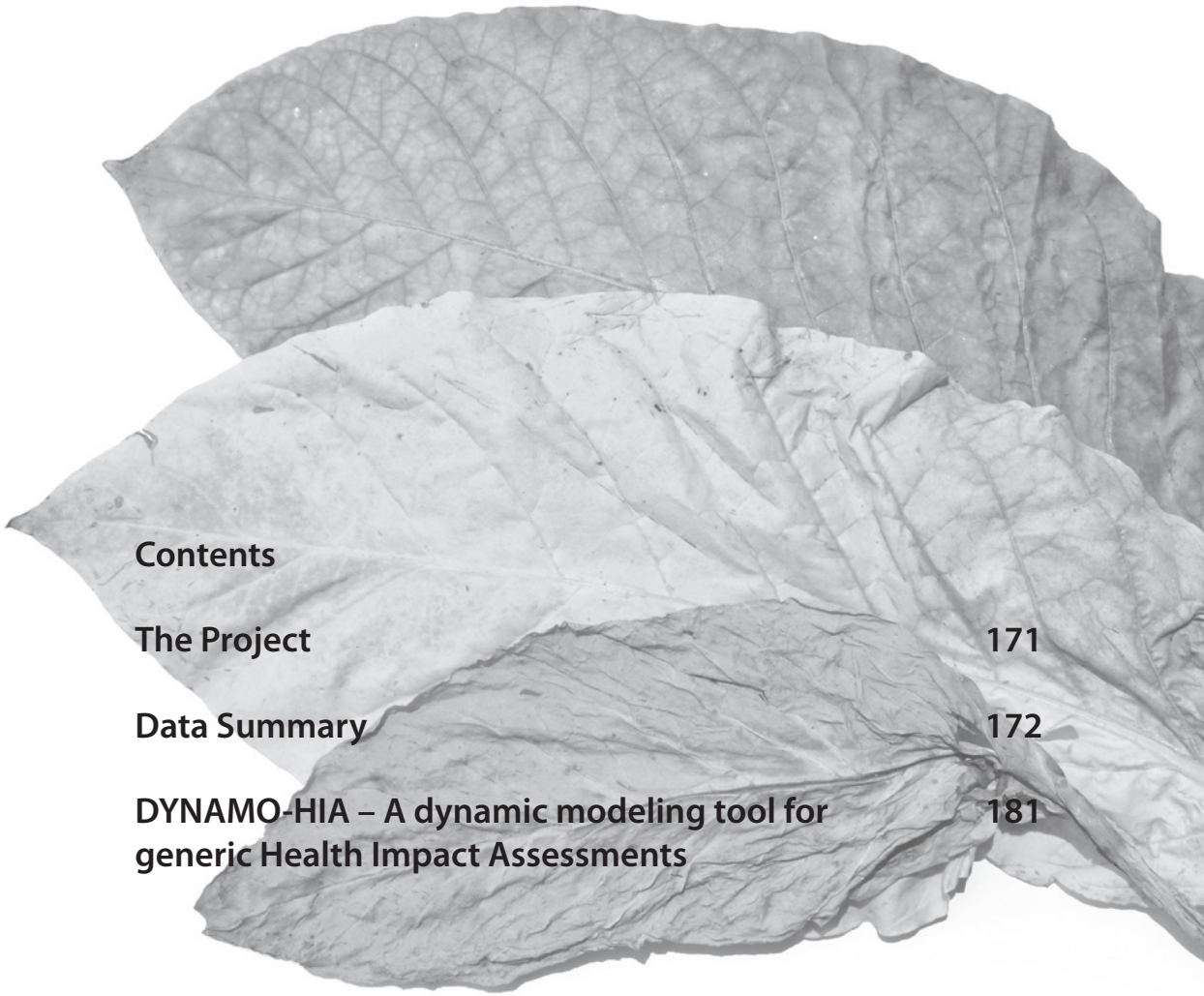
We toonden aan dat er een continue behoefte is aan anti-tabaksbeleid, met name voor beleid dat rekening houdt met sociaaleconomische positie. Dit beleid zouden moeten leiden tot een afname in roken in lagere sociaaleconomische groepen, en tegelijkertijd het algehele welzijn van mensen die al slechter af zijn niet verder nadelig beïnvloeden. Een goedgebalanceerd pakket van maatregelen op het gebied van anti-tabaksbeleid zou verschillende interventies moeten omvatten die elkaar complementeren, en zou ook de noodzaak van dataverzame-ling moeten benadrukken, om zo de effectiviteit van maatregelen te kunnen monitoren. Veel meer aandacht zou besteed moeten worden aan manieren om de toevoerzijde van de tabaksmarkt te beteugelen, met als ultieme doel om roken uit te bannen. Bij beslissingen over de implementatie van beleid zouden beleidsmakers rekening moeten houden met de huidige positie van hun land binnen de rookepidemie om zo beter te kunnen identificeren welke bevolkingsgroepen waarschijnlijk het meeste baat hebben bij specifieke interventies. De *DYNAMO-HIA* en *PAF-tools* kunnen helpen bij het vinden van het meest effectieve pakket van beleidsmaatregelen voor een bepaald land. Gezien de *lag time* tussen anti-tabaksbeleid

en het moment waarop de effecten ervan, in termen van gezondheids- en gelijkheidswinst, zichtbaar worden, moeten beleidsmakers bereid zijn beleid te maken voor de lange termijn.

APPENDIX

APPENDIX I

PROJECT INFORMATION, DATA AND METHODS: THE DYNAMO-HIA PROJECT



Contents

This thesis originated from and contributed to two projects: DYNAMO-HIA and Euro-GBD-SE.

THE DYNAMO-HIA PROJECT

The aim of the DYNAMO-HIA project was to develop and build an instrument to quantify the health impact of changes in health determinants as a result of different policies and to apply it to selected life-style risk factors and resulting diseases across EU countries. The research project had three objectives: First, to develop and implement a stand-alone software tool (DYNAMO-HIA) for the estimation of the health impact of policies and interventions by comparing the population health impact of one or more policies and interventions with a baseline scenario. Second, to compile and make publicly available datasets (consistent across EU countries) of selected risk factors (smoking, obesity, alcohol consumption) and their effect on selected diseases (breast, lung, colorectal, esophageal, and oral cancer; chronic obstructive pulmonary disease (COPD), ischemic heard disease (IHD), stroke and diabetes). Third, to apply the tool and illustrate its possibilities by assessing the health effects of several health-relevant policy options with regard to these determinants.

The DYNAMO-HIA project was funded by the EU Public Health Programme 2003–2008 of the European Commission's Directorate General for Health and Consumer Affairs (DG SANCO), with co-financing from the Erasmus Medical Center Rotterdam (The Netherlands), the Institute of Public Health and the Environment (The Netherlands), the Catalan Institute of Oncology (Spain), the International Obesity Task Force, the London School for Hygiene and Tropical Medicine (England), the Haughton Institute in Dublin, Ireland and the Instituto Tumori in Milan, Italy.

The Work Packages of the DYNAMO-HIA project were:

WP1: Coordination of Project
WP2: Dissemination of Results
WP3: Evaluation of Project
WP4: Model Specification
WP5: Construction of Software Tool
WP6: Smoking Data Collection
WP7: Overweight/Obesity Data Collection
WP8: Alcohol Data Collection
WP9: CVD and Diabetes Data Collection
WP10: Cancer Data Collection
WP 11: COPD Data Collection and Definition of Scenarios

The DYNAMO-HIA software is equipped with an extensive database of disease data, risk factor data and the corresponding relative risks, all by gender and single year of age. Below we summarize the data that was collected within the DYNAMO-HIA project and was used for the particular application of the DYNAMO-HIA tool to the smoking scenarios presented in chapter 4 (Tables A1.1, A1.2, A1.3, A1.4 below). More details about the entire database and about the sources of the data and adjustments applied are given in the work package documentation and are available here: www.dynamo-hia.eu. More in-depth information about the development of the methods resulting in the DYNAMO-HIA tool, is included below in this appendix.

DATA SUMMARY

Table A1.1: Baseline prevalence of smokers, former smokers and never smokers in the Netherlands in percent

	Males			Females		
age	never smokers	former smokers	current smokers	never smokers	former smokers	current smokers
0	100	0	0	100	0	0
1	100	0	0	100	0	0
2	100	0	0	100	0	0
3	100	0	0	100	0	0
4	100	0	0	100	0	0
5	100	0	0	100	0	0
6	100	0	0	100	0	0
7	100	0	0	100	0	0
8	100	0	0	100	0	0
9	100	0	0	100	0	0
10	100	0	0	100	0	0
11	98.95	0	1.05	99.05	0	0.95
12	97.9	0	2.1	98.1	0	1.9
13	89.52	0	10.48	90.48	0	9.52
14	78	0	22	80	0	20
15	72.76	0	27.24	75.24	0	24.76
16	58.31	12.24	29.45	57.63	15.62	26.75
17	53.8	13.62	32.58	54.24	16.58	29.19
18	49.28	15	35.72	50.84	17.54	31.62
19	44.76	16.38	38.85	47.44	18.5	34.06
20	40.25	17.76	41.99	44.04	19.47	36.49
21	40.08	18.14	41.77	44.18	19.94	35.88
22	39.92	18.53	41.55	44.32	20.42	35.26
23	39.76	18.91	41.34	44.46	20.89	34.65

Table A1.1: (Continued)

	Males			Females		
age	never smokers	former smokers	current smokers	never smokers	former smokers	current smokers
24	39.59	19.29	41.12	44.6	21.37	34.04
25	39.43	19.67	40.9	44.74	21.84	33.42
26	39.26	20.05	40.68	44.87	22.32	32.81
27	39.1	20.43	40.46	45.01	22.79	32.2
28	38.94	20.82	40.25	45.15	23.27	31.58
29	38.77	21.2	40.03	45.29	23.74	30.97
30	38.61	21.58	39.81	45.43	24.22	30.35
31	37.72	22.34	39.94	43.97	25.36	30.68
32	36.83	23.1	40.07	42.51	26.49	31
33	35.95	23.85	40.2	41.05	27.63	31.32
34	35.06	24.61	40.33	39.59	28.77	31.64
35	34.17	25.37	40.46	38.13	29.91	31.96
36	33.28	26.13	40.59	36.67	31.05	32.28
37	32.4	26.89	40.72	35.21	32.18	32.6
38	31.51	27.65	40.85	33.75	33.32	32.92
39	30.62	28.4	40.98	32.29	34.46	33.25
40	29.73	29.16	41.1	30.84	35.6	33.57
41	28.84	30.65	40.51	30.83	36.14	33.03
42	27.95	32.13	39.92	30.82	36.68	32.5
43	27.05	33.61	39.33	30.81	37.23	31.96
44	26.16	35.09	38.74	30.8	37.77	31.43
45	25.27	36.58	38.15	30.79	38.32	30.89
46	24.38	38.06	37.56	30.78	38.86	30.36
47	23.48	39.54	36.97	30.77	39.4	29.82
48	22.59	41.02	36.38	30.76	39.95	29.29
49	21.7	42.51	35.79	30.75	40.49	28.75
50	20.81	43.99	35.2	30.74	41.04	28.22
51	20.51	44.81	34.68	31.79	40.82	27.39
52	20.22	45.63	34.15	32.83	40.61	26.56
53	19.93	46.45	33.63	33.87	40.39	25.73
54	19.63	47.27	33.1	34.92	40.18	24.9
55	19.34	48.09	32.57	35.96	39.96	24.08
56	19.05	48.91	32.05	37	39.75	23.25
57	18.75	49.73	31.52	38.05	39.54	22.42
58	18.46	50.55	31	39.09	39.32	21.59
59	18.17	51.36	30.47	40.13	39.11	20.76
60	17.87	52.18	29.94	41.17	38.89	19.93
61	16.96	53.83	29.21	42.11	38.28	19.6
62	16.04	55.48	28.48	43.05	37.67	19.28

Table A1.1: (Continued)

	Males			Females		
age	never smokers	former smokers	current smokers	never smokers	former smokers	current smokers
63	15.12	57.13	27.74	43.99	37.07	18.95
64	14.21	58.78	27.01	44.93	36.46	18.62
65	13.29	60.43	26.28	45.86	35.85	18.29
66	12.37	62.08	25.54	46.8	35.24	17.96
67	11.46	63.73	24.81	47.74	34.63	17.63
68	10.54	65.38	24.08	48.68	34.02	17.3
69	9.62	67.03	23.34	49.61	33.41	16.97
70	8.71	68.68	22.61	50.55	32.8	16.65
71	8.94	68.72	22.34	51.76	32.43	15.81
72	9.18	68.75	22.08	52.97	32.05	14.97
73	9.41	68.78	21.81	54.19	31.68	14.14
74	9.65	68.82	21.54	55.4	31.3	13.3
75	9.88	68.85	21.27	56.61	30.93	12.46
76	10.11	68.88	21	57.82	30.55	11.62
77	10.35	68.91	20.74	59.03	30.18	10.79
78	10.58	68.95	20.47	60.24	29.81	9.95
79	10.82	68.98	20.2	61.45	29.43	9.11
80	11.05	69.01	19.93	62.67	29.06	8.28
81	11.25	69.31	19.43	63.53	28.4	8.06
82	11.45	69.61	18.94	64.4	27.75	7.85
83	11.65	69.91	18.44	65.27	27.1	7.64
84	11.84	70.21	17.95	66.13	26.44	7.42
85	12.04	70.51	17.45	67	25.79	7.21
86	12.24	70.81	16.95	67.87	25.14	6.99
87	12.44	71.11	16.46	68.73	24.49	6.78
88	12.63	71.41	15.96	69.6	23.83	6.57
89	12.83	71.71	15.46	70.47	23.18	6.35
90	13.03	72.01	14.97	71.33	22.53	6.14
91	13.22	72.31	14.47	72.2	21.88	5.92
92	13.42	72.61	13.97	73.07	21.22	5.71
93	13.62	72.9	13.48	73.93	20.57	5.5
94	13.82	73.2	12.98	74.8	19.92	5.28
95	14.01	73.5	12.48	75.67	19.26	5.07

Source: Based on CBS (2005) Permanent Onderzoek Leefsituatie (POLS), retrieved December 2010 from: http://www.cbs.nl/NR/rdonlyres/B3BC273E-D153-4037-96C4-D6EAFE18F9D1/0/2005polstoelichtingversie210306.pdf. and Jeugdmonitor (2010) retrieved December 2010 from: http://jeugdmonitor.cbs.nl/nl-NL/menu/indicatoren/gezondheid/actief-en-passief-roken.htm?showindicators=true. For further information please refer to the data documentation section of the DYNAMO-HIA project website: www.dynamo-hia.eu

Table A1.2: Baseline smoking (re)start and quit transition probabilities in the Netherlands

	Males			Females		
age	start transition probability	quit transition probability	restart transition probability	start transition probability	quit transition probability	restart transition probability
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8	0	0	0	0	0	0
9	0	0	0	0	0	0
10	0.0105	0	0	0.0095	0	0
11	0.0106	0	0	0.0096	0	0
12	0.0856	0	0	0.0777	0	0
13	0.1287	0	0	0.1158	0	0
14	0.0672	0	0	0.0595	0	0
15	0.0303	0	0	0.0264	0	0
16	0.054	0.0332	0.3927	0.0545	0.0666	0.3426
17	0.0549	0.0409	0.4294	0.0537	0.079	0.3827
18	0.0529	0.0477	0.4242	0.0506	0.0878	0.3907
19	0.0487	0.0537	0.3882	0.0458	0.0937	0.3741
20	0.0431	0.059	0.3326	0.0398	0.0974	0.3402
21	0.0367	0.0635	0.2688	0.0334	0.0997	0.2963
22	0.0303	0.0674	0.2079	0.0271	0.1011	0.25
23	0.0244	0.0707	0.1612	0.0216	0.1024	0.2085
24	0.0192	0.0734	0.1268	0.0167	0.1036	0.1721
25	0.0146	0.0754	0.1027	0.0126	0.1044	0.1409
26	0.0108	0.0769	0.0869	0.0092	0.1047	0.1151
27	0.0077	0.0776	0.0776	0.0064	0.1045	0.095
28	0.0054	0.0777	0.0728	0.0043	0.1036	0.0807
29	0.0037	0.0772	0.0714	0.0028	0.102	0.0712
30	0.0027	0.0762	0.0724	0.0017	0.0996	0.0655
31	0.002	0.0746	0.0747	0.001	0.0966	0.0626
32	0.0017	0.0726	0.0771	0	0.0927	0.0615
33	0.0017	0.0702	0.0787	0	0.0881	0.0611
34	0.0018	0.0675	0.0794	0	0.083	0.0611
35	0.002	0.0647	0.079	0	0.0775	0.0613
36	0.0024	0.062	0.0775	0	0.072	0.0613

Table A1.2: (Continued)

	Males			Females		
age	start transition probability	quit transition probability	restart transition probability	start transition probability	quit transition probability	restart transition probability
37	0.0027	0.0595	0.0748	0	0.0667	0.0609
38	0.003	0.0573	0.0707	0.0013	0.0618	0.0596
39	0.0033	0.0555	0.0657	0.0017	0.0573	0.0577
40	0.0035	0.0541	0.0601	0.0021	0.0535	0.0552
41	0.0038	0.0532	0.0542	0.0025	0.0504	0.0523
42	0.004	0.0528	0.0484	0.0029	0.0481	0.049
43	0.0042	0.0529	0.043	0.0032	0.0467	0.0456
44	0.0044	0.0534	0.0382	0.0035	0.0461	0.042
45	0.0047	0.0542	0.034	0.0037	0.0461	0.0384
46	0.0049	0.0553	0.0306	0.0038	0.0467	0.0349
47	0.0052	0.0564	0.0278	0.0039	0.0477	0.0317
48	0.0056	0.0576	0.0259	0.0038	0.049	0.0288
49	0.006	0.0587	0.0246	0.0037	0.0505	0.0262
50	0.0063	0.0598	0.0236	0.0035	0.0521	0.0238
51	0.0066	0.0608	0.0226	0.0033	0.0539	0.0218
52	0.0068	0.0619	0.0212	0.0031	0.0556	0.0199
53	0.0068	0.063	0.0193	0.0029	0.0574	0.0182
54	0.0067	0.0641	0.0171	0.0026	0.0591	0.0166
55	0.0065	0.0652	0.0148	0.0024	0.0607	0.0153
56	0.0062	0.0664	0.0128	0.0022	0.0624	0.0141
57	0.0058	0.0676	0.0112	0.002	0.064	0.0131
58	0.0053	0.0689	0.0105	0.0018	0.0656	0.0122
59	0.0048	0.0702	0.0102	0.0016	0.0672	0.0115
60	0.0043	0.0715	0.0104	0.0014	0.0688	0.0109
61	0.0038	0.0725	0.0108	0.0012	0.0704	0.0105
62	0.0034	0.0732	0.0112	0	0.072	0.0101
63	0.0031	0.0734	0.0114	0	0.0736	0.0098
64	0.003	0.0734	0.0115	0	0.0752	0.0095
65	0.0029	0.0731	0.0114	0	0.0768	0.0093
66	0.0029	0.0726	0.011	0	0.0784	0.009
67	0.0028	0.072	0.0105	0	0.08	0.0087
68	0.0027	0.0713	0.0096	0	0.0816	0.0083
69	0.0026	0.0706	0.0086	0	0.0832	0.0078
70	0.0024	0.0701	0.0076	0	0.0848	0.0072
71	0.0022	0.0697	0.0065	0	0.0864	0.0067
72	0.002	0.0695	0.0055	0	0.088	0.0062
73	0.0018	0.0697	0.0047	0	0.0896	0.0057

Table A1.2: (Continued)

	Males			Females		
age	start transition probability	quit transition probability	restart transition probability	start transition probability	quit transition probability	restart transition probability
74	0.0016	0.0702	0.0041	0	0.0912	0.0052
75	0.0014	0.0709	0.0036	0	0.0928	0.0048
76	0.0012	0.0719	0.0033	0	0.0945	0.0044
77	0	0.0732	0.003	0	0.0961	0.004
78	0	0.0746	0.0029	0	0.0978	0.0036
79	0	0.0761	0.0028	0	0.0994	0.0031
80	0	0.0777	0.0028	0	0.101	0.0027
81	0	0.0793	0.0028	0	0.1026	0.0023
82	0	0.0809	0.0029	0	0.1041	0.0019
83	0	0.0824	0.0029	0	0.1055	0.0015
84	0	0.0837	0.003	0	0.1068	0.0011
85	0	0.0849	0.003	0	0.1079	0
86	0	0.0858	0.003	0	0.1088	0
87	0	0.0866	0.003	0	0.1096	0
88	0	0.087	0.003	0	0.11	0
89	0	0.0873	0.003	0	0.1103	0
90	0	0.0874	0.003	0	0.1103	0
91	0	0.0873	0.003	0	0.1103	0
92	0	0.0873	0.003	0	0.1103	0
93	0	0.0872	0.003	0	0.1102	0
94	0	0.0871	0.003	0	0.1101	0
95	0	0.0871	0.003	0	0.1101	0

Source: Based on Jeugdmonitor (2010) retrieved December 2010 from: http://jeugdmonitor.cbs.nl/nl-NL/menu/indicatoren/gezondheid/actief-en-passief-roken.htm?showindicators=true. and Hoogenveen R, van Baal P, Bemelmans W (2004) CDM Technical Report no.3: Smoking start, stop and relapse rates, analysis on retrospective data from STIVORO.

Table A1.3: Relative risks from smoking categories to disease and all-cause mortality

Outcome	Males aged 35 years and over			Females aged 35 years and over		
	Smoking categories			Smoking categories		
	never	current	former	never	current	former
All-cause mortality:						
Persons Aged 35-39	1	2.07	*	1	1.74	*
Persons Aged 40-44	1	2.07	*	1	1.74	*
Persons Aged 45-49	1	2.07	*	1	1.74	*
Persons Aged 50-54	1	2.07	*	1	1.74	*
Persons Aged 55-59	1	2.07	*	1	1.74	*
Persons Aged 85-95	1	2.07	*	1	1.74	*
Persons Aged 85-95	1	2.07	*	1	1.74	*
IHD, Persons Aged 35-64	1	2.8	*	1	3.08	*
IHD, Persons Ages 65+	1	1.51	*	1	1.6	*
Stroke, Persons Ages 35-64	1	3.27	*	1	4	*
Stroke, Persons Ages 65+	1	1.63	*	1	1.49	*
Diabetes mellitus	1	1	*	1	1	*
COPD	1	10.58	*	1	13.08	*
Lung cancer	1	23.26	*	1	12.69	*
Colorectal cancer	1	1	*	1	1	*
Oral cancer	1	10.89	*	1	5.08	*
Breast cancer	-	-	-	1	1	*
Esophageal cancer	1	6.67	*	1	7.75	*

Source: DYNAMO-HIA database (American Cancer Society's Cancer Prevention Study II age-specific relative risks, 1982-1988). For further information please refer to the data documentation section of the DYNAMO-HIA project website: www.dynamo-hia.eu

* For former smokers the relative risk is equal to the relative risk for current smokers at the moment of quitting, and afterwards declines towards1. The rate of decline is similar to that described in: Hoogenveen RT, van Baal PH, Boshuizen HC, Feenstra TL., Dynamic effects of smoking cessation on disease incidence, mortality and quality of life: The role of time since cessation. Cost Eff Resour Alloc. 2008 Jan 11;6:1.

Table A1.4: Baseline age-specific disease prevalence rates in the Netherlands

		Age Range	Breast Cancer	Colorectal Cancer	COPD	Diabetes	Esophageal Cancer	IHD	Lung Cancer	Oral Cancer	Stroke
Netherlands	males	(0,15]	-	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		(15,30]	-	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		(30,45]	-	0.00%	0.10%	1.30%	0.00%	0.30%	0.00%	0.00%	0.10%
		(45,60]	-	0.30%	1.50%	5.70%	0.00%	3.50%	0.10%	0.20%	0.90%
		(60,75]	-	1.70%	5.00%	12.70%	0.10%	13.60%	0.40%	0.50%	4.50%
		(75,95]	-	4.10%	6.60%	15.90%	0.10%	28.20%	0.80%	0.90%	12.60%
	females	(0,15]	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		(15,30]	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		(30,45]	0.50%	0.00%	0.10%	1.00%	0.00%	0.10%	0.00%	0.00%	0.10%
		(45,60]	2.60%	0.30%	1.90%	4.20%	0.00%	1.60%	0.10%	0.10%	0.70%
		(60,75]	5.70%	1.30%	4.80%	11.70%	0.00%	7.80%	0.20%	0.30%	3.50%
		(75,95]	8.60%	3.00%	5.30%	17.40%	0.00%	18.90%	0.20%	0.40%	10.10%

Source: own calculations based on DYNAMO-HIA database. For further information please refer to the data documentation section of the DYNAMO-HIA project website: www.dynamo-hia.eu

METHOD DEVELOPMENT

DYNAMO-HIA – A dynamic modeling tool for generic Health Impact Assessments

Lhachimi SK, Nusselder WJ, Smit HA, van Baal P, Baili P, Bennett K, Fernandez E, Kulik MC, Lobstein T, Pomerleau J, Mackenbach JP, Boshuizen HC (2012)

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ABSTRACT

Background: Currently, no standard tool is publicly available that allows researchers or policy makers to quantify the impact of policies using epidemiological evidence within the causal framework of Health Impact Assessment (HIA). A standard tool should comply with three technical criteria (real-life population, dynamic projection, explicit risk factor states) and three usability criteria (modest data requirements, rich model output, generally accessible) to be useful in the applied setting of HIA. With DYNAMO-HIA (Dynamic Modeling for Health Impact Assessment), we introduce such a generic software tool specifically designed to facilitate quantification in the assessment of the health impacts of policies.

Methods and Results: DYNAMO-HIA quantifies the impact of user-specified risk factor changes on multiple diseases and in turn on overall population health, comparing one reference scenario with one or more intervention scenarios. The Markov-based modeling approach allows for explicit risk factor states and simulation of a real-life population. A built-in parameter estimation module ensures that only standard population-level epidemiological evidence is required, i.e. data on incidence, prevalence, relative risks, and mortality. DYNAMO-HIA provides a rich output of summary measures – e.g. life expectancy and disease-free life expectancy – and detailed data – e.g. prevalences and mortality/survival rates – by age, sex, and risk factor status over time. DYNAMO-HIA is controlled via a graphical user interface and is publicly available from the internet, ensuring general accessibility. We illustrate the use of DYNAMO-HIA with two example applications: a policy causing an overall increase in alcohol consumption and quantifying the disease-burden of smoking.

Conclusion: By combining modest data needs with general accessibility and user friendliness within the causal framework of HIA, DYNAMO-HIA is a potential standard tool for health impact assessment based on epidemiological evidence.

INTRODUCTION

Health Impact Assessment (HIA) is a combination of procedures, methods, and tools that judges the effect of (intended) programs, projects, or policies on overall population health and the distributional effects within a population [1]. The rationale behind HIA is that many risk factors for chronic diseases are affected by policy measures outside the realm of health policy (e.g. transportation, food, or urban planning). Health impact assessments have been carried out at all governmental levels (e.g. local [2], regional [3], national [4], and supranational [5]). The number of HIAs is likely to rise due to increased institutional adoption [6] and political will, in particular at EU level [7]. Currently, there is a diversity of approaches to the quantification of policy interventions [8]. However, for the quantification step in HIA, a generic modeling tool – i.e. allowing for various and multiple chronic diseases and arbitrary risk factors – that takes into account the standard causal pathway assumed in HIA has been lacking [9].

The standard HIA causal pathway assumes that a policy intervention leads to a change in risk factor prevalence which in turn leads to changes in disease incidence and disease-related mortality [10]. The two objectives of HIA – to predict future consequences of implementing different options and to inform decision makers in choosing between options [11] – address the technical core of quantification (*predict*) as well as the context (*inform*) in which an HIA takes place. Hence, a potential standard tool should aim for technical accuracy in the prediction of the effects of interventions on population health, and yet be effective in the applied setting of an HIA, where time and resources are scarce. These objectives were operationalized into six criteria that a generic model should fulfill to be useful as a standard tool [9]. The first three criteria (*real-life population*, *dynamic projection*, and *explicit risk factor states*) ensure that the model structure is sufficiently accurate in modeling changes in risk factor exposure over time in a real-life population in a transparent way. The last three criteria (*modest data requirements*, *rich model output*, and *generally accessible*) ensure a wide usability by accounting for the constraints of a decision-making process.

This article proposes a software – DYNAMO-HIA (DYNamic MOdeling for Health Impact Assessment) –as a standard tool for the quantification of user-specified policy interventions within the HIA-framework.

MATERIAL AND METHODS

Implementation of requirements for a standard tool

We designed DYNAMO-HIA to satisfy the six criteria that a generic standard tool for HIA should fulfill. DYNAMO-HIA models a closed *real life population*, i.e. stratified by sex and age in 1 year age categories up to the age of 95 without migration (including the expected number of newborns). The model is *dynamic* in 1-year time steps and projects reference and (several) intervention scenario(s) over time. DYNAMO-HIA has *explicit risk factor states*, i.e. at every time step of the simulation each simulated individual is classified into a specific risk factor category. This ensures an accurate, unbiased estimation and increases the transparency of the simulation and the resulting output data.

DYNAMO-HIA has a parameter estimation module, mostly using methods taken from the Chronic Disease Model of the Dutch National Institute for Public Health (RIVM-CDM) [12], *reducing data needs* substantially. Incidence and prevalence of a disease are only needed at the population level, i.e. specified by age and sex and not by each risk factor state. The module back-calculates the risk factor specific values using the relative risk from each risk factors state on diseases. The user can inspect these intermediate results when desired, thus improving transparency. DYNAMO-HIA provides *rich simulation output* available in three forms: (1) raw output data, allowing detailed analysis by age, sex, and risk factor status. This raw data give either the cohort disease life table for every simulated cohort or the period data for every simulated year; (2) several dynamic plots, e.g. population pyramids or survival rates, based on the data that contrast key information between the reference scenario and the intervention scenario; (3) a range of summary outcome measures, e.g. cohort-, period-, or disease-free life expectancy. The graphical user interface allows *general accessibility*; no programming or other advanced computing skills are required.

Model core

DYNAMO-HIA is a Markov-type model based on a multi-state model (MSM). The change of the state depends only on current characteristics, i.e. age, sex, risk factor status, and health status. The MSM is implemented as a *partial micro-simulation* combining a stochastic micro-simulation to project risk factor behavior with a deterministic macro approach for the disease life table [13]. In the micro-simulation module, large numbers of distinctive risk factor biographies are simulated: Given the age and sex-specific transition probabilities between risk factor states, the risk factor status of each simulated individual is updated in annual increments (see Fig. 1 for details). In the macro module, a separate disease life table is constructed for each of the risk factor biographies. These disease life tables account for competing risks and multiple morbidity [14]. The exact configuration of the disease life tables, i.e. the number and types of diseases, can be specified by the user (see Fig. 2 for details). For every risk factor biography, the probability of

disease incidence and mortality over time is calculated, accounting for the current age, risk factor, and disease status (see Fig. 3 for details). These biography-specific life tables are calculated for each birth-cohort, i.e. all individuals that are born in the same calendar year. For example, for a cohort of newborns, risk factor biographies are projected and subsequently disease life tables are calculated. Older cohorts, i.e. those born before the first simulation year, already have the disease prevalence as specified by the input data, which is then similarly updated. Population values are obtained by aggregating the individual biography/diseases life tables: either across cohorts at a given simulation time point to obtain period measures or along cohorts to obtain cohort specific measures (see Fig. 4 for details). The split into a micro and a macro module is done purely for computational convenience; micro- and macro-simulations yield the same result when used with the same data [15,16]. However, time and memory requirements in macro-simulations rise exponentially when the number of simulated states increases. In contrast, micro-simulations – unlike customary multi-state life tables – do not require the a priori specification of all theoretically possible combinations of diseases/risk factor states, but only those states that are actually occupied. However, for simulating rare events – e.g. lung cancer at young ages – micro-simulations require the simulation of large numbers of individuals, offsetting the savings in time and memory requirements.

risk-factor biography	Age x	x+1	x+2	x+3	x+4
1	N	N	P	P	O
2	O	O	P	N	N
3	P	P	N	N	N
4	N	N	P	O	O
5	N	N	P	O	O
6	P	P	P	P	P
7	N	P	P	P	P
8	N	P	O	O	O
9	N	N	N	N	N
10	N	P	P	N	N

N= Normal Weight, P=Overweight, O= Obese

Figure 1: Example of risk-factor biographies for a risk-factor with three categories. DYNAMO-HIA simulates individuals and projects their risk-factor biographies. The risk-factor status is being updated in one-year increments, given age- and sex-specific transition probabilities. The age- and sex-specific risk-factor status determines the relative risk of a person to contract a disease or to die. DYNAMO-HIA allows one risk-factor per scenario. This risk-factor can be either categorical (up to ten categories), duration dependent (up to ten categories, of which one is duration dependent, i.e. the risk on disease in this category depends on how long a person is in the category), or a continuous distribution (normal or log-normal, specified by entering mean, standard deviation, and, in the case of the log-normal, skewness).

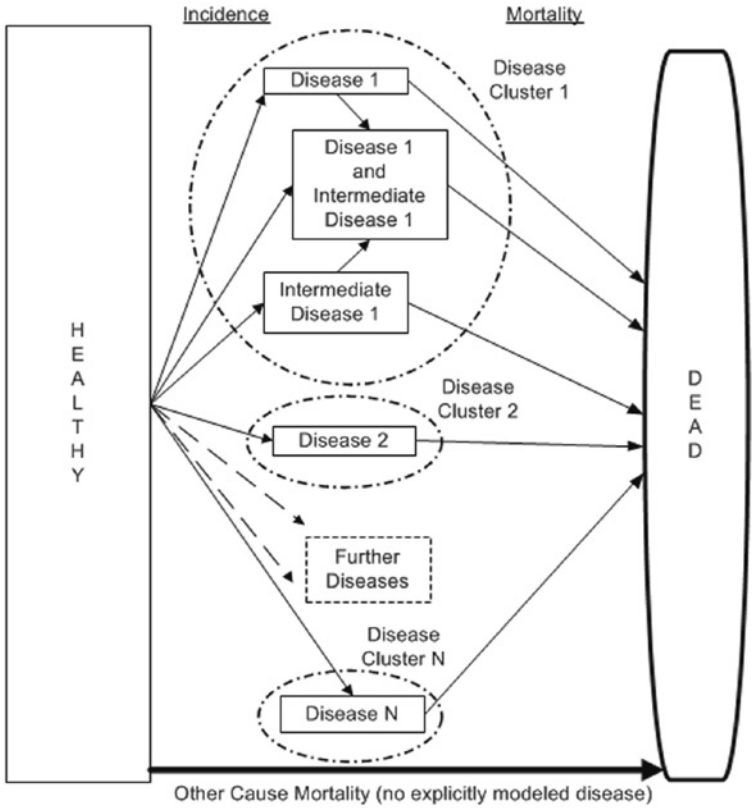

Figure 2: Stylized structure of disease life table. The disease life tables contain disease clusters. Each disease cluster consists of one or more diseases. Within disease clusters, intermediate diseases – that is, a disease that increase the risk of getting another disease – can be specified (e.g. having diabetes increases the risk of getting IHD). All diseases are chronic diseases, i.e. excess mortality depends on age and sex and not on time since onset of disease. However, acutely fatal and/or cured fraction can be specified for diseases. The disease life table assumes independence between disease clusters. The user can freely specify the relative risks from risk-factor to disease, from risk-factor to death, and from intermediate disease to other diseases.

The epidemiological model uses relative risks by risk factor class, i.e. incidences in exposed risk factor classes are a multiple of the incidence in the non-exposed. The total mortality, i.e. population level mortality by age and sex, is being decomposed in the mortality due to the diseases included in the model and other-cause mortality. This decomposition assumes additive mortality: the total mortality rate in the population is explained as the sum of the mortality rate of the included diseases and other-cause mortality, i.e. mortality from all causes/diseases that are not explicitly included in the model.

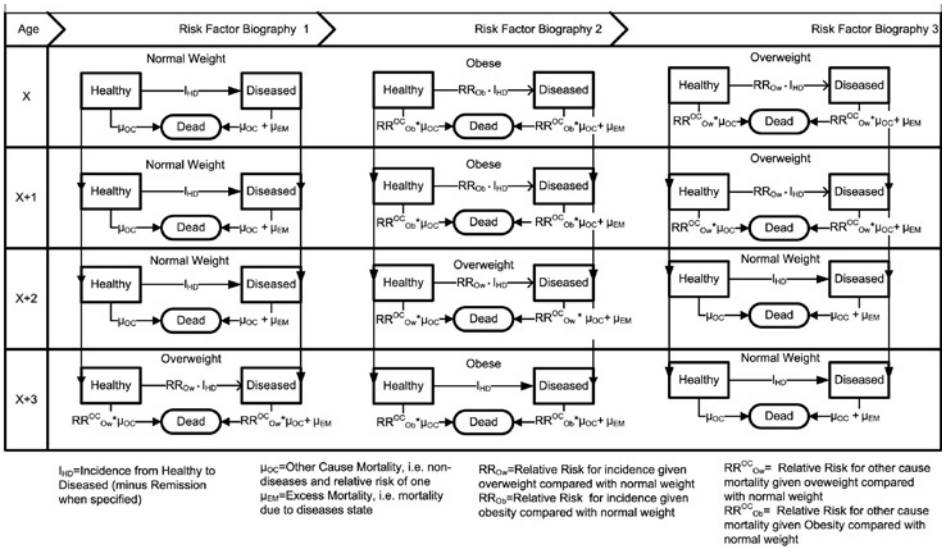

Figure 3: Stylized cohort life tables (with only one disease, three different biographies, and five time steps). For every risk-factor biography, a disease life table is constructed. Disease incidence, i.e. transition from a healthy to a diseased status, equals the baseline incidence – that is, the incidence when in a risk-factor class with a relative risk of one for the specific age- and sex-category – times the relative risk due to the given risk-factor and diseases status (in the case of an intermediate disease). The transition from healthy to dead equals the baseline other-cause mortality of the healthy, i.e. age- and sex-specific total mortality rate minus the excess mortality rate of the diseases included in the disease life table, multiplied by the relative risk due to the given risk-factor status on other-cause mortality. The transition from diseased to dead equals the sum of the excess mortality of the disease (given each age and sex) and the baseline other-cause mortality of the healthy, multiplied by the relative risk in the given risk-factor status. Remission is not explicitly modeled, but for diseases with cured fraction the excess mortality is zero in a "cured", i.e. user-specified, fraction. Partly acutely fatal diseases, i.e. diseases with very high mortality immediately after contracting the disease while for those who survive this critical period the excess mortality only depends on age and sex, are modeled by specifying the fraction of the incidence cases that die immediately.

Modeling policies with DYNAMO-HIA

The goal of HIA is to compare the effect of several policies/interventions on future population health, keeping the status quo as the reference scenario. Within DYNAMO-HIA, policies can be modeled in two ways (both approaches can be applied simultaneously and/or targeted at selected parts of the population only). The first approach is to define a counterfactual risk factor prevalence that is assumed to be reached after a successful one-time, sustained intervention, e.g. a reduction in alcohol consumption caused by a tax increase or a ban on smoking in public. The approach of defining counterfactual risk factor prevalences is akin to epidemiological methods, where total or partial eradication of a risk factor is quantified. DYNAMO-HIA does this quantification dynamically, i.e. effects are projected over time. The second approach is to alter the transition probabilities between different risk factor states, i.e. changing the risk factor behavior of the population. This approach is closer to the reality

of many health interventions that try to influence life style choices of individuals, e.g. halving the future number of teenagers that become obese. The specification of the transition probabilities influences greatly the future development of the risk factor prevalence, which is always debatable. As an option, DYNAMO-HIA provides the use of net transition probabilities [17]: DYNAMO-HIA estimates internally the transition probabilities that keep the age-specific risk factor prevalence constant, ignoring any future cohort effects.

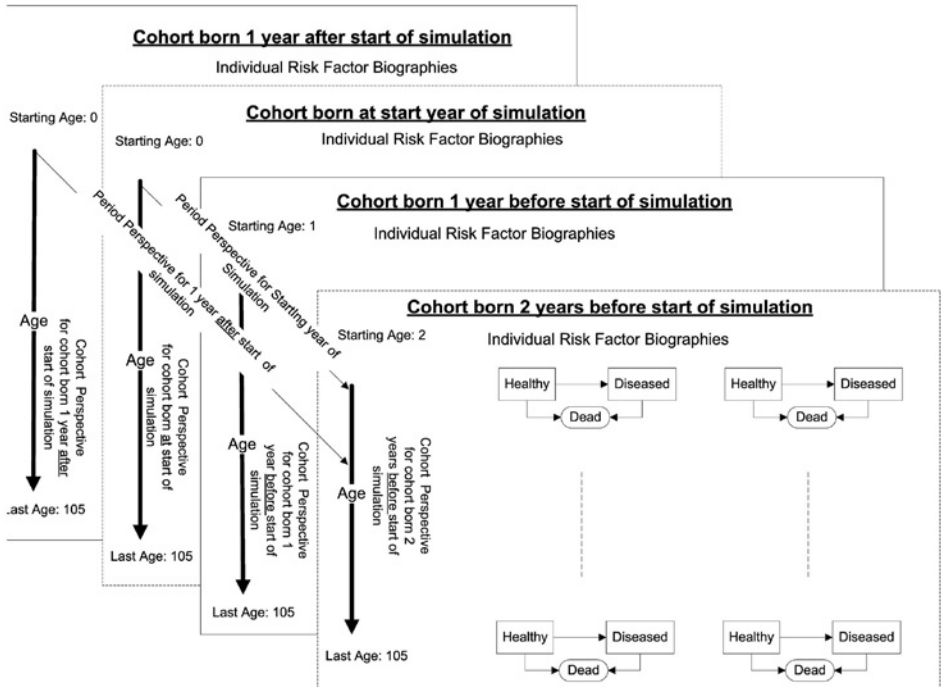

Figure 4: Schematic overview of the dimension of a multi-cohort, multistate-life table. Each plane is a distinct cohort with varying starting ages for cohorts already existing at the starting year of the simulation and starting age zero for cohorts born during the simulation run. The cohort life tables, consisting of the set of individual risk-factor biographies, follow every already existing birth cohort until the cohort reaches 105 years of age. In addition, every year of the simulation a cohort of newborns is created and – after simulating individual risk-factor biographies for them – is followed through the appropriate disease life tables as well. This allows collecting health data for each cohort according to their risk-factor status (longitudinal) or the health status of the population by age, sex, and risk-factor status by each year of the simulation (cross-sectional).

Illustration

To illustrate the usability of DYNAMO-HIA, we present two stylized example applications. The first illustration projects the consequences of a policy-induced increase in alcohol consumption and resembles a prospective HIA. The second illustration quantifies the changes in population health if smoking were to be eradicated and resembles a burden of disease study. In both applications, we model the effects of risk factors on total mortality and nine diseases

(ischemic heart disease, stroke, diabetes, COPD, breast-, lung, esophageal-, colorectal-, and oral-cancer) and keep the age-specific risk factor prevalence constant over time by using net transition probabilities between risk factor classes, i.e. ignoring any future cohort effects. Hence, the difference between the reference scenarios and the intervention scenarios depends solely on the different initial risk factor prevalences. The data sources and the relative risk used are shown in detail in the supporting information (see Tables A3 through A7 in the appendix to this paper).

Liberalizing access to alcohol: the Swedish case

In 2004, Sweden was forced to lift its ban on private alcohol imports [18]. Prospective studies were forecasting an increase in overall alcohol consumption and consequently a worsening of a number of alcohol-related harm indicators. In our reference scenario, we keep the alcohol consumption prevalence observed in 2002 constant during the projection period and assume a one-time change in the consumption of pure alcohol by 1 L per-capita, producing a counterfactual risk factor prevalence for the intervention scenario as seen in Fig. 5. We project both scenarios for 25 years into the future (see Table 1).

The annual excess number of deaths due to increased alcohol consumption is on average approx. 170 deaths, accruing to some 4,300 additional deaths over the 25 year period. This projected difference in overall population mortality also reflects all other effects a risk factor has on other-cause mortality, accounting for not included diseases and – more salient in the case of alcohol – injuries/accidents via the relative risk of a risk factor on total mortality. This

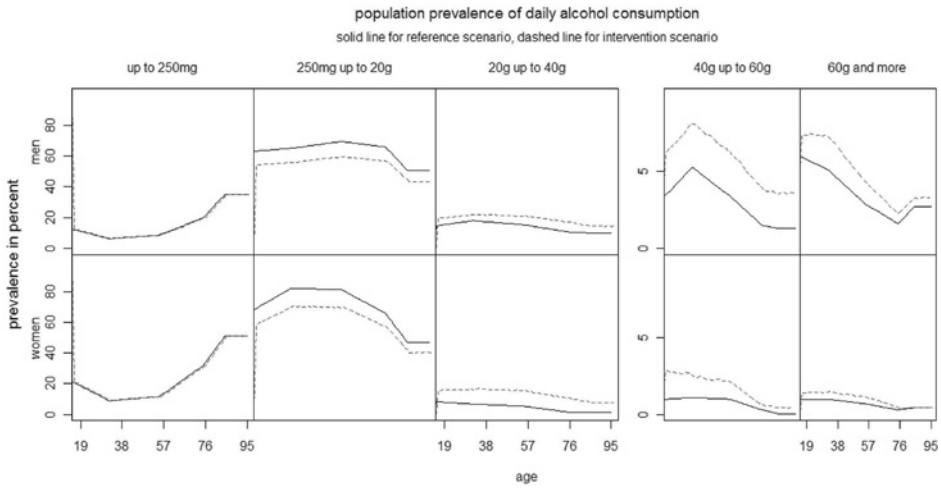

Figure 5: Swedish prevalence of alcohol consumption intervention scenario compared with reference scenario (Alcohol consumption is measured by five categories of daily intake of grams of pure alcohol: 0 - <0.25g/d, 0.25 - <20g/d, 20 - <40g/d, 40- <60g/d, ≥60g/d).

absolute number is rather small compared to the overall population of some 9 million; hence, the effect on total life expectancy and, similarly, the overall difference in disease-free life expectancies between the reference and the intervention scenario are negligible.

Alcohol intake has a pronounced effect on a number of the diseases projected in the model. In projection year 25, the biggest difference in absolute cases is for diabetes with approx. 6,600 more cases, followed by stroke with an excess prevalence of approx. 1,700 cases. Ischemic heart disease, the most prevalent of the included diseases, is overall less affected by the change in alcohol intake. The population prevalence differs only marginally over the

Table 1: Number of disease cases and population prevalence (in percent) for example applications.

	Swedish Alcohol Example					UK Smoking Example				
	Reference Scenario			Intervention Scenario (1 L increase per capita alcohol consumption)		Reference Scenario			Intervention Scenario (All are never smokers)	
	year	numbers	%.	numbers	%	year	Numbers	%	numbers	%
IHD	*1*	354,747	3.9%	354,747	3.9%	1	2,183,447	3.6%	2,183,447	3.6%
	25	428,727	4.7%	428,026	4.6%	25	2,666,917	4.4%	2,144,465	3.5%
Stroke	*1*	150,271	1.7%	150,271	1.7%	1	1,002,594	1.7%	1,002,594	1.7%
	25	192,924	2.1%	194,616	2.1%	25	1,374,698	2.3%	1,156,176	1.9%
Diabetes	*1*	368,787	4.1%	368,787	4.1%	1	1,559,679	2.6%	1,559,679	2.6%
	25	385,216	4.2%	391,793	4.3%	25	1,850,392	3.1%	1,999,847	3.2%
Lung	*1*	4,613	0.1%	4,613	0.1%	1	82,082	0.1%	82,082	0.1%
Cancer	*25*	5,753	0.1%	5,750	0.1%	25	107,393	0.2%	20,334	0.0%
Oral	*1*	9,377	0.1%	9,377	0.1%	1	55,804	0.1%	55,804	0.1%
Cancer	*25*	11,738	0.1%	12,495	0.1%	25	70,949	0.1%	33,013	0.1%
Esophageal	*1*	971	0.0%	971	0.0%	1	11,231	0.0%	11,231	0.0%
Cancer	*25*	1,241	0.0%	1,300	0.0%	25	14,535	0.0%	5,324	0.0%
Colorectal	1	36,415	0.4%	36,415	0.4%	1	248,380	0.4%	248,380	0.4%
Cancer	25	47,775	0.5%	48,062	0.5%	25	329,116	0.5%	370,596	0.6%
Breast	1	90,444	1.0%	90,444	1.0%	1	543,738	0.9%	543,738	0.9%
Cancer	25	108,854	1.2%	110,661	1.2%	25	670,013	1.1%	705,919	1.1%
COPD	1	105,052	1.2%	105,052	1.2%	1	525,247	0.9%	525,247	0.9%
	25	131,118	1.4%	130,850	1.4%	25	1,016,422	1.7%	278,194	0.4%
With at least	1	918,921	10.2%	918,921	10.2%	1	5,148,112	8.6%	5,148,112	8.6%
one disease	25	1,081,720	11.7%	1,088,547	11.8%	25	6,726,107	11.1%	5,792,303	9.4%
Size of	1	9,002,148		9,002,148		1	59,987,010		59,987,010	
total population	*25*	9,210,437		9,206,131		25	60,416,567		61,929,848	

For data sources see appendix to this paper (Table A3 through Table A7 below)

simulation period, but still accounts for approx. 700 additional cases; this is partly caused by the beneficial effect of moderate drinking by some age groups (see Table A5). From the five included cancers, the increase in breast cancer is the most notable: in projection year 25, the excess prevalence is approx. 1,800 cases in the intervention scenario. For the other cancers, the increase in prevalence cases is relatively minor: for oral cancer approx. 750, for colorectal cancer approx. 280, and for esophageal cancer approx. 60 additional cases in the counterfactual scenario. COPD shows a slight decrease in absolute numbers, although it is not causally related to alcohol intake. This is due to the higher number of deaths, thus there are less persons alive to contract this disease.

Total elimination of smoking: a projection with UK data

Smoking is a major public health concern. This illustration quantifies the gain in population health obtainable if an entire population consisted of never smokers compared to a real life population that keeps the currently observed smoking behavior unchanged. Smoking is measured in three categories (never, former, current smoker). The data for this illustration are from the UK and are projected 25 years into the future (see Table 1 and Table 2). In the counterfactual, the whole population consists of never smokers and there is no uptake of smoking.

In 25 years, the population of non-smokers is projected to have approx. 1,510,000 more individuals than a population keeping the current smoking behavior. This translates into a total life expectancy of 81.4 years for the counterfactual compared to 79.0 years for the reference scenario. This gain in life expectancy is substantially larger for men than for women: For men the difference is more than 3 life years (76.9 in the reference scenario compared to 80.0 in the intervention scenario) and for women 1.8 years (81.0 compared to 82.8). The projected life expectancies clearly demonstrate that in DYNAMO-HIA no autonomous trends are assumed, e.g. a secular increase in life expectancy that one may expect over the next 25 years.

Smoking also has a causal effect on a number of diseases. The biggest reduction in the modeled diseases is for COPD. In projection year 25, the average life years lived with COPD is approx. 0.9 years less in the intervention scenario than in the reference scenario, more than halving population prevalence from 1.7% to .5%. The next biggest reduction is for IHD, with approx. half a year less expected life years with this disease; a difference in prevalence of one percentage point. Similarly, the prevalence of stroke goes down by approx. 0.4 percentage points (from 2.3% to 1.9%). The three included cancers that are related to smoking are reduced as well (lung cancer by approx 87,000 cases, esophageal cancer by approx 38,000, and oral cancer by approx 9,200 cases). However, other included diseases that are not causally related to smoking (diabetes, breast-, and colorectal cancer) increase in prevalence thanks to the larger number of surviving individuals that are now at risk of contracting those diseases.

Table 2: Period-based total life expectancy and expected number of years with a disease for the UK example application

		Women			Men		
	year	Reference Scenario	Difference between Reference and Intervention Scenario	Intervention Scenario (All are never smokers)	Reference Scenario	Difference between Reference and Intervention Scenario	Intervention Scenario (All are never smokers)
total life	*1*	81.3	0.2	81.5	77.0	0.8	77.8
expectancy	*25*	81.0	1.8	82.8	76.9	3.1	80.0
IHD	*1*	3.3	0	3.3	4.3	0.2	4.5
	25	3.0	-0.4	2.6	3.8	-0.6	3.2
Stroke	*1*	1.9	0	1.9	1.8	0.1	1.9
	25	1.8	-0.2	1.6	1.8	-0.2	1.6
Diabetes	*1*	2.3	0	2.3	2.6	0.1	2.7
	25	2.1	0.1	2.2	2.5	0.3	2.8
Lung	*1*	0.1	0	0.1	0.2	0	0.2
Cancer	*25*	0.1	-0.1	0.0	0.2	-0.2	0.0
Oral	*1*	0.1	0	0.1	0.1	0	0.1
Cancer	*25*	0.1	-0.1	0.0	0.1	-0.1	0.0
Esophageal	*1*	0.0	0	0.0	0.0	0	0.0
Cancer	*25*	0.0	0	0.0	0.0	0	0.0
Colorectal	*1*	0.4	0	0.4	0.5	0	0.5
Cancer	*25*	0.4	0.1	0.5	0.5	0.1	0.6
Breast	*1*	1.7	0	1.7	n/a	n/a	n/a
Cancer	*25*	1.7	0.1	1.8	n/a	n/a	n/a
COPD	*1*	0.8	0	0.8	0.9	0.1	1.0
	25	1.3	-0.9	0.4	1.2	-0.9	0.3
With at least	*1*	8.9	-0.8	8.8	8.4	0.3	8.7
one disease	*25*	8.7	-0.8	7.8	8.2	-0.9	7.3

For data sources see appendix to this paper (Table A3 through Table A7 below)

DISCUSSION

Within the rapidly developing field of HIA no standard method for quantification has emerged yet [19], but three approaches predominate in the field: regression based methods, quantitative risk assessment, and population health models. The regression based methods originated in econometrics and usually estimate the long term relationship between exposure (e.g. per-capita consumption) or proxy variables (e.g. tax rate on alcohol) and health outcomes of interest on an aggregate level, adjusting for further variables as suggested by (economic) theory. This approach usually takes only limited notice of underlying epide-

miological mechanisms. Quantitative risk assessment, originating from (environmental) exposure assessment of toxic substances, makes explicit use of dose-response relationships derived through epidemiological studies. These approaches are usually static, i.e. do not account for changes over time in real-life populations. Population health models combine epidemiological evidence and insights on causality to dynamically quantify the effect of risk factors on population health.

DYNAMO-HIA fills a gap among the already existing population health models that are suggested for application in HIA [9,20]. Compared to existing models, DYNAMO-HIA strikes a balance between being sufficiently technically accurate and ensuring wide usability. Technically equal or more complex models – e.g. POHEM, ARMADA, RIVM-CDM – allow for greater flexibility in modeling but are not publicly available, and require highly specialized input data and proficiency in specialized programming languages (except ARMADA). More accessible models – e.g. PREVENT, Proportional Multi-state Life Table (MSLT), GBD – lack dynamic projection capabilities (except PREVENT and multiple cohort versions of the MSLT [21]) and do not have explicit risk factor states. This technical simplification ignores mortality selection and may lead to biased estimates [9].

DYNAMO-HIA is specially designed to fit within the standard framework of HIA, synthesizing elements of already well-established modeling approaches. Our approach allows for a flexible risk factor configuration (categorical, duration dependent, continuous); generic chronic diseases as specified by the user (with intermediate diseases, partially fatal diseases, and/or diseases with a cured fraction); arbitrary specification of – age and sex-specific – relative risks; and minimal data needs by requiring only population level data (see Fig. 6). Furthermore, a mouse-driven graphic user interface allows straightforward handling of the software, i.e. no knowledge of a programming language is required. In addition to exporting the existing, partly customizable, graphs into files – e.g. detailed plots of mortality rates or prevalences of risk factors or diseases, both over time and age-specific – most calculated data can be exported for use in separate software (e.g. Excel). These raw output data allow further analyses, such as grouping diseases into categories (e.g. IHD and stroke or all cancers), including costs, or constructing additional graphs.

DYNAMO-HIA simulates the effect of a single risk factor on a population without migration. However, the categorical risk factor can be used to partition the population in up to ten distinctive categories. For example, a population could be partitioned along a risk factor – say, non-smokers and smokers – and socioeconomic status – say, with and without college education – having in total four different groups to assess policies that are more successful for people with certain socioeconomic status. The possibility of partitioning a population also allows quantification of the effect of an environmental hazard. In this case, for example,

the population is partitioned according to their proximity to the hazard source – say, noise exposure or air pollution due to a new airport – with 5% of the total population living less than 5km from the hazard source, 5% to 10% living less than 10km and so on. This requires, of course, sufficient insight into which part of the population is affected and knowledge of the relative risks of the modeled exposure on the included diseases and total mortality.

A category may also represent a combination of known risk factors: For example, smoking status and BMI – smoking/non-smoking and normal weight/overweight/obese – could be modeled by partitioning the population into six distinctive risk factor categories. However,

- Disease data (for every included disease)
  - Excess mortality
  - Incidence
  - Prevalence
  - RR given risk-factor class
  - RR from other diseases (optional)
  - DALY weights
- Population data
  - Size
  - Newborns (optional*)
  - Overall mortality
  - Overall DALY weights
- Risk Factors
  - Prevalence (categorical, continuous, or by duration)
  - RR for death (optional*)
  - Transition probabilities between risk-factor classes (net transitions and zero transitions available as default)

*omitting RR for death implies a slightly different model interpretation than presented in article

Figure 6: Overview of required input data (age- and sex-specific)

this would require knowledge about the relative risk of the combined risk factor class – say, relative risk of being obese and a smoker on the included diseases and total mortality.

The overall performance of a model crucially depends on the quality of the input data. In particular for dynamic models, the epidemiological data has to be mutually consistent, otherwise projected changes in the prevalences might be caused by mismatching data and not by the changes in the risk factors. A limitation is that an autonomous trend in the rates, e.g. annual reduction in overall mortality or disease incidence, cannot be specified. Autonomous trends are often observed for past time periods and caused by a number of factors; chief among them improved curative interventions and changed risk factor behavior. In a risk factor based model, however, the specification of a future autonomous trend must be net of any underlying risk factor behavior, as this is already specified explicitly at some other place in the model. Such specific data on future trends is hardly reliably available, if at all, and would, in most cases, only modestly affect the difference between reference and intervention scenarios. Hence, an ordinal ranking of policy alternatives would be rarely affected while still revealing the most effective intervention.

In health impact assessment, three criteria are used to assess validity: formal validity, plausibility, and predictive validity [22].

Formal validity assesses the degree to which correct methods are applied correctly. The model structure of DYNAMO-HIA is well-founded in epidemiological evidence – incidence, prevalence, and excess mortality – and demographic modeling practice, i.e. a multistate Markov-type model of chronic disease with explicit risk factor states and inclusion of intermediate diseases.

Plausibility assesses the degree to which an observer deems the theoretical framework understandable, applicable, and plausible. Hence, DYNAMO-HIA deliberately restricts itself to the well-established causal chain "risk factor exposure -> incidence -> prevalence -> disease-related mortality -> overall population health" and requires only data that is available in sufficient quality for the most common diseases (e.g. cancer, CVD, diabetes, COPD) and risk factors (e.g. smoking, BMI, alcohol) in developed countries. In the Swedish application example, our results for the number of excess deaths are slightly lower than estimates based on a regression approach utilizing historical relationships and aggregate-data pooled from several Nordic countries [18]. One reason for this difference lies in the relative risks on all-cause mortality used in our illustration. These are taken from epidemiological studies and capture only the effect of individual exposure, i.e. drinking behavior. Consequently, our results do not account for broader effects that a change in alcohol consumption may have on population

health, i.e. abstainers or moderate drinkers becoming victims of increased alcohol-induced violence or accidents caused by the increased number of intoxicated drinkers.

Plausibility and well-established formal methods should not be mistaken for constantly delivering expected results. Dynamic projections may reveal counterintuitive yet correct results and, hence, lead to important insights. In the smoking application, for example, the number of breast cancer cases in the never-smoker scenario is larger than in the reference scenario, although smoking has no causal link to breast cancer incidence. This seemingly unexpected result is caused by an increase in overall longevity of a healthier living population and, hence, an increased number of females susceptible to breast cancer. This phenomenon is well known among modelers of health care costs; dynamic analysis has shown repeatedly that a population-level reduction in obesity or smoking may lead to higher health care costs in the long run [23,24].

Predictive validity is the degree to which predictions are confirmed by facts; according to Veerman et al [22], however, this criterion usually cannot be established in the context of HIA. The sometimes decades-long time-lag between a change in policy and a change in the corresponding health effects makes it difficult to conduct a full evaluation of the HIA prediction. Moreover, a HIA might influence policy in such a way as to (successfully) invalidate its own predictions.

We emphasize that a software model like DYNAMO-HIA is only a decision-support tool. It helps to quantify the expected differences in population health given two (or more) different scenarios: one of them a baseline scenario (without the intervention) and one (or more) scenario(s) with intervention(s). It does not predict the development of future population health as such. Decision makers must be constantly aware that real-world phenomena are necessarily more complex and that no model can predict future events with 100% accuracy. In HIA, it may be useful to avoid calling the results of mathematical models 'predictions', but rather *projections* of "what if" scenarios in a clearly defined and simplifying framework. The term 'prediction' should be reserved for the entire process, in which a software model is only one element of the utilized evidence [9,25,26].

Internal validity was extensively tested. To allow future thorough checking of cross validity by outside experts as well, the software and the source code are publicly available (www.DYNAMO-HIA.eu). In its current form, DYNAMO-HIA also facilitates unproblematic one- and multi-way sensitivity analysis, by allowing easy manipulation of all input parameters. Like most other population health models, however, the current version of DYNAMO-HIA does not include a probabilistic sensitivity analysis (PSA). Implementing a PSA in population health models is time and cost intensive; the extra data needed to conduct a PSA are difficult to

obtain and preparing them requires expert knowledge. However, DYNAMO-HIA can be used in batch mode, allowing users with sufficient computing skills to build a PSA shell around the software, if desired.

DYNAMO-HIA is available for free download and includes a data set covering a large number of EU countries (www.dynamo-hia.eu). This internally consistent data set has prevalence data for three risk factors (smoking, BMI, alcohol), nine diseases (incidence, prevalence, excess mortality), and population data (e.g. total mortality, projected number of newborns). This data set allows instant use of DYNAMO-HIA for the covered countries. However, DYNAMO-HIA is also usable with external data on other countries, (sub-)populations, diseases, or risk factors. Furthermore, the already included data set can be easily updated when more recent data become available. DYNAMO-HIA can be used for a range of applications, in particular if additional data are available.

Recent applications of DYNAMO-HIA include a comparison of tobacco control scenarios [27]; the effect of an increase in obesity levels for the Dutch population [13]; the EU-wide gains in population health when increasing prices on alcohol [28]; and the potential health gains and losses in the EU achievable through feasible prevalences of life-style related risk factors [29]. The current focus of DYNAM-HIA is on policies at the national level, but the software can, in principle, also be used for applications at the regional or local level.

Conclusion

DYNAMO-HIA differs from other population health models for HIA [20] in several important aspects. From the outset, it has been designed for public use within HIA-applications by featuring a user-friendly graphic interface, and employing a model structure that ensures accurate simulation using epidemiological evidence while having modest data needs.

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APPENDIX TABLES

Table A3: Overview of data sources for disease data used in the example applications

		Sweden	UK
All five cancers included	*Prevalence*	Back calculated using DisMod II	Back calculated using DisMod II
	Incidence	Cancer Incidence in 5 Continents. Vol IX , 100% of population (1998-2002) (remission equal to zero)	Cancer Incidence in 5 Continents. Vol IX, Some 95% of population (periods vary by registry between 1998-2002) (remission equal to zero)
	Excess Mortality/ Case Fatality	WHO, mortality database, 100% of population (2000-2002)	WHO, mortality database, 100% of population (2000-2002)
Diabetes	*Prevalence*	Ostergotland Study	UK GPRD
	Incidence	IPM based on prevalence & GPRD RR	IPM based on prevalence & GPRD RR
	Excess Mortality/ Case Fatality	Based on RR from UK GPRD	UK GPRD
IHD	*Prevalence*	Back calculated using DisMod II	Back calculated using DisMod II
	Incidence	Based on UK GPRD incidence adjusted for Swedish IHD mortality	UK GPRD
	Excess Mortality/ Case Fatality	Based on RR from UK GPRD	UK GPRD
COPD	*Incidence*	Derived from smoking prevalence	UK GPRD
	Prevalence	Back calculated using DisMod II	UK GPRD
	Excess Mortality/ Case Fatality	Based on RR from UK GPRD	UK GPRD
Stroke	*Incidence*	WHO estimates Truelson et al review(2002)	WHO estimates Truelson et al review(2002)
	Prevalence	IPM based on incidence & GPRD RR	IPM based on incidence & GPRD RR
	Excess Mortality/ Case Fatality	Based on RR from UK GPRD	UK GPRD

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Further details available on the data reports on www.dynamo-hia.eu

Table A4: Overview of data sources for risk factors used in the example applications

	Name of survey, year	Number of respondents	Age range of respondents
Sweden (alcohol)	The (Alcohol) Monitoring Study, 2002	N=~18,000 (national sample)	16-80 years
UK (Smoking)	English Health Survey, 2001	N=15767 (national sample for England, covering some 85% of the UK population)	16 years and abour

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Further details available on the data reports on www.dynamo-hia.eu

Table A5: Overview of relative risks from alcohol to diseases and total mortality used in the example applications (below the age of 15 all relative risks are set to 1)

Outcome	Males aged 15 years and over					Females aged 15 years and over				
	Drinking categories (grams per day)					Drinking categories (grams per day)				
	0 - <0.25	0.25 - <20	20 - <40	40 - <60	≥60	0 - <0.25	0.25 - <20	20 - <40	40 - <60	≥60
All-cause mortality										
Persons Aged 16-24	1.00	1.07	1.25	1.48	1.88	1.00	1.04	1.17	1.31	1.58
Persons Aged 25-34	1.00	1.05	1.21	1.40	1.75	1.00	1.04	1.15	1.29	1.54
Persons Aged 35-44	1.00	1.00	1.10	1.23	1.47	1.00	1.03	1.15	1.30	1.56
Persons Aged 45-54	1.00	0.96	1.01	1.10	1.26	1.00	1.02	1.13	1.26	1.51
Persons Aged 55-64	1.00	0.94	0.98	1.04	1.16	1.00	1.00	1.09	1.22	1.46
Persons Aged 65-74	1.00	0.94	0.97	1.02	1.11	1.00	0.99	1.06	1.17	1.38
Persons Aged 75-84	1.00	0.95	0.97	1.02	1.11	1.00	0.98	1.05	1.15	1.35
Persons Aged 85-95	1.00	0.96	0.98	1.02	1.09	1.00	0.98	1.03	1.12	1.27
IHD	1.00	0.82	0.82	0.87	1.13	1.00	0.82	0.82	0.87	1.13
Stroke	1.00	0.91	1.01	1.18	1.55	1.00	0.7	0.79	1.08	2.74
Diabetes mellitus	1.00	0.72	0.86	1.00	1.00	1.00	0.72	0.86	1.00	1.00
COPD	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Lung cancer	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Colon cancer	1.00	1.00	1.08	1.30	1.72	1.00	1.00	1.11	1.33	1.62
Oral cancer	1.00	1.31	2.08	3.02	4.32	1.00	1.33	2.18	3.26	4.85
Breast cancer	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.23	1.42	1.68
Esophageal cancer	1.00	1.17	1.61	2.19	3.18	1.00	1.17	1.61	2.19	3.18

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Further details available on the data reports on www.dynamo-hia.eu

Table A6: Overview of relative risks from smoking to diseases and total mortality used in the example applications (below the age of 35 all relative risks are set to 1)

Outcome	Male aged 35 and above			Female aged 35 and above		
	Never Smoker	Current Smoker	Former Smoker	Never Smoker	Current Smoker	Former Smoker
All-cause mortality	1.00	2.07	1.35	1.00	1.74	1.23
Lip, Oral Cavity, Pharynx	1.00	10.89	3.40	1.00	5.08	2.29
Esophagus	1.00	6.76	4.46	1.00	7.75	2.79
Lung cancer	1.00	23.26	8.70	1.00	12.69	4.53
IHD (ages 35-64)	1.00	2.80	1.64	1.00	3.08	1.32
IHD (ages 65+)	1.00	1.51	1.21	1.00	1.60	1.20
Stroke (ages 35-64)	1.00	3.27	1.04	1.00	4.00	1.30
Stroke (ages 65+)	1.00	1.63	1.04	1.00	1.49	1.03
COPD	1.00	10.58	6.80	1.00	13.08	6.78

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Further details available on the data reports on www.dynamo-hia.eu

Table A7: Overview of relative risks from diabetes to IHD and stroke used in the example applications

	Males	Females
Diabetes to IHD		
Persons Aged up to 55	2.66	3.53
Persons Aged 56+	1.93	2.59
Diabetes to stroke		
Persons Aged up to 49	2.00	2.90
Persons Aged 50+	1.80	2.20

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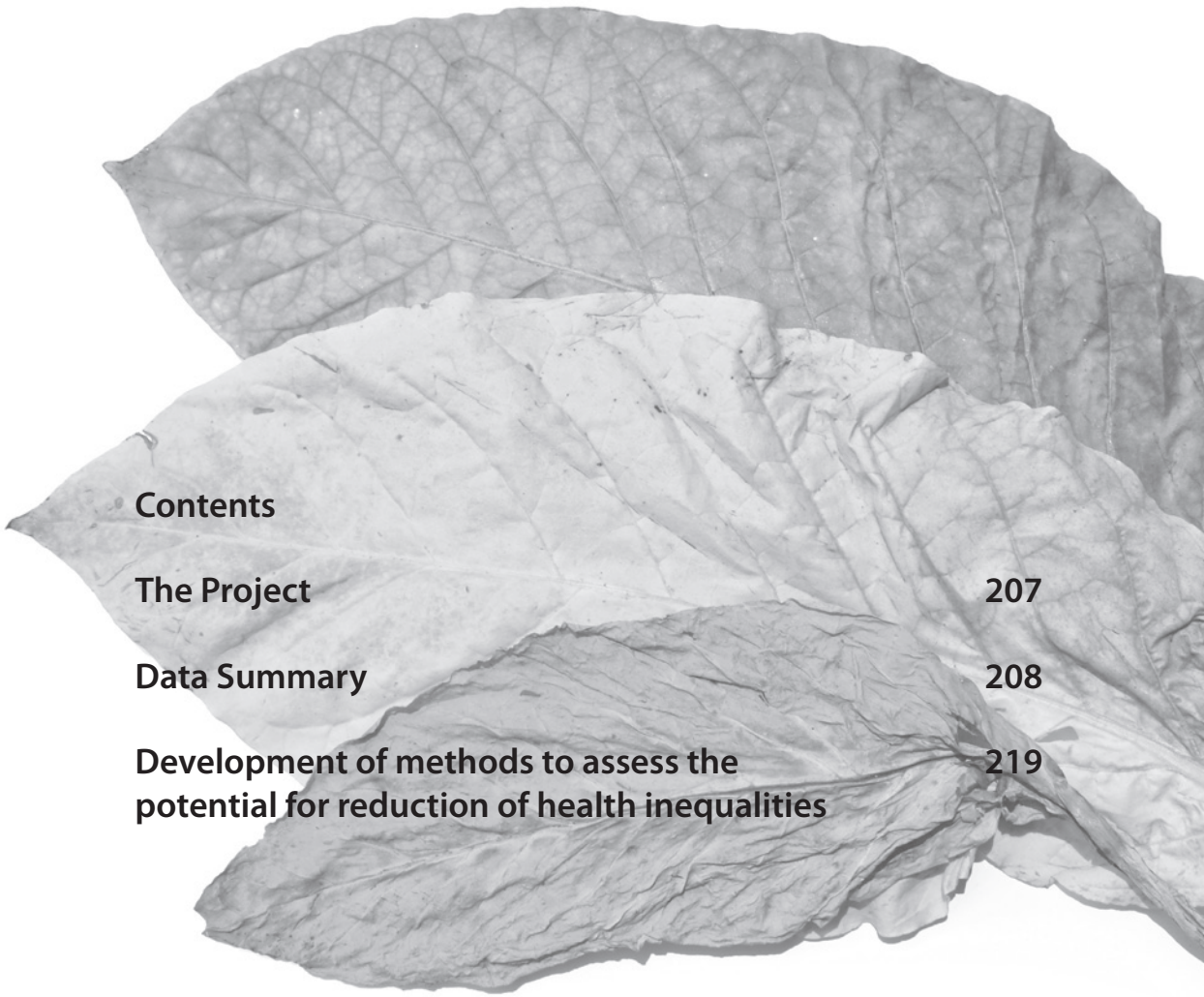
Further details available on the data reports on www.dynamo-hia.eu

APPENDIX II

PROJECT INFORMATION, DATA AND METHODS: THE EURO-GBD-SE PROJECT



Contents

THE EURO-GBD-SE PROJECT

The Euro-GBD-SE project had three main objectives. The first objective was to provide updated estimates of the magnitude of socioeconomic inequalities in health in Europe. The second objective was to estimate the contribution of risk factors to the explanation of these health inequalities. The third objective was to estimate the extent to which health inequalities in Europe can realistically be reduced by policies and interventions on socioeconomic determinants as well as on specific risk factors. The first objective was addressed by collecting, harmonizing and analyzing recent European data on inequalities in mortality and morbidity. The second and third objectives were addressed by collecting, harmonizing and analyzing data on inequalities in risk factors in Europe, and by relating these to inequalities in health outcomes using a number of different "counterfactual" scenarios. A total of 85 risk factors was originally considered and after a careful literature review reduced to only 9 risk factors which fulfilled all project requirements: 6 proximate risk factors (smoking, overweight/BMI, physical inactivity, diabetes mellitus, fruit and vegetables consumption, and social participation), and 3 distal risk factors (income, economic activity, and occupational class).

An important innovation was the construction of an excel-based application (PAF tool) by applying methodology recently developed within the Global Burden of Disease study to estimate the contribution of risk factors to health inequalities, as well as the reduction in health inequalities that would be obtained, if the distribution of determinants of health inequalities would be more equal than is currently the case. In order to additionally construct Confidence Intervals (CIs) around the outcomes of the PAF tool we applied the following procedure: We constructed replicas by drawing numbers from the Poisson distribution with the observed numbers as parameters. Recalculating the PAF using the replica numbers lead to a distribution around the point estimate from which the 2.5 and the 97.5 percentile were taken to represent the CI. We used the statistical program R for this procedure. We assumed the relative risks of the effect of the particular risk factors on mortality not to be subject to sampling variation. We focused on the largest source of uncertainty which was the prevalence of the risk factors. In the particular analysis in chapter 5 it was the country-specific numbers of current, former and never smokers at the outset which were the driving force of the magnitude of the CIs.

The Euro-GBD-SE project was funded by the European Commission, through the Public Health Programme, grant agreement 20081309 and through the Netherlands Organization for Health Research and Development (ZonMw), project number 121020026.

The Work Packages of the Euro-GBD-SE project were:

WP1: Coordination of Project
WP2: Dissemination of Results
WP3: Evaluation of Project
WP4: Development of Methods
WP5: Building a Harmonized Database
WP6: Developing Counterfactual Distributions
WP7: Estimating Magnitude of Inequalities in Mortality and Morbidity
WP8: Estimating Magnitude of Inequalities in Summary Measures of Population Health
WP9: Estimating Potential for Reduction of Health Inequalities
WP10: Formulating Policy Recommendations

The Euro-GBD-SE data has generated two important sets of data containing harmonized data from, respectively, national mortality registries and national health surveys. Below we summarize the data that was used for the particular calculations and applications in chapters 2, 3 and 5 (Tables A2.1, A2.2, A2.3, A2.4, A2.5 below). More details about the entire database and about the sources of the data and adjustments applied are given in the work package documentation and are available here: www.euro-gbd-se.eu. More in-depth information about the development of the methods to assess the potential for reduction of health inequalities, and resulting in the PAF tool, is included below in this appendix.

DATA SUMMARY

Euro-GBD-SE data collaborators:

Mortality data: Pekka Martikainen (Finland), Olle Lundberg (Sweden), Bjorn H Strand (Norway), Anita Lange (Denmark), Suzanne Fry and Myer Glickman (England & Wales), Chris Dibben (Scotland), CBS (Netherlands), Patrick Deboosere (Belgium), Gwenn Menvielle (France), Matthias Bopp (Switzerland), Johannes Klotz (Austria), Carme Borrell (Barcelona, Spain), Santiago Esnaola (Basque Country, Spain), Enrique Regidor (Madrid, Spain), Giuseppe Costa (Turin, Italy), Annibale Biggeri (Tuscany, Italy), Katalin Kovacs (Hungary), Jitka Rychtarikova (Czech Republic), Bogdan Wojtyniak (Poland), Domantas Jasilionis (Lithuania), Mall Leinsalu (Estonia).

Risk factor prevalence data: Satu Helakorpi (Finland), Bo Burström (Sweden), Espen Dahl (Norway), Ola Ekholm (Denmark), Ken Judge (England), Richard Layte (Ireland), Chris Dibben (Scotland), J.J.M. Geurts (Netherlands), Herman van Oyen (Belgium), Uwe Helmert (Germany) Frédérique Ruchon (France), Centre Maurice Hallbawachs (France), Office Fédéral de la

Statistique (Switzerland), Santiago Esnaola (Basque Country, Spain), Enrique Regidor (Spain), Giuseppe Costa (Italy), Paula Santana (Portugal), Ferenc Marton (Hungary), D. Dzurova (Czech Republic), Bogdan Wojtyniak (Poland), Jurate Klumbiene (Lithuania), Mare Tekkel (Estonia).

Table A2.1: Initial smoking prevalence rates, PAF tool format as used in chapter 5

		Men				Women			
	age	30-44	45-59	60-69	70-79	30-44	45-59	60-69	70-79
Education	Smoking	AUSTRIA							
Low	Current	0.591	0.354	0.182	0.096	0.338	0.198	0.065	0.017
	Former	0.148	0.297	0.402	0.443	0.130	0.186	0.124	0.054
	Never	0.261	0.349	0.416	0.460	0.532	0.616	0.811	0.928
Middle	Current	0.497	0.373	0.251	0.165	0.349	0.259	0.136	0.061
	Former	0.179	0.281	0.369	0.429	0.183	0.156	0.164	0.193
	Never	0.325	0.347	0.380	0.406	0.469	0.586	0.700	0.746
High	Current	0.198	0.331	0.189	0.053	0.164	0.267	0.063	0.005
	Former	0.176	0.339	0.379	0.326	0.207	0.216	0.195	0.164
	Never	0.626	0.330	0.432	0.621	0.629	0.517	0.742	0.832
		BARCELONA							
Low	Current	0.592	0.470	0.295	0.161	0.453	0.173	0.040	0.009
	Former	0.172	0.278	0.409	0.530	0.141	0.074	0.034	0.016
	Never	0.236	0.252	0.295	0.309	0.406	0.753	0.926	0.975
Middle	Current	0.514	0.471	0.317	0.171	0.461	0.353	0.129	0.030
	Former	0.197	0.261	0.419	0.616	0.181	0.173	0.121	0.073
	Never	0.289	0.268	0.264	0.214	0.359	0.475	0.751	0.898
High	Current	0.398	0.359	0.274	0.192	0.349	0.395	0.167	0.033
	Former	0.192	0.351	0.476	0.545	0.209	0.233	0.175	0.107
	Never	0.410	0.289	0.249	0.263	0.443	0.372	0.657	0.860
		BASQUE COUNTRY							
Low	Current	0.533	0.420	0.288	0.188	0.460	0.182	0.064	0.027
	Former	0.159	0.243	0.317	0.370	0.131	0.093	0.051	0.025
	Never	0.309	0.338	0.394	0.443	0.410	0.725	0.885	0.948
Middle	Current	0.476	0.370	0.224	0.119	0.381	0.287	0.148	0.063
	Former	0.145	0.311	0.433	0.484	0.221	0.156	0.146	0.162
	Never	0.379	0.318	0.343	0.398	0.398	0.557	0.707	0.775
High	Current	0.347	0.316	0.249	0.184	0.318	0.272	0.138	0.052
	Former	0.176	0.325	0.403	0.410	0.193	0.210	0.139	0.071
	Never	0.476	0.359	0.348	0.406	0.490	0.518	0.722	0.877
		BELGIUM							
Low	Current	0.551	0.426	0.291	0.190	0.423	0.273	0.138	0.065
	Former	0.203	0.352	0.495	0.595	0.182	0.234	0.243	0.225
	Never	0.247	0.221	0.215	0.216	0.395	0.493	0.619	0.711

Table A2.1: (Continued)

		Men				Women			
	age	30-44	45-59	60-69	70-79	30-44	45-59	60-69	70-79
Education	**Smoking**	**BELGIUM**							
Middle	Current	0.417	0.382	0.278	0.177	0.338	0.271	0.163	0.086
	Former	0.245	0.391	0.516	0.599	0.249	0.304	0.319	0.308
	Never	0.338	0.227	0.206	0.224	0.413	0.426	0.518	0.606
High	Current	0.301	0.311	0.255	0.186	0.224	0.250	0.157	0.071
	Former	0.242	0.437	0.547	0.581	0.275	0.334	0.355	0.349
	Never	0.457	0.253	0.198	0.234	0.501	0.416	0.489	0.581
		CZECH REPUBLIC							
Low	Current	0.613	0.453	0.280	0.162	0.463	0.346	0.120	0.026
	Former	0.176	0.371	0.428	0.374	0.147	0.223	0.171	0.089
	Never	0.211	0.177	0.292	0.463	0.391	0.431	0.709	0.885
Middle	Current	0.392	0.288	0.193	0.129	0.254	0.302	0.199	0.091
	Former	0.187	0.356	0.384	0.313	0.124	0.187	0.219	0.221
	Never	0.421	0.356	0.423	0.559	0.622	0.511	0.582	0.688
High	Current	0.239	0.256	0.164	0.078	0.216	0.161	0.088	0.043
	Former	0.182	0.354	0.342	0.229	0.225	0.287	0.345	0.391
	Never	0.579	0.390	0.494	0.693	0.559	0.552	0.566	0.565
		DENMARK							
Low	Current	0.570	0.548	0.479	0.395	0.560	0.498	0.386	0.276
	Former	0.160	0.260	0.361	0.439	0.149	0.209	0.246	0.259
	Never	0.270	0.192	0.160	0.166	0.291	0.293	0.368	0.465
Middle	Current	0.455	0.466	0.413	0.336	0.461	0.426	0.342	0.253
	Former	0.195	0.292	0.413	0.526	0.181	0.212	0.262	0.317
	Never	0.351	0.241	0.174	0.138	0.358	0.362	0.397	0.430
High	Current	0.327	0.367	0.346	0.295	0.326	0.325	0.295	0.256
	Former	0.191	0.308	0.407	0.472	0.218	0.288	0.333	0.353
	Never	0.483	0.325	0.248	0.233	0.456	0.387	0.373	0.391
		ENGLAND&WALES							
Low	Current	0.455	0.362	0.242	0.151	0.411	0.344	0.242	0.157
	Former	0.188	0.383	0.556	0.660	0.200	0.292	0.356	0.387
	Never	0.356	0.255	0.202	0.189	0.389	0.363	0.402	0.456
Middle	Current	0.356	0.263	0.187	0.136	0.314	0.226	0.148	0.098
	Former	0.238	0.386	0.508	0.586	0.252	0.297	0.351	0.401
	Never	0.405	0.351	0.305	0.278	0.434	0.477	0.501	0.501
High	Current	0.224	0.125	0.094	0.089	0.182	0.174	0.130	0.087
	Former	0.256	0.424	0.527	0.569	0.241	0.336	0.394	0.416
	Never	0.520	0.451	0.379	0.342	0.578	0.491	0.477	0.497
		ESTONIA							
Low	Current	0.659	0.580	0.456	0.335	0.405	0.274	0.126	0.049

Table A2.1: (Continued)

		Men				Women			
	age	30-44	45-59	60-69	70-79	30-44	45-59	60-69	70-79
Education	**Smoking**	**ESTONIA**							
	Former	0.156	0.235	0.301	0.344	0.171	0.155	0.063	0.017
	Never	0.185	0.186	0.243	0.321	0.424	0.571	0.811	0.933
Middle	Current	0.630	0.567	0.512	0.471	0.305	0.281	0.129	0.039
	Former	0.219	0.307	0.171	0.052	0.166	0.157	0.177	0.212
	Never	0.151	0.127	0.317	0.477	0.529	0.562	0.694	0.748
High	Current	0.337	0.375	0.333	0.261	0.159	0.234	0.102	0.021
	Former	0.253	0.250	0.407	0.656	0.181	0.201	0.122	0.054
	Never	0.411	0.375	0.259	0.082	0.659	0.565	0.776	0.925
		FINLAND							
Low	Current	0.491	0.365	0.273	0.215	0.436	0.261	0.119	0.052
	Former	0.209	0.341	0.384	0.357	0.152	0.172	0.103	0.044
	Never	0.300	0.294	0.344	0.428	0.412	0.567	0.778	0.905
Middle	Current	0.438	0.332	0.165	0.065	0.308	0.214	0.095	0.035
	Former	0.224	0.359	0.468	0.534	0.185	0.194	0.150	0.100
	Never	0.338	0.309	0.367	0.401	0.507	0.592	0.755	0.865
High	Current	0.258	0.244	0.155	0.080	0.187	0.152	0.101	0.063
	Former	0.166	0.252	0.429	0.635	0.141	0.181	0.116	0.051
	Never	0.576	0.505	0.417	0.286	0.673	0.667	0.783	0.886
		FRANCE							
Low	Current	0.536	0.341	0.208	0.137	0.399	0.209	0.082	0.031
	Former	0.172	0.258	0.312	0.332	0.121	0.093	0.068	0.050
	Never	0.292	0.402	0.480	0.531	0.480	0.698	0.850	0.919
Middle	Current	0.446	0.286	0.160	0.089	0.379	0.224	0.117	0.063
	Former	0.183	0.320	0.399	0.418	0.151	0.112	0.092	0.081
	Never	0.371	0.394	0.441	0.493	0.470	0.664	0.791	0.856
High	Current	0.278	0.262	0.193	0.125	0.245	0.212	0.137	0.077
	Former	0.143	0.310	0.384	0.363	0.171	0.171	0.136	0.098
	Never	0.579	0.428	0.424	0.512	0.584	0.617	0.727	0.825
		LITHUANIA							
Low	Current	0.708	0.543	0.393	0.290	0.322	0.074	0.033	0.026
	Former	0.088	0.163	0.218	0.239	0.051	0.018	0.020	0.041
	Never	0.204	0.294	0.390	0.471	0.627	0.908	0.947	0.932
Middle	Current	0.597	0.505	0.294	0.127	0.221	0.119	0.023	0.003
	Former	0.153	0.215	0.279	0.335	0.058	0.038	0.023	0.015
	Never	0.250	0.280	0.427	0.538	0.721	0.843	0.953	0.982
High	Current	0.467	0.376	0.267	0.181	0.208	0.141	0.043	0.009
	Former	0.115	0.218	0.317	0.383	0.045	0.058	0.029	0.009

Table A2.1: (Continued)

		Men				Women			
	age	30-44	45-59	60-69	70-79	30-44	45-59	60-69	70-79
Education	Smoking	LITHUANIA							
	Never	0.418	0.406	0.417	0.436	0.747	0.802	0.929	0.982
		MADRID							
Low	Current	0.592	0.470	0.295	0.161	0.453	0.173	0.040	0.009
	Former	0.172	0.278	0.409	0.530	0.141	0.074	0.034	0.016
	Never	0.236	0.252	0.295	0.309	0.406	0.753	0.926	0.975
Middle	Current	0.514	0.471	0.317	0.171	0.461	0.353	0.129	0.030
	Former	0.197	0.261	0.419	0.616	0.181	0.173	0.121	0.073
	Never	0.289	0.268	0.264	0.214	0.359	0.475	0.751	0.898
High	Current	0.398	0.359	0.274	0.192	0.349	0.395	0.167	0.033
	Former	0.192	0.351	0.476	0.545	0.209	0.233	0.175	0.107
	Never	0.410	0.289	0.249	0.263	0.443	0.372	0.657	0.860
		NETHERLANDS							
Low	Current	0.536	0.448	0.347	0.263	0.434	0.339	0.231	0.150
	Former	0.226	0.359	0.506	0.625	0.246	0.361	0.374	0.324
	Never	0.238	0.194	0.148	0.112	0.320	0.300	0.395	0.526
Middle	Current	0.408	0.359	0.282	0.212	0.286	0.286	0.222	0.151
	Former	0.234	0.434	0.588	0.674	0.295	0.408	0.442	0.424
	Never	0.358	0.207	0.129	0.115	0.419	0.306	0.335	0.425
High	Current	0.300	0.287	0.253	0.215	0.234	0.216	0.190	0.165
	Former	0.216	0.400	0.560	0.661	0.270	0.442	0.458	0.377
	Never	0.485	0.313	0.187	0.124	0.496	0.342	0.353	0.458
		POLAND							
Low	Current	0.612	0.574	0.387	0.193	0.490	0.354	0.144	0.042
	Former	0.131	0.234	0.373	0.508	0.107	0.170	0.132	0.069
	Never	0.257	0.192	0.240	0.300	0.403	0.476	0.724	0.889
Middle	Current	0.457	0.455	0.320	0.174	0.322	0.342	0.201	0.080
	Former	0.173	0.288	0.409	0.506	0.131	0.186	0.210	0.207
	Never	0.370	0.256	0.271	0.320	0.548	0.472	0.589	0.713
High	Current	0.250	0.303	0.175	0.063	0.196	0.264	0.210	0.123
	Former	0.177	0.331	0.470	0.561	0.119	0.221	0.251	0.219
	Never	0.573	0.366	0.355	0.376	0.686	0.515	0.539	0.658
		SCOTLAND							
Low	Current	0.604	0.406	0.275	0.204	0.560	0.462	0.317	0.196
	Former	0.164	0.353	0.508	0.590	0.168	0.292	0.369	0.391
	Never	0.232	0.241	0.217	0.206	0.271	0.246	0.314	0.413
Middle	Current	0.378	0.318	0.217	0.135	0.367	0.265	0.190	0.144
	Former	0.267	0.418	0.545	0.630	0.226	0.323	0.361	0.353
	Never	0.355	0.265	0.237	0.236	0.407	0.412	0.449	0.503

Table A2.1: (Continued)

		Men				Women			
	age	30-44	45-59	60-69	70-79	30-44	45-59	60-69	70-79
Education	**Smoking**	**SCOTLAND**							
High	Current	0.195	0.153	0.109	0.076	0.199	0.179	0.121	0.071
	Former	0.307	0.483	0.603	0.666	0.274	0.370	0.433	0.464
	Never	0.498	0.365	0.289	0.258	0.527	0.451	0.447	0.465
		SWEDEN							
Low	Current	0.345	0.279	0.195	0.130	0.472	0.348	0.217	0.129
	Former	0.285	0.437	0.527	0.562	0.198	0.269	0.260	0.209
	Never	0.370	0.284	0.278	0.308	0.330	0.383	0.523	0.662
Middle	Current	0.179	0.266	0.199	0.099	0.260	0.307	0.192	0.081
	Former	0.269	0.444	0.521	0.522	0.305	0.324	0.315	0.292
	Never	0.553	0.290	0.280	0.379	0.435	0.369	0.493	0.627
High	Current	0.090	0.131	0.113	0.074	0.116	0.181	0.139	0.073
	Former	0.245	0.419	0.511	0.532	0.234	0.333	0.356	0.327
	Never	0.664	0.450	0.376	0.394	0.650	0.485	0.504	0.600
		SWITZERLAND							
Low	Current	0.466	0.438	0.341	0.237	0.409	0.269	0.159	0.095
	Former	0.195	0.307	0.380	0.410	0.138	0.175	0.162	0.126
	Never	0.340	0.255	0.279	0.354	0.453	0.555	0.679	0.779
Middle	Current	0.424	0.367	0.272	0.188	0.317	0.269	0.162	0.082
	Former	0.165	0.316	0.417	0.454	0.167	0.223	0.220	0.184
	Never	0.411	0.317	0.311	0.358	0.516	0.508	0.619	0.734
High	Current	0.336	0.325	0.265	0.199	0.242	0.243	0.217	0.183
	Former	0.182	0.329	0.410	0.423	0.204	0.250	0.221	0.164
	Never	0.483	0.347	0.325	0.377	0.554	0.506	0.561	0.652
		TURIN							
Low	Current	0.462	0.353	0.241	0.161	0.281	0.180	0.090	0.042
	Former	0.199	0.338	0.445	0.504	0.138	0.120	0.102	0.089
	Never	0.339	0.309	0.314	0.335	0.581	0.701	0.808	0.869
Middle	Current	0.342	0.330	0.248	0.163	0.249	0.255	0.197	0.131
	Former	0.192	0.358	0.486	0.553	0.184	0.199	0.196	0.184
	Never	0.466	0.312	0.266	0.284	0.567	0.545	0.607	0.686
High	Current	0.267	0.318	0.248	0.150	0.212	0.271	0.212	0.125
	Former	0.168	0.319	0.453	0.536	0.180	0.215	0.233	0.237
	Never	0.565	0.363	0.299	0.314	0.608	0.514	0.556	0.638
		TUSCANY							
Low	Current	0.462	0.353	0.241	0.161	0.281	0.180	0.090	0.042
	Former	0.199	0.338	0.445	0.504	0.138	0.120	0.102	0.089
	Never	0.339	0.309	0.314	0.335	0.581	0.701	0.808	0.869
Middle	Current	0.342	0.330	0.248	0.163	0.249	0.255	0.197	0.131

Table A2.1: (Continued)

		Men				Women			
	age	30-44	45-59	60-69	70-79	30-44	45-59	60-69	70-79
Education	Smoking	TUSCANY							
	Former	0.192	0.358	0.486	0.553	0.184	0.199	0.196	0.184
	Never	0.466	0.312	0.266	0.284	0.567	0.545	0.607	0.686
High	Current	0.267	0.318	0.248	0.150	0.212	0.271	0.212	0.125
	Former	0.168	0.319	0.453	0.536	0.180	0.215	0.233	0.237
	Never	0.565	0.363	0.299	0.314	0.608	0.514	0.556	0.638

Source: National Health Interview Surveys (NHIS) collected as part of the EUROTHINE project. Austrian data comes from the European Community Household Panel (ECHP, wave 7). See Table A2.2 below

Table A2.2: Sources of smoking prevalence data

Country	Name of survey[a]	Years	N	Survey non-response
Austria	European Community Household Survey, wave 7	2000	5801	30 (22)[c]
Basque Country	Health Survey of the Basque Country	2002	13244	NA
Belgium	Health Interview Survey 1997 + 2001	97/01	18481	41.5/38.6
Czech Republic	Sample Survey of the Health Status of the Czech Population	2002	2476	29.3
Denmark	Danish Health and Morbidity Survey 2000	2000	16690	25.8
England & Wales	English Health Survey 2001	2001	15767	33.0
Estonia	Finbalt Health Monitor	02/04	4376	33.0/33.8
Finland	Finbalt Health Monitor	94/98/00/02/04	20371	28.0-35.0
France	National Health Survey (Enquête Décennale Santé) (Insee)[b]	2002	13603	NA
Italy	Health and health care utilization 1999-2000	99-00	118245	13.4/18.3
Lithuania	Finbalt Health Monitor	94/98/00/02/04	11647	28.0-39.0
Netherlands	Permanent Onderzoek Leefsituatie (POLS)	04/04	15803	41.7/38.7
Poland	Second nationwide sample survey of the health status of the Polish population	2004	35248	NA
Scotland	Scottish Health Survey	2003	6912	NA
Spain	National Health Survey 2001	2001	20748	15.0
Sweden	Swedish Survey of Living Conditions	00-01	11484	23.9/22.2
Switzerland	Swiss Health Survey	2002	19511	NA

[a] we only used surveys in which the percentage of missing smoking information was lower than 20%
[b] Santé - 2003 (standard version) - (2003) [electronic file], INSEE [data producer], Centre Maurice Halbwachs (CMH) [data distributer]
[c] attrition rate sine first wave

Table A2.3: Summary of mortality data used: Age-standardized mortality rates per 100,000 person-years, by sex and level of education; ages 30-74; Lung Cancer, Aero-digestive Cancer, COPD/asthma

		Cause of Death	Lung Cancer		Aero-digestive Cancer		COPD/asthma	
European Region	Population	Level of Education	Men	Women	Men	Women	Men	Women
Nordic	Finland	low	76.1	23.4	15.8	4.1	29	9.6
		middle	53.3	14.6	11.2	3	17.9	5.6
		high	26.3	11.2	7.4	2.8	7.6	2.3
	Sweden	low	50	43.6	14.7	4.6	18.7	20.1
		middle	37.6	32.6	12	3.6	12.4	12.5
		high	24.1	18.5	7.3	2.7	5.7	5.5
	Norway	low	88.4	57.9	20.4	4.7	36	32.2
		middle	54.1	32	13	3.5	20.7	13.8
		high	27.7	16	6.6	1.9	6.9	4.9
	Denmark	low	94.8	80.6	34.8	8.9	52.9	54.3
		middle	78.4	54.7	27.8	7.6	33.2	29.6
		high	48.9	32.1	15.2	5.6	12.8	16.7
West	England & Wales	low	88.3	42.1	30.4	11.3	41.1	29.5
		middle	50.8	24.9	24	3.6	21.7	16
		high	28.9	22.4	12.7	4	20.9	9.9
	Scotland	low	103.1	75	39.5	12.6	42.8	47
		middle	62	39.6	23.8	7.9	15.3	22.9
		high	28	21.6	12.1	10	14	7.4
	Netherlands	low	117.2	44	21.8	7.4	32.4	16.8
		middle	76.5	34.2	26.9	7.1	15.2	3.9
		high	45.9	17.2	11.6	4.4	7.2	2.7
	Belgium	low	117.3	29.8	31.6	6.5	40.6	15.1
		middle	76.6	23.9	24.3	5.1	21.3	8.8
		high	50.6	19.2	17.8	3.4	11.9	7.2
	France	low	109.5	16.9	59	6.8	13.3	5.8
		middle	78.7	19.9	42	6.8	11.4	3.3
		high	51	15.5	10.5	5.7	2.5	0
	Switzerland	low	88.1	29.9	34.1	5.6	29.3	9.7
		middle	57.1	21.3	22.1	4.4	13.9	5.2
		high	30.9	16.5	11.3	2.9	5.4	2.6
	Austria	low	98.6	26.9	37.6	5	38.3	10.4
		middle	74.6	26.4	29.9	4.9	21.7	7.4
		high	42	15.2	12.7	2.5	9.5	4.2
South	Spain	low	105.9	13.8	44.4	3.6	26.7	4.5
		middle	86.5	23.4	29.9	4.1	16.1	5.2
		high	72.6	17.7	18.5	3.1	12.5	2.4

Table A2.3: (Continued)

		Cause of Death	Lung Cancer		Aero-digestive Cancer		COPD/asthma	
European Region	**Population**	**Level of Education**	**Men**	**Women**	**Men**	**Women**	**Men**	**Women**
	Italy	low	106.8	24.5	20.6	4.3	15.1	4.4
		middle	66.2	27.8	13	4.1	5.9	3.9
		high	41	23.5	7.2	3.1	4.7	4.4
Central/ East	Hungary	low	251.1	54.6	141.7	14	73.2	22.7
		middle	111.9	44.7	57.3	10.7	20.1	9.9
		high	74.8	42.8	22.9	5.1	11.9	9.8
	Czech Republic	low	168.9	30.1	47.9	4.7	31.5	9.2
		middle	73.4	26.8	19.5	3.4	12.6	5.1
		high	37.5	16	7.6	2	6.6	4
	Poland	low	192.5	31.4	53.8	6.5	46.5	9.9
		middle	144.3	34.3	39.6	5.1	21.3	6.6
		high	52.5	21.5	10.4	1.8	4.8	3.3
	Lithuania	low	151.6	14.7	76.6	4.9	65.4	13.6
		middle	91.8	9.7	44.8	2.3	27.6	5.4
		high	46.8	8.3	12.8	2.4	9.5	2.4
	Estonia	low	178.4	19.6	64.6	3.3	38.5	9.6
		middle	132.5	17.9	35.5	4.2	23.5	6
		high	58	8.9	11.9	0.5	7.6	3

Source: See Table A2.4 below

Table A2.4: Sources of mortality data

European Region	Population	Type of dataset	Period	Geographic coverage	Demographic coverage
Nordic	Finland	longitudinal	2001-2007	National	20% of Finns are excluded (at random)
	Sweden	longitudinal	2001-2006	National	whole population
	Norway	longitudinal	2001-2006	National	whole population
	Denmark	longitudinal	2001-2005	National	whole population
West	England & Wales	longitudinal	2001-2006	National	1% of the population
	Scotland	longitudinal	2001-2006	National	whole population
	Netherlands	longitudinal	1998-2003-> 2003-2007	National	from labor force survey
	Belgium	longitudinal	2004-2005	National	whole population
	France	longitudinal	1999-2005	National	1% of the population (born outside France mainland excluded)
	Switzerland	longitudinal	2001-2005	National	Non-Swiss nationals excluded
	Austria	longitudinal	2001-2002	National	whole population
South	Spain (Barcelona)	cross-sectional, linked	2000-2006	Urban	whole population
	Spain (Basque Region)	longitudinal	2001-2006	Regional	whole population
	Spain (Madrid)	cross-sectional, linked	2001-2003	Regional	whole population
	Italy (Turin)	longitudinal	2001-2006	Urban	whole population
	Italy (Tuscany)	longitudinal	2001-2005	Florence, Leghorn, Prato	whole population
Central/East	Hungary	cross-sectional	1999-2002	National	whole population
	Czech Republic	cross-sectional	1999-2003	National	whole population
	Poland	cross-sectional	2001-2003	National	whole population
	Lithuania [a]	longitudinal	2001-2005	National	whole population
	Estonia	cross-sectional	1998-2002	National	whole population

[a] Calculations were performed based on an aggregated census-linked dataset of frequencies provided by Statistics Lithuania

Table A2.5: Relative risks for the impact of smoking on all-cause and cause-specific mortality

	MEN				WOMEN			
	age 30-44	age 45-59	age 60-69	age 70-79	age 30-44	age 45-59	age 60-69	age 70-79
All-cause mortality								
current	2.07	2.07	2.07	2.07	1.74	1.74	1.74	1.74
former	1.35	1.35	1.35	1.35	1.23	1.23	1.23	1.23
never	1	1	1	1	1	1	1	1
Cancer of lip, oral cavity, pharynx								
current	10.89	10.89	10.89	10.89	5.08	5.08	5.08	5.08
former	3.4	3.4	3.4	3.4	2.29	2.29	2.29	2.29
never	1	1	1	1	1	1	1	1
Esophageal cancer								
current	6.76	6.76	6.76	6.76	7.75	7.75	7.75	7.75
former	4.46	4.46	4.46	4.46	2.79	2.79	2.79	2.79
never	1	1	1	1	1	1	1	1
Cancer of larynx, trachea, bronchus, lung								
current	23.26	23.26	23.26	23.26	12.69	12.69	12.69	12.69
former	8.7	8.7	8.7	8.7	4.53	4.53	4.53	4.53
never	1	1	1	1	1	1	1	1
Chronic Airway Obstruction								
current	10.58	10.58	10.58	10.58	13.08	13.08	13.08	13.08
former	6.8	6.8	6.8	6.8	6.78	6.78	6.78	6.78
never	1	1	1	1	1	1	1	1

Source: Unpublished estimates provided by American Cancer Society (ACS). See Thun MJ, Day-Lally C, Myers DG, et al. Trends in tobacco smoking and mortality from cigarette use in Cancer Prevention Studies I (1959 through 1965) and II (1982 through 1988). In: Changes in cigarette-related disease risks and their implication for prevention and control. Smoking and Tobacco Control Monograph 8. Bethesda, MD: US Department of Health and Human Services, Public Health Service, National Institutes of Health, National Cancer Institute 1997;305–382. NIH Publication no. 97–1213. https://apps.nccd.cdc.gov/sammec/show_risk_data.asp

METHOD DEVELOPMENT

Development of methods to assess the potential for reduction of health inequalities

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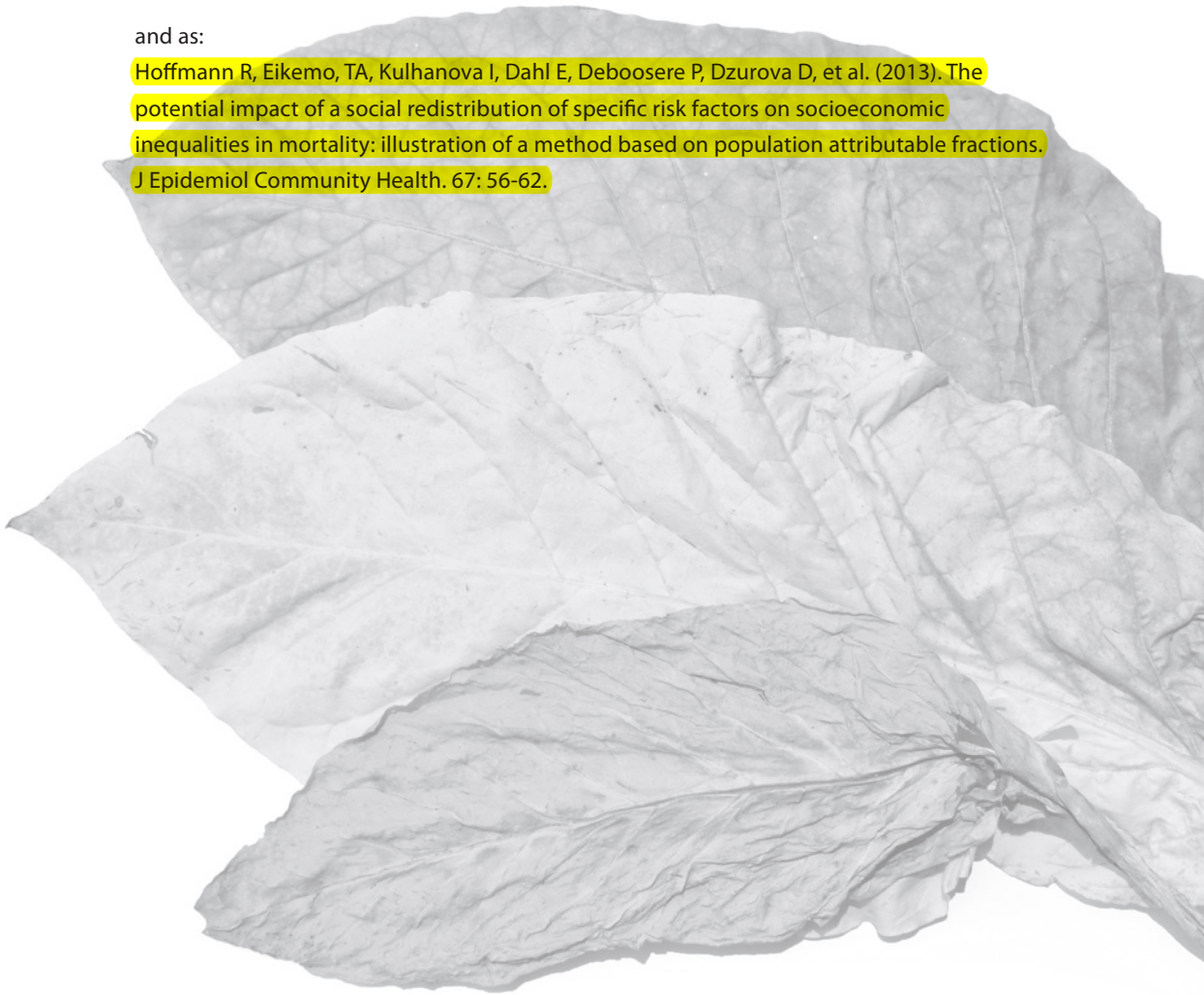

SUMMARY

Socioeconomic differences in health are a major challenge for public health. However, realistic estimates to what extent they are modifiable are scarce. This problem can be met through the systematic application of the Population Attributable Fraction (PAF) to socioeconomic health inequalities.

For developing the methods for the Euro-GBD-SE project we use preliminary data that was taken from the Eurothine project. This is cause-specific mortality data by educational level from Norway, Denmark, Belgium, France, Spain, Hungary, the Czech Republic, Lithuania and Estonia, and data on the prevalence of smoking, alcohol, lack of physical activity and high body mass index from national health surveys. Information on the impact of these risk factors on mortality comes from the epidemiological literature.

In this document we describe the development of the methods to assess the potential for reduction of health inequalities. We develop an Excel tool covering a wide range of possible scenarios and calculate PAFs to quantify the impact of a social redistribution of risk factors on socioeconomic health inequalities. To illustrate further methodological issues we show how confidence intervals for PAFs can be calculated.

In a scenario where the whole population is assumed to have the risk factor prevalence currently seen among the highly educated, inequalities in mortality can be reduced substantially. According to our illustrative results the reduction of inequality for all risk factors combined varies between 7% among Lithuanian women and 76% among Spanish men.

After discussing the underlying assumptions of the PAF, we conclude that our approach is promising for estimating the extent to which health inequalities can be potentially reduced by interventions on specific risk factors. This reduction is likely to differ substantially between countries, risk factors and between men and women.

The results in this document are purely illustrative and are aimed at demonstrating the basic tool methodology. A more elaborate version of the tool and more complete and up-to-date input data were used for the calculations in chapter 5 of this thesis and in other publications based on the tool.

INTRODUCTION

Inequalities in health between socioeconomic groups are increasingly recognized as one of the main challenges for health policy. Studies from Europe have shown that health inequalities are substantial, but that there are important variations between countries in the magnitude of health inequalities [1], suggesting great scope for reducing health inequalities. Yet, socioeconomic inequalities in health are persisting and widening in countries throughout the world. In 2005, the WHO established the Commission on Social Determinants of Health (CSDH) to provide advice on how to reduce socioeconomic inequalities in health. However, it is currently unknown to what extent these inequalities are actually modifiable, which is a serious barrier for effective policy-making, because it hinders both priority setting and the formulation of realistic quantitative targets for reducing health inequalities.

We know that inequalities in risk factors between socioeconomic groups are larger in some countries than in others, and that countries with smaller inequalities in risk factors have smaller inequalities in mortality. Also, some countries have a more skewed distribution of socioeconomic determinants in their populations than others, which may also translate into larger inequalities in health.

Until recently, however, no methods were available to quantify the impact on health inequalities of modifying the distribution of underlying socioeconomic determinants or specific risk factors. Previous research has merely examined socioeconomic and healthcare determinants of health disparities or (to a lesser extent) the impact of major modifiable risk factors on life expectancy. Using mortality as the health outcome, this working document intends to do both by applying a methodology recently developed within the Global Burden of Disease (GBD) study. More specifically, the tool introduced here estimates the contribution of risk factors to educational health inequalities, as well as the reduction in educational health inequalities that would be obtained, if the distribution of determinants of health inequalities were more equal than is currently the case.

The GBD study links risk factors to health outcomes through the Population Attributable Fraction (PAF), which estimates the proportion of a population health outcome that is attributable to a particular exposure, or in other words, the proportion by which a population health outcome would be reduced if exposure to a particular risk factor were completely eliminated. As yet, the GBD project methodology has never been systematically applied to the problem of socioeconomic inequalities in health in Europe. The present project is thus one of the first efforts to use this methodology in the context of socioeconomic inequalities in health [2,3].

Specification of scenarios

We apply different types of scenarios which help to assess the contribution of specific determinants and risk factors to health inequalities, and to assess the potential for reduction of health inequalities (Box 1).

Box 1: Scenario rules

Scenario rules

A) Changes in the educational distribution

1. Take educational distribution from another country, e.g. best practice.
2. Evidence-based educational distribution, e.g. based on projected cohort trends in education.
3. Arbitrary educational distribution: e.g. everybody has high education (theoretical maximum) or everybody moves up one level of education.

B) Changes in direct risk factors (RF)

1. RF distribution from another country, e.g. best practice.
2. Evidence based RF distribution, e.g. from studies on smoking intervention, or derived from health equity targets.
3. Arbitrary RF distribution, e.g. as in the highest educational group.

In the "Illustrative Results" section of this working document, we show examples of the two main types of scenarios presented above (A and B). The first type (A) implies that the distribution of the socioeconomic indicator itself would change, which would mean that those lower educated would have the same education, and thereby the same mortality, as the higher educated. We refer to this as the educational redistribution scenario, or just as scenario type A. We present three further sub-scenarios. Firstly, we present estimates of the PAF given that the educational distribution would change to the distribution observed in an example country (see A1 above). We chose Norway as the example country on the basis of the educational distribution among men. Norway has the largest share of high educated and the lowest share of low educated (after Lithuania) for men. We also chose Norway as the example country in the analyses for women, even though Table 1 demonstrates that Denmark and Estonia have slightly larger shares of high educated people and the lowest share of low educated people for women. Secondly, we estimate the fraction by which mortality could be reduced if the whole population had an educational level that was higher by one level (i.e. the lower educated would have the education of the mid educated, and the mid educated the education of the high educated). Finally, we estimate the fraction by which mortality could be reduced if the whole population climbed another step on the educational ladder, meaning that the whole population would have the education of the highest educational group. The two latter sub-scenarios of the educational redistribution scenario both correspond to scenario A3 above.

The second main type of scenario assumes that the level of a risk factor (or several risk factors combined) would be reduced to the level currently seen among the highest educated within each country (corresponds to scenario B3), thereby identifying one possible upper limit to what can be achieved. We refer to this as the risk factor redistribution scenario or just scenario type B. Together, the risk factor scenario and the more radical educational redistribution scenarios provide a good first picture of the theoretical potential for reduction of educational health inequalities within countries. The overall aim of the current working document is to illustrate the approach taken as to how these scenarios may be calculated and interpreted. In this working document, we present exercises based on available sources of data which have been used for other analyses of health inequalities, stemming mainly from the Eurothine project [4].

DATA

The data needed for calculating a PAF are twofold: risk factor prevalence data and mortality rate ratios (RR), both for all categories of the risk factors. The RRs that we apply are sex-specific as shown in Tables 2a and 2b, and they are also age-specific. We do this because the impact of risk factors differs by sex and age [5]. It needs to be pointed out that the risk factor data used in this example is from 2000 and the mortality data from the 1990s. While this reversed time-lag would limit the substantial interpretation of the results, we would like to stress again that the following presentation is driven by illustrative purposes.

The European data on risk factors (physical activity, alcohol consumption, smoking and BMI), cause-specific mortality (ischemic heart disease, cerebrovascular disease, and lung cancer) and all-cause mortality stratified by country, sex, age and socioeconomic status were taken from the Eurothine study, which comprises data for 22 countries. This exercise includes data for men and women in five age groups in nine European countries: Norway, Denmark, Belgium, France, Spain, Hungary, the Czech Republic, Lithuania and Estonia.

Information on the excess mortality of groups under risk (rate ratios) comes from four different sources. While rate ratios for education were calculated for each country using the Eurothine data, rate ratios for specific risk factors were found in the literature. For this first exercise we used the results of a literature study on physical activity and smoking as performed in the GIDS-project in Rotterdam ("Gezond in de stad"), and of a literature study on alcohol as performed in the DYNAMO-HIA project at Erasmus MC (www.dynamo-hia.eu). The majority of rate ratios come from a major study on risk factor assessment [5].

For this document we chose the following categories for the exposure variables. These are not necessarily identical to the categories chosen in the final version of the PAF tool. Education is measured on three levels: (1) primary and lower secondary education, (2) higher secondary education, and (3) post-secondary and tertiary education. Smoking is measured as smokers (current, regular and occasional) versus non-smokers (ex-smokers and never smokers). Alcohol is measured on four levels: no alcohol (reference group: no drinks containing alcohol within the last year), DI (0-19.99 g of pure alcohol daily (females) and 0-39.99 g (males)), DII (20-39.99 g (females) and 40-59.99 g (males), DIII (>40 g (females) and > 60 g (males)). This scale is based on gram alcohol per day, where the exact amount is different for men and women. Physical activity is measured on three levels: sedentary or almost sedentary, middle, and high level of physical activity. BMI is measured in three categories (-25, 25-30, and 30+).

It should be noted that prevalence data for physical activity for France was unavailable and was imputed by the average of all nine countries. Also, for Estonia, Lithuania, the Czech Republic and Spain we did not have prevalence data for very old ages because the health surveys only include persons up to age 69, respectively 79. Further, for France we did not have cause-specific mortality rate ratios. In Denmark at ages 80+, the middle category for education is empty because education was not reported on a detailed level for the oldest cohorts during the census in 1970. Finally, the all-cause mortality rate ratios for physical activity are very crude estimates based on cause-specific mortality rate ratios found in the literature. We have accepted these limitations for the present methodological illustration and applied stricter quality criteria for the final Euro-GBD-SE data.

The input data used in our calculations, in terms of prevalence rates of educational attainment and risk factor groups for men and women, are presented in Table 1. The rate ratios of cause-specific and all-cause mortality according to education are reported in Table 2a, and according to four risk factor categories in Table 2b. It should be noted that the rate ratios of education vary by country, while rate ratios according to the risk factors are the same for all countries.

METHODS

The PAF approach

To address the two scenarios presented above, we used the Population Attributable Fraction (PAF) and assessed the expected changes in population health that would result from modifying the population distribution of exposure to a risk factor. These Comparative Risk Assessment methods were derived from the epidemiological measure of the PAF, and were adapted to estimate the impact of "counterfactual" distributions of socioeconomic determinants and specific risk factors on the magnitude of health inequalities (Box 2).

Table 1: Prevalence of education and of the exposure to four risk factors, by country, sex and educational group

Country		Norway		Denmark		Belgium		France		Spain		Hungary		Czech R		Lithuania		Estonia	
Sex		M	W	M	W	M	W	M	W	M	W	M	W	M	W	M	W	M	W
Education	low	30.5	38.7	43.5	55.2	61.4	68.5	50.8	64.9	64.5	93.6	65.2	63.5	61.9	63.5	29.5	31.6	30.6	29.8
	middle	48.2	45.6	37.6	26.9	21.8	18.1	36.3	25.6	18.6	2.6	20.7	25.5	24.7	28.6	54.9	51.7	52.6	53
	high	21.3	15.8	18.9	17.9	16.8	13.4	12.8	9.5	16.9	3.8	14.1	11	13.4	7.9	15.6	16.7	16.7	17.3
Physical activity	**categories**																		
Low education	no	34.5	57.3	23.2	24.2	39.3	50.7	46.2*	53.4*	51.5	54.6	38.7	45.9	65.7	78.7	49.1	54.1	70.9	64
	little	31.9	29.2	74.6	75.5	43.5	43.3	34.8*	33.4*	45.7	43.3	18.6	20.7	18.2	9.7	24.6	21.9	18.6	22.1
	much	33.6	13.4	2.2	0.3	17.1	6	19.0*	13.2*	2.7	2.2	42.6	33.4	16.2	11.6	26.2	24.2	10.4	13.9
Middle education	no	29.6	43.1	15.3	17.1	29.6	35.8	36.7*	42.7*	34.7	40.5	29.2	38.1	51.3	69	40.3	39.2	66.3	60.7
	little	38.6	36.5	81.6	81.7	49.1	55.9	43.3*	42.4*	60.3	53.8	28.2	29.2	32.2	22.8	32.7	30.1	21.7	26.8
	much	31.7	20.4	3.2	1.2	21.3	8.3	20.0*	14.9*	4.9	5.9	42.6	32.6	16.5	8.2	27	30.9	11.8	12.5
High education	no	18.6	28.8	10.6	12.5	24.1	31.7	32.4*	38.3*	28.6	37	30.5	33.8	50.7	67.9	38.6	44.8	58.3	50.8
	little	44.1	47.6	85.5	86.5	53.9	57.7	48.6*	47.0*	63.1	59.3	35.3	31.4	37.3	20.7	32.3	32.1	36.3	38.2
	much	37.2	23.6	4.1	1	21.9	10.6	19.1*	14.7*	8.3	3.8	34.1	34.7	12	11.4	29.1	23.2	5.4	10.9
Alcohol	**categories**																		
Low education	DIII	0.7	0	3.3	0.9	7.6	2.5	0.8	0.3	22.8	2.9	10	2	10.5	2.5	0.9	0.1	1.7	0.4
	DII	1	0.8	5.7	6.6	6.4	10.6	2.5	0.8	11.2	6.4	9.4	7.9	13.3	7.8	1.6	0.4	2.4	0.6
	DI	36.1	18.2	67.4	52.6	48.2	24	67.6	37	40.3	23.7	77	67.9	76.2	89.7	67.7	36.4	71.1	44.5
	no	62.2	81	23.8	41.5	37.8	62.9	29.2	61.9	25.8	67.1	3.6	22			29.8	63.2	24.7	54.3
Middle education	DIII	0.8	0.4	2.5	1.2	6.5	2.5	0.6	0.4	18.3	5.8	6	1.4	6.3	1.8	1.4	0.1	1.1	1.2
	DII	0.2	0.7	6.3	10.2	7.2	16.3	2.5	1.2	10.1	9	7.6	5.5	6.9	7.5	2.2	0.2	3.5	0.5
	DI	40.1	24.6	78.7	63.7	58	34.9	74.7	53	48.1	35	80.4	80.7	86.9	90.7	71.1	51.3	70	49.6
	no	58.9	74.3	12.5	24.9	28.4	46.2	22.2	45.4	23.4	50.2	6	12.4			25.2	48.4	25.2	48.6
High education	DIII	0.5	0	2.5	1.6	5	3.2	0.5	0.2	14.6	3.2	1.7	0	7.8	3.4	0.7	0.1	1.2	0.2

APPENDIX II

Table 1: (Continued)

Country		Norway		Denmark		Belgium		France		Spain		Hungary		Czech R		Lithuania		Estonia	
Sex		M	W	M	W	M	W	M	W	M	W	M	W	M	W	M	W	M	W
Alcohol	**categories**																		
	DII	0.2	0.2	5.9	14.2	7.4	18.1	1.5	3.1	10.2	11.7	7.4	5.7	5.4	5.8	1.2	0.2	1.2	0.3
	DI	47.5	49.5	82.8	68.1	64	39.5	77.5	58.6	53.2	33.2	86.5	81.3	86.8	90.7	80.8	57.8	80.4	64.6
	no	51.7	50.3	9	16.1	23.6	39.2	20.5	38.2	21.9	51.9	4.4	11.9			17.3	42	17	34.8
Smoking	**categories**																		
Low education	smoker	46	36.3	49	37.7	37.6	21.2	27	15.8	40.3	18.1	49.1	46.8	42.7	23.8	58.6	14.6	58.7	29.1
	non-smoker	54	63.7	51	62.3	62.4	78.8	73	84.2	59.7	81.9	50.9	53.2	57.3	76.2	41.4	85.4	41.3	70.9
Middle education	smoker	40.9	40.3	40.6	36.8	35.9	26.4	25.2	22.4	47.2	39.9	52.4	48.9	29.9	25.2	54.7	16.7	59.7	27.4
	non-smoker	59.1	59.7	59.4	63.2	64.1	73.6	74.8	77.6	52.8	60.1	47.6	51.1	70.1	74.8	45.3	83.3	40.3	72.6
High education	smoker	29.1	25.1	29.1	26.5	28.6	21.2	23	18.6	36.2	33.4	48.3	51.9	21.7	16.8	40.8	17	35.1	18.2
	non-smoker	70.9	74.9	70.9	73.5	71.4	78.8	77	81.4	63.8	66.6	51.7	48.1	78.3	83.2	59.2	83	64.9	81.8
BMI	**categories**																		
Low education	30+	12.4	10.5	16.9	15	16.2	18.2	15	15.5	16	19.8	23	25.4	19.6	25.6	14.6	27.4	20.5	27.9
	25-30	42.7	33.9	46.6	31.8	43.1	31.2	42.6	27.9	52.3	37.1	40.2	33.9	46.8	36.3	40.7	36.3	35.7	32.8
	-25	45	55.7	36.7	53.2	40.7	50.6	42.4	56.5	31.8	43.2	36.8	40.6	33.5	38	44.7	36.4	43.7	39.2
Middle education	30+	11	8.8	10.8	9.5	14	10.9	9.3	9.2	11	7.9	21.6	19.8	12.2	11.9	15.5	23.5	15.1	20.6
	25-30	48.6	32	45.8	27.2	42.8	28.4	42.2	22.2	51.7	27.9	43.9	34.6	56.2	38.4	41.6	37.4	41.5	34.3
	-25	40.4	59.1	43.5	63.3	43.3	60.8	48.6	68.6	37.3	64.3	34.4	45.6	31.6	49.7	42.9	39.2	43.3	45
High education	30+	5.4	6.5	7.2	6.8	9.4	7.1	7	7.2	9.8	7.4	18.7	13.6	13.4	9.8	15.1	22.2	18.1	15.7
	25-30	43.8	23.2	39.4	24.1	40.2	21.8	38.6	16.4	48.2	27	45.9	32.5	53.7	32.9	48.7	30.4	42.4	32.5
	-25	50.8	70.3	53.6	69.1	50.4	71.1	54.4	76.4	42	65.7	35.4	53.8	32.9	57.2	36.2	47.4	39.4	51.7

M = men, W = women

* No data on physical activity is available. We took the average of all other countries in order to complete the data for this illustration.

Source: Data from the Eurothine project

Table 2a: Rate ratios of cause-specific and all-cause mortality according to education for men and women in nine countries

	RR		RR Lung cancer		RR Ischemic		RR Cerebrovascular	
Educational level	**Low**	**Middle**	**Low**	**Middle**	**Low**	**Middle**	**Low**	**Middle**
MEN								
Norway	1.59	1.3	2.08	1.52	1.79	1.42	1.46	1.26
Denmark	1.85	1.43	1.89	1.73	2.07	1.53	1.8	1.36
Belgium	1.58	1.23	2.26	1.46	1.48	1.24	1.46	1.22
France	1.84	1.35	NA	NA	NA	NA	NA	NA
Spain	1.17	0.9	1.25	0.94	0.97	0.86	1	0.79
Hungary	2.36	1.32	2.51	1.36	2.04	1.21	2.64	1.29
Czech Republic	2.64	1.43	4.12	1.88	2.63	1.46	2.71	1.37
Lithuania	2.58	1.68	3.27	1.89	2.12	1.45	2	1.45
Estonia	2.3	1.81	3.03	2.26	2.14	1.74	1.97	1.64
WOMEN								
Norway	1.43	1.19	2.3	1.58	1.78	1.33	1.39	1.17
Denmark	1.74	1.23	2.09	1.56	2.94	1.56	2.12	1.33
Belgium	1.39	1.07	1.45	1.22	1.68	1.04	1.4	1.07
France	1.48	1.07	NA	NA	NA	NA	NA	NA
Spain	1.12	0.89	0.65	0.9	1.18	0.86	1.16	0.88
Hungary	1.66	0.98	1.22	1.06	1.85	0.9	1.9	0.92
Czech Republic	2.1	1.38	1.77	1.57	2.67	1.46	2.28	1.28
Lithuania	2.77	1.32	1.67	1.33	3.52	1.26	2.65	1.19
Estonia	1.94	1.6	1.54	1.8	2.12	1.63	1.98	1.69

NA = not available
Source: Data from the Eurothine project

The PAF estimates the proportion of a population health outcome that is attributable to a particular exposure, i.e. the proportion with which a population health outcome would be reduced if exposure to a particular risk factor were completely eliminated [7-11]. The Population Attributable Fraction is closely related to another measure, the Potential Impact Fraction (PIF), which estimates the proportion by which a population health outcome would be reduced if exposure to a particular risk factor were partially eliminated. Because both measures are very similar, we will only use the term PAF in this exercise.

We calculated the PAF for the fundamental risk factor low education and for the proximate risk factors smoking, alcohol, lack of physical activity and high BMI. The impact of the proximate risk factors were analyzed separately for each educational group and then combined for the whole population. Equation 1 in Box 2 shows the basic calculation, while equation 2 shows the calculation for the combined effect of two or more risk factors. Both equations apply to categorical risk factors. For a detailed calculation example, see below.

Table 2b: Rate ratios of cause-specific and all-cause mortality according to four risk factors for men and women*

Sex	Physical act	AC	ID	CD	LC	Alcohol	AC	ID	CD	LC	Smoke	AC	ID	CD	LC	BMI	AC	ID	CD	LC
MEN	No	1.50	1.83	1.62	1.00	DIII	1.22	1.00	2.07	1.00	Yes	2.06	2.58	2.11	21.3	30+	1.40	1.59	1.20	1.00
	Little	1.20	1.37	1.17	1.00	DII	1.08	0.80	0.92	1.00	No	1.00	1.00	1.00	1.00	25-30	1.15	1.21	1.08	1.00
	Much	1.00	1.00	1.00	1.00	DI	0.98	0.79	0.92	1.00						-25	1.00	1.00	1.00	1.00
						No	1.00	1.00	1.00	1.00										
WOMEN	No	1.50	1.83	1.62	1.00	DIII	1.33	1.00	1.14	1.00	Yes	1.82	2.33	3.00	12.5	30+	1.33	1.66	1.23	1.00
	Little	1.20	1.37	1.17	1.00	DII	1.09	0.80	1.03	1.00	No	1.00	1.00	1.00	1.00	25-30	1.11	1.24	1.09	1.00
	Much	1.00	1.00	1.00	1.00	DI	1.00	0.79	0.95	1.00						-25	1.00	1.00	1.00	1.00
						No	1.00	1.00	1.00	1.00										

AC = all-cause mortality, ID = ischemic heart disease, CD = cerebrovascular disease, LC = lung cancer

*The rate ratios are the same for all nine countries and age-specific rate ratios that we used in our calculations are not shown here, among those also the continuous rate ratio functions for the continuous calculation of the PAF for BMI.

Source: all-cause rate ratios for physical activity, and smoking, and cause-specific rate ratios for BMI come from the GIDS study ("Gezond in de stad").

Sources for the rate ratios for alcohol (all-cause mortality and lung cancer mortality), and all-cause mortality rate ratios for BMI have been collected by the Dynamo-HIA project and are documented in [6]. The remaining cause specific rate ratios were taken from [5].

Box 2: The Population Attributable Fraction

The Population Attributable Fraction (PAF)

PAF is the proportional reduction in population morbidity or mortality that would occur if exposure to a risk factor were reduced to an alternative ideal exposure scenario (e.g. no tobacco use). The PAF can be calculated using Equation 1.

Equation 1

$$PAF = \frac{\sum_{i=1}^{n} P_i RR_i - \sum_{i=1}^{n} P_i' RR_i}{\sum_{i=1}^{n} P_i RR_i}$$

n = number of exposure categories

P_i = proportion of population currently in the i_{th} exposure category

P'_i = proportion of population in the i_{th} exposure category in the counterfactual (alternative) scenario

RR_i = relative risk of disease-specific mortality for the i_{th} exposure category

Many diseases are caused by multiple risk factors. In order to estimate the combined impact of more than one risk factor on the occurrence of morbidity or mortality, equation 2 can be used to calculate an attributable fraction that takes into account multi-causality [12].

Equation 2

$$PAF = 1 - \prod_{i=1}^{n} (1 - PAF_i)$$

PAF_i = the proportion of the disease preventable by reducing exposure to the i_{th} risk factor

Product of all $(1\text{-}PAF_i)$s = the fraction of disease not preventable through interventions on any of the n risk factors.

In a cause-specific analysis, preventable deaths can be summed across causes of death to obtain the total (all-cause) mortality that would be prevented through interventions on all risks.

Calculation example

In the following calculation example we first show how to calculate the PAF for smoking among men in Belgium for all-cause mortality, given the scenario that all educational groups have the smoking prevalence of the high educated. This value (2.9%) can be found in the third row in Table 9 (second to last column). Secondly, we show the impact of the smoking scenario on mortality inequality among Belgian men, as shown in the third row of Table 10. Table 3 shows which data is needed for the first step: smoking prevalence by age and education and mortality rate ratios for smokers versus non-smokers by age.

After applying Equation 1 from Box 2 to the group that is young and low educated, we obtain a PAF of 0.151 (=15.1%). This is done for all 15 groups. The resulting PAFs are applied to the numbers of deaths per 100,000 and result in the number of saved deaths for each group

Table 3: Smoking prevalence by age and education, and mortality rate ratios for smokers versus non-smokers by age for Belgian men

	Education		Age 30-44	Age 45-59	Age 60-69	Age 70-79	Age 80+
Current smoking	low	smoker	0.546	0.443	0.253	0.222	0.088
prevalence		non-smoker	0.454	0.557	0.747	0.778	0.912
	middle	smoker	0.414	0.396	0.258	0.164	0.154
		non-smoker	0.586	0.604	0742	0.836	0.846
	high	smoker	0.297	0.332	0.201	0.187	0.163
		non-smoker	0.703	0.668	0.799	0.813	0.837
Mortality rate ratios	all education	smoker	1.90	2.47	2.33	2.06	1.53
for smoking	groups	non-smoker	1	1	1	1	1

Table 4: PAFs and number of saved deaths per 100,000 by age and education

	education	30-44	45-59	60-69	70-79	80+
PAF	low	0.151	0.099	0.051	0.030	-0.038
	middle	0.077	0.060	0.056	-0.021	0.005
	high	0	0	0	0	0
Saved deaths	low	8	19	20	14	-15
	middle	2	2	3	-1	0
	high	0	0	0	0	0

(Table 4). Note that PAF is 0 and no deaths are saved among the high educated because they do not change their smoking behavior.

The sum of all saved deaths is 52. This is 2.9% out of the total number of deaths (1815 per 100,000) and results in a PAF for all groups combined of 0.029 (Mortality numbers are not shown here but included in the Excel calculation tool). The next step is to calculate the impact of this smoking scenario on social inequality in mortality. The next two tables (Tables 5 and 6) show (1) the current level of mortality by age and education, and (2) the mortality levels in the scenario. The second is obtained by applying the 15 age-specific and education-specific PAF values to the 15 mortality rates. Based on this, new mortality rate ratios can be calculated that show a decrease in the mortality disadvantage by 14% for the low educated (the RR drops from 1.58 to 1.50) and by 13% for the middle educated (the RR drops from 1.23 to 1.20) compared to the high educated (Table 10).

Stratification by sex, age and cause of death

We aim at quantifying scenarios for total mortality in Europe with precise estimates. This makes considerable demands on the methodological approach. For example, there are

Table 5: Mortality in current situation

	Age	30-44	45-59	60-69	70-79	80+	All ages
Mortality rates	low	281	959	2899	7320	17630	1320
	middle	196	683	2262	5907	15078	1028
	high	133	509	1856	4983	13391	835
Rate Ratios	low	2.11	1.88	1.56	1.47	1.32	1.58
	middle	1.47	1.34	1.22	1.19	1.13	1.23
	high	1	1	1	1	1	1

Table 6: Mortality in scenario

	Age	30-44	45-59	60-69	70-79	80+	All ages
Mortality rates	low	239	864	2750	7100	18303	1159
	middle	181	642	2134	6029	15147	921
	high	133	509	1856	4983	13391	766
Rate Ratios	low	1.80	1.70	1.48	1.42	1.37	1.51
	middle	1.36	1.26	1.15	1.21	1.13	1.20
	high	1	1	1	1	1	1

substantial differences between men and women in how educational status relates to health [13] and in the determinants of educational inequalities in health. Analyses of health determinants on health should therefore be stratified by sex.

In this exercise we carry out age- and cause-specific analyses. This allows for a more realistic picture of the PAF because we know that the impact of risk factors on mortality is different in different stages of the life course and according to different causes of death. We apply all calculations to the age-groups 30-44, 45-59, 60-69, 70-79, and 80+. However, the highest age group has been omitted for the final calculations of the project because of insufficient data validity. We also calculate outcomes for all ages combined based on the age-specific calculations, by summing up the saved deaths for each age category and then calculating a new PAF for all ages together. The reason for choosing the age-specific approach is that input and output information is more specific and thus more informative.

Furthermore, we analyze cause-specific mortality from ischemic heart disease (IHD), cerebrovascular disease and lung cancer. Theoretically, all cause-specific PAFs add up to the PAF for all-cause mortality, but we cannot show this here, because the list of causes of death in this analysis is far from complete. We do cause-specific PAF calculations because it is important to see which causes contribute most to an overall number of saved deaths because this differs by sex, age and risk factor, and maybe also by country. Only a cause-specific analysis can take into account that each risk factor only affects certain causes of death but not others.

We address both scenarios by country, sex, age-group (both age-specific and all-age), risk factors (both separately and combined), socioeconomic status and cause of death (cause-specific and all-cause). Calculating the PAF in such a level of detail is possible because of the flexibility of the methodological tool (PAF tool) developed in the Euro-GBD-SE project. This tool is constructed in such a manner that we are able to add more risk factors, causes of death, other indicators of socioeconomic status and more countries for calculating more results.

Main assumptions

While the PAF involves a relatively simple calculation and methodology, the assumptions behind this measure are strong. In the following we list the main assumptions and briefly refer to implications and literature. It is obvious that some of the assumptions will not always be met, which is also true for many of the PAF calculations in the literature. Because of that it is important that problematic assumptions are communicated and taken into account when interpreting the results. The main assumptions are:

1. The relative risks used in the PAF calculation accurately reflect the causal effects of the risk factors on mortality in the population under consideration [14]. This implies that the risk factor has a causal effect on mortality. Only then can the corresponding fraction of mortality be interpreted as being "attributable" to the risk factor, and only then can we expect mortality to be reduced if the exposure to the risk factor is reduced. But this assumption also implies that the actual relative risk estimate used in the calculations reflects this causal effect (and does not over- or underestimate this causal effect, e.g. because the observed association is mixed with selection effects or confounded by other variables). Below we review a few specific aspects of this assumption:

a. The causality assumption may be particularly problematic for the educational scenarios (type A), because here we are interested in the mortality attributable to a 'social exposure' (i.e. education) rather than a biological one. Social causation tends to be even more complex than biological causation.

b. The assumption may be less problematic for scenarios where we calculate the contributions of proximate risk factors, such as smoking and BMI (type B). As long as we select risk factors for which a causal effect on mortality is undisputed, we can safely apply the PAF approach. But here too we need to make sure that the estimates of relative risk that we use in the calculations, do reflect the causal effect of the risk factor on mortality (e.g. by checking that these estimates were adjusted for the effect of confounders).

c. Most of the relative risks are assumed to be the same for all countries for which the calculations are carried out [15]. The main exception is the relative risk of education, which we know to be different between countries, and which we calculated within the project. But the relative risks for proximate risk factors came from the literature, and we assumed that these are the same in all countries included in the analysis. There is an increasing body of evidence stating that, when the metric of exposure is comparable, the RRs are similar across populations in different world regions [16].

d. The relative risks of proximate risk factors are assumed to be the same for all educational groups. Whether a rate ratio for e.g. smoking can be regarded as a biological constant or whether the impact of smoking differs between socioeconomic groups is still an open question [17]. Evidence from the Whitehall II study suggests, that smoking is more harmful for those placed lower in the social hierarchy [18] and evidence from New Zealand shows that the impact of smoking on mortality varies over time and by ethnicity [19], but there is no systematic evidence on how the impact of proximate risk factors would differ by socioeconomic group.

e. Note that out calculations in scenario type B do not assume that education has a causal effect on exposure to the risk factors. Calculations for scenario type B indicate how much of the educational inequalities in mortality would be reduced, if exposure to one or more proximate risk factors would be equally distributed between educational groups. Only if the results of these scenarios are interpreted in terms of "mediation" (of the effect of education on mortality, through these proximate risk factors), one would need to assume a causal effect of education on exposure to the risk factors. Our analyses, however, are not intended to quantify mediation.

f. A potential problem with scenario type A is that if education causes health because of a hierarchy effect that makes the high educated healthier, eliminating that hierarchy would presumably lead to the worsening of health among the highest educated. One would therefore have to assume that the health returns to education would remain the same, even if parts of the population, or everyone achieved higher education.

2. The prevalence rates used in the PAF calculation accurately reflect the relevant exposures to the risk factors in the population under consideration. Because we only use data on educational distributions and risk factor exposure by educational group which come from the population under consideration, there is no need to assume portability of estimates across national boundaries, as in the case of the risk ratios. But there are other potential problems with this assumption:

a. The risk ratio estimates come from other studies than the prevalence rates. While the risk ratio estimates are often derived from carefully conducted epidemiological studies, which were designed to give unbiased estimates of the effect of risk factors on mortality, the prevalence estimates usually come from large-scale surveys (like national health interview or multipurpose surveys), which were designed for monitoring purposes. Both, the content of the risk factor information (e.g. how the survey question has been phrased) and the accuracy of measurement may differ, and we must make sure that the risk ratio estimates do apply to the prevalence estimates of a potentially slightly different phenomenon.

b. The prevalence data must, of course, be accurate. For scenarios type A, the main requirement is that educational distributions have been correctly estimated, while for scenarios type B the prevalence of proximate risk factors by educational group must have been correctly estimated in each country for which the calculations are done. Errors in data collection, between-country differences in data classification, survey non-response, et cetera may all lead to violations of this assumption. Careful checking of all data is therefore part of the routine for these calculations.

c. The prevalence rates must reflect exposure at the point in time when the risk factor actually exerted its causal effect on mortality. In scenarios type A this will not be a problem, because we mostly use data from longitudinal studies which link the level of education as measured during a census to mortality during a follow-up period. But in scenarios type B this can be a problem, if exposure data are not collected for a point in time that allows an appropriate delay before a causal effect can occur [12].

In addition to these two main assumptions, we list a few others that are of less general importance.

3. The multi-causal relationship in Equation 2 is based on the assumption that exposures to risks are uncorrelated. In the present document we can only account for the correlation with education by stratifying the analysis by educational group. Equation 2 also assumes that the effect of one risk factor is not mediated through another risk factor [15]. To explore if there is mediation between the risk factors, sensitivity analyses could be used, which has not been done in the present study. The consistent use of adjusted rate ratios as input in the PAF calculation represents another solution to this problem, but it is difficult to find such consistently adjusted rate ratios in the literature.

4. Our scenarios do not specify the time dimension of the proposed changes. The implicit time frame is that we can only expect to see the reductions in mortality after persons that have been moved from one exposure group to another also have acquired the mortality risk

of the new group [20]. This may happen immediately, e.g. for the risk of traffic accidents after moving to a different area, but it may also take 20 years, which is the time a person who quit smoking needs to reach the disease level of a permanent non-smoker.

5. For our calculations of the PAF for all-cause mortality we assume independence of causes of death: an avoided death from one cause of death should be really avoided and not shifted to another cause of death category. This assumption is partly met by clustering the causes of death by their joint risk factors: interrelated causes of death are assumed to be influenced simultaneously by their joint risk factors while other causes of death are independent [16]. For cause-specific analysis where only one cause of death is considered, this assumption does not apply.

Confidence intervals

To calculate confidence intervals for the Population Attributable Fraction we use the bootstrap method and do the calculations with the R software. Bootstrapping allows for uncertainty analyses producing randomly drawn numbers from specific distributions. To calculate a standard error and a confidence interval for a PAF it is necessary to know the standard error for each of the input information into the PAF formula, i.e. for all rate ratios and all prevalence rates involved. Under the assumption that the errors of a rate ratio have a log-normal distribution, the standard error (SE) for a rate ratio can be specified as:

$$SE(\ln(RR) = \sqrt{\frac{1}{d_1} + \frac{1}{d_2}},$$

where d is the number of deaths in each of the groups related by the rate ratio. If the original sample sizes on which rate ratios are based are not available, published standard errors or confidence intervals can also be used. The standard error of the prevalence rates is specified as:

$$SE(p) = \sqrt{\frac{p \times (1-p)}{N}},$$

where p is the prevalence of one risk exposure level, expressed as a share (percent/100). N is the total sample size (all risk levels combined). Based on these standard errors, distributions for all input values into the PAF formula can be specified. The program then produces a high number of random numbers, e.g. 1,000, simultaneously drawn from each of these distributions.

Example: we want to calculate the confidence interval for a PAF that represents the fraction of mortality that could be saved if the educational distribution changed. The necessary input for the PAF formula includes two rate ratios (for the middle and for the low educational group, the highest educational group being the reference) and three prevalence rate (one for each educational group). Our R program draws these five values at least 1,000 times and based on these 1,000 sets of numbers we calculate 1,000 PAF values. These PAF values again have a distribution from which we can specify the desired standard error and confidence interval of the original PAF value. Table 7 shows the all-cause mortality PAFs for the maximum educational scenario for selected countries of our project and the corresponding confidence intervals. In this scenario the whole population has high education.

Table 7: PAFs for maximum educational scenario with confidence intervals

MEN	CI	lower bound	higher bound
Norway	36	34.4	37.5
Denmark	30.8	29.5	32.1
Belgium	35.3	32.3	38.5
Barcelona	25.8	23.8	27.9
Basque Country	22	19.2	24.5
Madrid	23.1	20.5	25.8
Hungary	54.1	53.4	54.8
Czech Republic	57.2	56.5	58
Estonia	48.6	46.7	50.3
WOMEN	CI	lower bound	higher bound
Norway	32.5	30	34.8
Denmark	30.3	28.6	32.1
Belgium	29.6	24.8	34.2
Barcelona	19.7	16	23.4
Basque Country	13.1	6.8	19.1
Madrid	19.2	13.3	24.9
Hungary	32	30.4	33.8
Czech Republic	50.1	48	52.1
Estonia	41.4	38.7	43.9

ILLUSTRATIVE RESULTS

In order to limit the amount of tables in this working document we demonstrate the research methods by focusing on different dimensions for the respective research questions. The first scenario, which aims at estimating the PAF, given changes in the educational distribution, has a particular focus on age-specific results (Table 8). The second scenario, which aims at estimating the PAF, given changes in the risk factor distribution, has a particular focus on causes

of death and risk factors (Table 9). Finally, the results of the potential reduction of relative health inequalities by redistributing risk factors (Table 10) focusses on the contribution of the four risk factors (separately and combined) and of the educational level (see overview below).

Tables and Figures are stratified by the following dimensions:

		Country	Sex	Educ	RF	Age	Cause
Table 1	Prevalence	X	X	X	X		
Table 2ab	Rate ratios	X	X		X		X
Table 8	Redistributing education	X	X			X	
Table 9	Redistributing risk factors	X	X		X		X
Table 10	Change of RRs	X	X	X	X		
Figure 2	Contribution of RF to the PAF	X	X				
Figure 3	Contribution of RF to inequalities	X	X				

Educ=educational level, RF=risk factor, cause=cause of death

The results are presented in line with our two scenarios. Therefore, we first report scenarios with education as a risk factor of mortality, followed by a section on scenarios with specific risk factors for mortality.

Scenarios type A: the impact of redistributing education

In this section we present an overview of the PAF of all-cause mortality in five age groups (and for all ages) given three different sub-scenarios which imply that the educational distribution itself would change (see Table 8).

Sub-scenario 1 estimates the PAF given that the educational distribution would change to the distribution observed in the country with the largest share of high educated men (Norway). According to our calculation mortality would decrease in all other countries (ages combined) for both men and women with the exception of Estonian women, where mortality would increase by 2.8% (Table 8). It is important to explain more clearly why the PAF for Estonian women decreases given a redistribution of education. An important quality of age-specific analyses is that we are able to go deeper into why this is the case by looking into the age-specific results. The pattern which emerges when examining this indicates that the PAF for Estonian women is negative in younger age groups (-29.2% in the age group 30-44) and only becomes positive in the oldest age group (1.3% in the age group 80+). Thus, it is the PAF at younger ages that drives the negative value for all ages combined.

Another relevant question to answer is why we see this pattern in the first place. The answer to this can be obtained by looking into the age-specific distributions of educational attainment. Table 1 shows that the share of higher educated is slightly larger among Estonian women

Table 8: The PAF (in %) of deaths (all-cause) given three scenarios in which the educational distribution itself changes

	Age 30-44			Age 45-59			Age 60-69			Age 70-79			Age 80+			All ages		
Scenario	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3
MEN																		
Norway	Ref.	33.6	40.6	Ref.	29.8	39.6	Ref.	19.6	29.6	Ref.	14.2	22.4	Ref.	6.7	10.2	Ref.	16.7	24.5
Denmark	11.7	36.1	48.8	2.1	25.9	38.2	0.7	16.4	28.8	6.3	23.8	38	17.6	39.6	54.5	7.5	27.1	40.7
Belgium	12.3	26.7	40.2	12.2	25.4	38.9	8.1	20	31.4	6	17.8	28.5	4	13.4	21.8	7.2	18.8	29.7
France	11	33.4	44.8	12.7	36.6	55.7	9.3	24.8	41.5	5.9	18.2	26.4	4.2	13.4	22.7	7.9	22.9	35.6
Spain	17.4	33.5	42.4	11	19.8	19.1	4.9	11.1	3.9	5.5	14.4	1.1	5.8	18.8	0.6	6.9	16.5	6.7
Hungary	29.6	43.9	72.3	20.2	43.8	63	13.5	40.1	52.2	9.4	36.2	41.8	8.5	35.3	31.3	13.8	39.1	48.7
Czech R	33	51.2	63.5	22.4	46.2	65.4	12.2	43	57.6	6.8	38.2	50.5	6.9	35.6	40.2	12	40.6	52.9
Lithuania	-9.5	57.6	63	-2	45.9	58	3.5	24.5	47.2	3.9	20.6	40	7.9	31.1	26.9	1.9	32.7	45.7
Estonia	-0.7	60.1	68.3	1.8	42.1	58.8	0.3	24.9	46.6	-0.2	15.2	35.4	0.7	9.8	23	0.5	27.3	44.9
WOMEN																		
Norway	Ref.	28	33.1	Ref.	26.1	34	Ref.	24.2	35.3	Ref.	15.4	23.5	Ref.	5.8	6.9	Ref.	14	19.6
Denmark	13.5	30.2	35.2	2.9	24.3	31.8	2.2	18.6	29.3	7.1	29.8	39.4	2	5.3	10.5	4.1	17.8	25.6
Belgium	11.1	22	29.6	7.8	17.6	22.3	7.4	22.1	24.2	6.7	24.4	28.9	4.4	16.3	19.9	5.9	19.6	23.5
France	11.8	23.6	27.4	13.1	31	36.9	9.6	28.1	30.7	5.8	20.4	35.9	5.1	18.4	6.7	6.7	21.3	20.3
Spain	7.6	14	19	6.5	12.5	-1.4	7.6	19.8	10.2	6.4	20.9	1.4	5.3	18.5	13.2	6.1	18.9	8.5
Hungary	21.2	43.1	60.7	9	36.1	48.8	9.6	33.7	32.6	9.3	34.1	22.9	10.3	40.4	-4.9	10.1	37.1	16.5
Czech R	21.7	40.9	50.8	12	36.4	52.1	7.4	30.9	52.7	6.1	23.1	51.3	9.8	38.7	30.3	8.7	32.6	41.8
Lithuania	-46.2	47.5	49.5	-19.9	39.2	45.8	-0.1	29.7	45.5	5	37.1	50.8	11.2	64.6	42.3	3	48.4	45.9
Estonia	-29.2	50.7	53.9	-16.2	42.2	51.1	-5.1	27.4	43	-0.9	17	37.3	1.3	10	20.4	-2.8	18.7	32.5

NA = Not available
Ref = Reference country
Scenario 1: Educational distribution as in Norway
Scenario 2: The lower and mid- educated get one level higher education, respectively
Scenario 3: The whole population has high education
Note 1: negative preventable fractions indicate the proportion by which mortality will increase as compared to the baseline value
Note 2: The results for all-ages are based on age-specific calculations

(17.3%) as compared to Norwegian women (15.8%) and the share of lower educated is substantially lower among Estonian women (29.8%) compared to Norwegian women (38.7%). The age-specific prevalence information, which is not shown in Table 1 but is used in the calculations, shows that these differences are larger in younger age groups. Thus, by redistributing the education of Estonian women, we decrease the overall educational attainment among younger Estonian women, which eventually leads to higher all-age mortality in the scenario, represented by a negative PAF value.

According to sub-scenario 2, we avoid a substantial fraction of deaths in all countries assuming that the whole population would have their education increased by one level. The all-age

column in Table 8 shows that the PAF varies between 14.0% (Norwegian women) and 48.4% (Lithuanian women). In the previous example, we explained how the age-specific PAFs can explain the PAFs for all ages. In this example, we would like to compare a few age-specific results directly between countries.

For example, among Lithuanian women aged 80+ the PAF value for the second scenario is 64.6%. This large value stands in contrast to the PAF of Danish women aged 80+, which is only 5.3%. The explanation of these differences in magnitude is a combination of the mortality rate ratio for education and the distribution of achieved educational attainment in these age groups. More than 80% of Lithuanian women only have primary education in the age group 80+ and the rate ratio of lower versus higher education is the highest compared to all other countries (RR = 2.77, Table 2a). When this group increases its educational attainment by one level, we save almost 65% of all deaths because the rate ratio of middle versus higher educational attainment is much lower (RR = 1.32). Additionally, only 2% of Lithuanian women aged 80+ have higher education, meaning that almost all women in this age group benefit from an educational increase of one level. We can do the same exercise in order to explain the comparatively low PAF among Danish women aged 80+. In this age group 100% of the people have low education, but they benefit only slightly from a higher education, since the rate ratio only decreases from 1.74 (low versus high education) to 1.23 (mid versus high education). Furthermore, there is no group left to benefit from having a high education, as all people moved from low to mid education (0% moved from mid to high).

In the third sub-scenario even more deaths can be avoided in all countries, if the total populations had the education of the highest educational group. In principle, this represents the theoretical limit as to what can be achieved. For example, the PAF for Czech men has increased from 40.6% (sub-scenario 2) to 52.9%, and for Estonian women we have seen an increase from 18.7% (sub-scenario 2) to 32.5%. However, in some cases the PAF decreases when changing from a scenario where the lower and mid-educated increase their education by one level respectively, to a scenario where all get higher education. This is the case for Spain along with Hungarian, and to a lesser extent French, women. For example, the PAF for Spanish men decreases from 16.5% to only 6.7%, and from 18.9% to 8.5% for Spanish women. The explanation is straightforward: As shown in Table 2a there is a reverse mortality gradient between the mid- and higher educated. Given that the lowest mortality is in the mid-educated group, no further deaths can be saved by moving all persons to the highest educated group.

The results of all three sub-scenarios show that the preventable fractions of deaths vary between age groups. This is because the very impact of education on mortality varies by age and because, starting from different educational distributions in different age groups, a

specific scenario implies more or less drastic changes of this distribution by age. This could provide policy makers with important tools, as we would know 1) at which age low education is most harmful, 2) at which ages we could avoid the largest fractions of deaths, and 3) at which ages interventions would be most efficient.

It is noteworthy that the magnitude of the impact of scenario type A depends on two factors: first, the existing level of social inequality in mortality and, second, the share of low and mid educated persons. Furthermore, rate ratios and group sizes are not independent of each other, because we use simple rate ratios that do not take group sizes into account. A small and therefore more extreme lowest or highest educational group may therefore result in a higher rate ratio. While this has to be generally taken into account while interpreting our results, the international pattern cannot be attributed to this measurement issue to any large extent.

Scenarios type B: redistributing risk factors by education

The second type of scenarios is addressed in two ways: first by estimating the actual decrease of cause-specific mortality (ischemic heart disease, cerebrovascular diseases and lung cancer) and all-cause mortality given the assumption that the prevalence of physical activity, alcohol consumption, smoking and BMI (separate and combined) would be the same for all educational groups and at the level observed for the higher educated. Secondly, we present the results of this scenario by estimating the potential reduction of health inequalities differentiated by risk factor and for all risk factors combined.

The potential avoidance of deaths

Table 9 presents estimates on the expected decrease of cause-specific mortality (ischemic heart disease, cerebrovascular diseases and lung cancer) and all-cause mortality given that the exposure to physical activity, alcohol consumption, smoking and BMI would be the same for all educational groups at the level observed for the higher educated. Furthermore, Table 9 also shows how much of the overall mortality we are covering with our three causes of death (see column 'total saved'), by presenting the share of saved deaths from these three causes out of the saved deaths from all causes.

A change in the exposure of all risk factors would cause the largest reduction of all-cause mortality among Norwegian men (17.7%) for which smoking contributes the most (11.1%). However, if we take the example of Hungarian women, we see that the overall PAF of all-cause mortality is 10.7%, in which the PAF of physical activity (11.0%) contributes by far the most. In order to understand this and similar questions, we have to carefully examine the table step-wise from left to right.

The first column of Table 9 estimates the PAF for ischemic heart disease given the scenario that the exposure to physical activity would be found at the level of the higher educated in the total population. It shows that countries with available data can avoid between -1.8% (Estonian men) and 13.5% (Hungarian women) of all deaths from ischemic heart disease by redistributing the prevalence of physical activity. Taking the next column, we can see that equalization in the exposure of alcohol consumption to the level currently seen in the higher educational group would reduce ischemic heart disease mortality by the highest percentage among Norwegian men (2.8%). Assuming an equalization in the exposure to smoking would reduce the largest proportion of deaths among men in Norway (7.8%) and among women in the Czech Republic (1.9%), while for BMI the scenario would reduce ischemic heart disease related deaths in all countries with available data (except among Estonian and Lithuanian men).

The interpretation is the same for the other two causes of death: cerebrovascular disease and lung cancer. In summary, for deaths from ischemic heart diseases smoking and physical activity are the most important risk factors. For cerebrovascular diseases physical activity is very influential, too, and for men also smoking. Not surprisingly, for lung cancer smoking is by far the most important risk factor, while alcohol and BMI have a comparatively small impact on all causes of death. Country-specific results show that this general assessment varies between countries: among Hungarian women 11.2% of deaths from cerebrovascular diseases are avoided given an upward leveling of physical activity to the level seen among the higher educated. Changing the exposure of alcohol consumption would prevent 3.6% of these deaths among Hungarian men. Equalizing the smoking pattern between educational groups would contribute to preventing up to 6.6% of mortality due to cerebrovascular diseases, for men in Estonia. An equalization of the BMI distribution to the level seen among the higher educated would prevent about 1% of these deaths in most countries with available data, with the exception of Lithuania and Estonia (for women only). An equalization of smoking exposure to the level of the higher educated would reduce lung cancer mortality among men by more than 20% in Norway (38.4%), Denmark (23.7%), the Czech Republic (35.6%), Lithuania (23.5%) and Estonia (26.2%).

It should be noted here that whenever the PAF value is negative, it implies that mortality would increase, rather than decrease in a given scenario. For example, among Spanish women, we would experience an increase of lung cancer by 42.3% given an equalization of the smoking distribution. In this case, the negative number reflects the reverse social gradient in smoking behavior, which leads to increasing mortality if all educational groups behave like the highest educational group.

The column 'total saved' gives the percentage of saved deaths (over the three causes: ischemic heart disease, cerebrovascular disease, and lung cancer) from all causes. These numbers

Table 9: The PAF (in %) of cause-specific and all-cause mortality for all educational groups, given the scenarios that the prevalence of physical activity, alcohol consumption, smoking, BMI (separately and combined) would be found at the level currently seen in the higher educational group

	Ischemic heart disease				Cerebrovascular disease				Lung cancer				% out of total saved	All-cause mortality				
Risk factor	PA	alc	smo	BMI	PA	alc	smo	BMI	PA	alc	smo	BMI		PA	alc	smo	BMI	all
MEN																		
Norway	6.8	2.8	7.8	2.5	5.5	0.8	5.6	1.2	0	0	38.4	0	44.21	4.6	0.7	11.1	2.6	17.7
Denmark	2.5	1.5	5	2.5	2.6	0	4.2	1.1	0	0	23.7	0	36	2.1	0	8	2.5	12.1
Belgium	3	2.4	3.8	2.3	2	0.5	2	0.9	0	0.1	9.1	0	43.12	1.9	0.3	2.9	1.8	6.7
France	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.6	0.3	-0.6	2.1	4.2
Spain	4.9	1.6	1.9	1.9	4.4	1.8	0.9	0.8	0	0	3.3	0	29.06	3.8	1.2	1.1	1.5	7.3
Hungary	5.1	1.2	1	1.2	4.8	3.6	0.9	0.6	0	0	3.1	0	46	3.5	1.4	0.9	1.4	7
Czech Republic	0.2	-0.1	6.3	1.8	-0.5	0.2	4	1	0	0	35.6	-0.1	50.63	0.1	0.2	8.6	2	10.4
Lithuania	6	1.7	5	-0.3	5.2	0.7	4.6	0	0	0	23.5	0	50.77	4	0.4	8.2	-0.4	11.8
Estonia	-1.8	1.9	7.1	-0.7	-0.8	0.9	6.6	-0.4	0	0	26.2	0	43.35	-0.5	0.6	10.8	-0.8	10.2
WOMEN																		
Norway	5.8	1.5	-0.5	2.6	5.3	0.4	-0.2	1.3	0	0	12.3	0	81.33	4.7	0.1	-3.2	1.9	3.6
Belgium	3.5	1.9	-0.1	2.9	2.9	0.2	-0.5	1.1	0	0	0.7	0	24.78	2.8	-0.2	0.4	2.1	5.1
Denmark	2.7	1.8	0.04	2	3	0.1	1	1	0.1	0.1	9.8	0	78.75	2.6	-1.1	-0.6	1.7	2.5
France	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4.6	0.1	-2.2	1.8	4.4
Spain	2.7	0.9	-4.2	2.9	2.7	0	-3.4	1.3	0	0	-42.3	0	-317	2.6	-0.5	-4.7	2.4	0.1
Hungary	13.5	0.7	-1.7	1.9	11.2	0.5	-3.2	1.2	0	0.1	-7.7	0	44.56	11	0.2	-2.2	1.6	10.7
Czech Republic	3.7	0	1.9	2.9	3.5	0.1	1.3	1.3	0	0	16.3	0	36.58	3.3	0.2	3	2.6	9
Lithuania	5.1	1.1	-0.8	0.4	4.9	0.2	-1	0.2	0.1	0	-10.6	0	77.85	4.2	0.2	-1.2	0.6	3.8
Estonia	3	1.8	1.5	1.7	3.5	0.4	1.6	0.9	0	0	11.6	0	62.1	3	0.4	2.1	1.6	6.9

Note: The cause-specific calculations are separate from the all-cause calculations

Total saved: percentage of saved deaths (over 3 causes) out of saved deaths from all causes

NA = Not available

Low = primary and lower secondary education

Mid = higher secondary education

are interesting because they estimate how much we can explain out of total mortality. These numbers typically vary between 30% and 50%. For Spanish women, however, the number is -317%. This requires further explanation that can only be based on data from the Excel tool which is not shown here: For Spanish women, we save -3.8 deaths (i.e. mortality increases) per 100,000 people for the three causes of death. On the other hand, we save 1.2 deaths per 100,000 for all-cause mortality. The surprising percentage of -317 thereby corresponds to the simple calculation -3.8/1.2*100, and tells us that there are other unspecified causes of death where we really save deaths. We could also go deeper into the explanation, by looking into which cause of death provides the highest "minus-deaths saved". For Spanish women, we see from Table 9 that lung cancer has a PAF of -42.3% for smoking, which is due to the reverse social gradient of smoking among Spanish women mentioned above and documented in Table 1.

The overall PAF of all-cause mortality of 10.7% among Hungarian women is mainly attributable to the impact of physical activity on ischemic heart disease and cerebrovascular disease combined with the fact that the PAF of smoking to lung cancer is negative (due to an inverted social gradient in smoking). We have also seen that equalization in the exposure of all risk factors would cause the largest reduction of all-cause mortality in Norway (17.7%), in which smoking (11.1%) contributes the most. This is related to the impact of smoking on lung cancer: 38.4% of all deaths due to lung cancer can potentially be avoided in Norway given a change in the exposure to the level of the higher educated.

The example of Norwegian men and Hungarian women is representing a more general pattern: according to the 'all-cause mortality' columns in Table 9, smoking is most important for men, while for women, physical activity is the most important risk factor. The explanation for this is that in most countries the prevalence of physical activity is most unequal for women while for men the most socially unequal distribution exists for smoking. Next to the mortality rate ratios for the risk factors that we assume to be the same in all countries, but not between the sexes, this inequality in the risk factor distributions influences the magnitude of the PAF values.

Figure 1 presents a graphical overview of the fraction of all-cause mortality preventable by a redistribution of education where the whole population would have high education (black bars, scenario A) compared to the fraction of all-cause mortality preventable by a redistribution of physical activity, alcohol consumption, smoking and BMI (gray bars, scenario B). The figure thereby illustrates the contribution of the risk factors to the theoretical potential. The height of the scenario A bars represents the preventable fraction of all-cause mortality in the most extreme scenario in which all persons have high education. A subset of this preventable mortality can be avoided assuming that all persons exercise, smoke, drink, and have the same

BMI as the high educated do. Figure 1 shows that between 40% and 50% of all-cause mortality among men in Denmark, Hungary, the Czech Republic, Lithuania and Estonia can be avoided if all persons had high education. This is also the case for Lithuanian and Czech women. In Spain, less than 10% is avoided for both men and women. A much lower fraction is avoided if all persons just had the same health behavior (physical activity, alcohol, smoking and BMI) as the highly educated. Among Spanish women, no deaths are avoided. This exceptional result for Spain can be explained by looking at Table 9, columns "all-cause mortality": If all Spanish women behave like the highly educated women, the behavioral change in physical activity and BMI would save deaths, but this would cancel out through additional deaths from the behavioral change in drinking and smoking, again due to the reverse social gradient in these two dimensions.

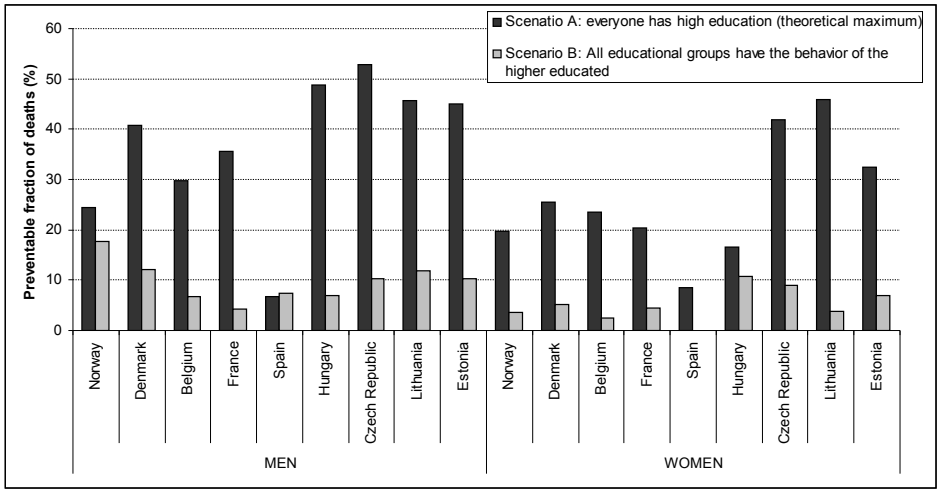

Figure 1: Fraction of all-cause mortality preventable by a redistribution of education (Scenario A, black bars), compared to the fraction of all-cause mortality preventable by a redistribution of physical activity, alcohol consumption, smoking and BMI (scenario B, gray bars)

The potential reduction of inequalities

To address the potential reduction of inequalities, Table 10 presents mortality rate ratios (RR) for educational groups for men and women in nine European countries, and scenario RRs (with percentage reduction as compared to the original RRs) based on the assumption that the prevalence of physical activity, alcohol consumption, smoking and BMI (both separately and combined) would be distributed as in the highest educational group.

The table shows that the original RRs are smallest in Spain (for both men and women) and largest in Lithuania (for women) and the Czech Republic (for men) when comparing the mortality between the low and high educated. More specifically, the RRs range from

1.17 (Spain) to 2.64 (Czech Republic) among men and from 1.12 (Spain) to 2.77 (Lithuania) among women. The respective RRs for the comparison between the mid and high educated are much smaller, but all countries except for Spain (men and women) and Hungary (women only) show a pattern in which those who are higher educated live longer than the mid educated.

The next columns of Table 10 show that the scenario RRs (SRR) are reduced when assuming that the prevalence of physical activity is observed at the level of the higher educated in all educational groups. The impact of physical activity to the reduction of health inequalities seems to be particularly large in Spain (35% and 25% for Spanish low educated men and women, respectively) compared to other European countries. To assess this finding we have to take into account that the level of inequality in mortality is already very low in Spain at the onset: For men the mortality rate ratio for the low educated only declines from 1.17 to 1.11 and for women from 1.12 to 1.09. Table 10 further shows that a similar change in the pattern of alcohol consumption would hardly alter the original RRs, except for Spain, where we would see a reduction of inequalities by 12% for men. Again this is due to the fact that mortality inequality in Spain is comparatively low: the rate ratio for men would fall from 1.17 to 1.15. However, a change in the smoking pattern to the level currently seen among the higher educated seems to be associated with a large decrease of the original RRs in some countries, and mainly among Norwegian men where a 44% reduction of inequality is observed. This substantial reduction occurs because the social smoking gradient is particularly high among Norwegian men and even more so in the higher ages where most deaths occur and can be saved. With regard to the SSRs of BMI, inequalities in health would be reduced only modestly by a redistribution to the level seen among the higher educated, but still slightly more than for alcohol. The largest decrease of inequalities is seen for Spanish women (33%). Table 10 further presents SRRs which are based on the assumption that the prevalence of physical activity, alcohol consumption, smoking and BMI are altogether distributed as in the highest educational group. This scenario would reduce inequalities in health in all countries, particularly for men, but still substantially for women where reductions of inequality are between 7% (Lithuanian women) and 28% (Norwegian women). The largest decrease of health inequalities would be seen among Spanish men with a 76% decrease of health inequalities (RR change from 1.17 to 1.04). Furthermore, we would experience a 66% decrease among Norwegian men (RR change from 1.59 to 1.20).

Figure 2 provides a graphical presentation on the impact of scenario B on the social inequality in mortality. It presents the excess mortality of the lower compared to the higher educated in percent (Y-axis), for the original RRs (baseline) and the scenario RRs (scenario). As we have demonstrated in Table 10, e.g. there is a reduction from a rate ratio of 1.59 to 1.20 for Norwe-

Table 10: All-cause mortality (RR) by educational group for men and women in nine European countries, scenario RRs (with percentage reduction as compared to the original RRs) based on the assumption that the prevalence of physical activity, alcohol consumption and smoking (both separately and combined) would be distributed as in the highest educational group

	RR		$RR_{Physical activity}$				$RR_{Alcohol}$				$RR_{Smoking}$				RR_{BMI}				$RR_{all factors combined}$			
Educ level	**Low**	**Middle**	**Low**	**%red**	**Middle**	**%red**	**Low**	**%red**	**Middle**	**%red**	**Low**	**%red**	**Middle**	**%red**	**Low**	**%red**	**Middle**	**%red**	**Low**	**%red**	**Middle**	**%red**
MEN																						
Norway	1.59	1.3	1.49	17	1.26	13	1.57	3	1.3	0	1.33	44	1.19	37	1.54	8	1.27	10	1.2	66	1.11	63
Denmark	1.85	1.43	1.8	6	1.42	2	1.85	0	1.43	0	1.61	28	1.33	23	1.77	9	1.39	9	1.5	41	1.28	35
Belgium	1.58	1.23	1.54	7	1.23	0	1.57	2	1.23	0	1.5	14	1.2	13	1.55	5	1.21	9	1.42	28	1.18	22
France	1.84	1.35	1.78	7	1.34	3	1.83	1	1.35	0	1.81	4	1.37	-6	1.78	7	1.34	3	1.69	18	1.35	0
Spain	1.17	0.9	1.11	35	0.89	-10	1.15	12	0.9	0	1.14	18	0.88	-20	1.14	18	0.9	0	1.04	76	0.86	-40
Hungary	2.36	1.32	2.27	7	1.33	-3	2.32	3	1.31	3	2.34	1	1.26	19	2.32	3	1.31	3	2.18	13	1.24	25
Czech Rep	2.64	1.43	2.63	1	1.43	0	2.63	1	1.44	-2	2.35	18	1.39	9	2.57	4	1.44	-2	2.28	22	1.4	7
Lithuania	2.58	1.68	2.44	9	1.65	4	2.57	1	1.67	1	2.26	20	1.58	15	2.61	-2	1.69	-1	2.16	27	1.56	18
Estonia	2.3	1.81	2.28	2	1.84	-4	2.29	1	1.8	1	2.02	22	1.57	30	2.31	-1	1.84	-4	2	23	1.61	25
WOMEN																						
Norway	1.43	1.19	1.35	19	1.15	21	1.43	0	1.19	0	1.42	2	1.21	-11	1.4	7	1.17	11	1.31	28	1.15	21
Denmark	1.74	1.23	1.69	7	1.21	9	1.75	-1	1.23	0	1.64	14	1.17	26	1.67	9	1.21	9	1.55	26	1.15	35
Belgium	1.39	1.07	1.33	15	1.09	-29	1.4	-3	1.08	-14	1.39	0	1.06	14	1.34	13	1.06	14	1.29	26	1.06	14
France	1.48	1.07	1.41	15	1.06	14	1.48	0	1.07	0	1.51	-6	1.09	-29	1.43	10	1.06	14	1.4	17	1.07	0
Spain	1.12	0.89	1.09	25	0.91	18	1.13	-8	0.89	0	1.18	-50	0.9	9	1.08	33	0.9	9	1.11	8	0.91	18
Hungary	1.66	0.98	1.55	17	0.95	-150	1.64	3	0.98	0	1.71	-8	1	100	1.6	9	0.96	-100	1.52	21	0.94	-200
Czech Rep	2.1	1.38	2.04	5	1.36	5	2.09	1	1.38	0	2.03	6	1.27	29	2	9	1.36	5	1.88	20	1.23	39
Lithuania	2.77	1.32	2.64	7	1.36	-13	2.77	0	1.32	0	2.81	-2	1.34	-6	2.73	2	1.3	6	2.64	7	1.37	-16
Estonia	1.94	1.6	1.88	6	1.56	7	1.94	0	1.59	2	1.89	5	1.55	8	1.88	6	1.57	5	1.78	17	1.49	18

RR = original rate ratio of mortality according to educational attainment, Low = primary and lower secondary education compared to post-secondary and tertiary education, Mid = higher secondary education compared to post-secondary and tertiary education, $SRR_{Physical activity}$ = Scenario rate ratio of mortality based on the assumption that the prevalence of physical activity is distributed as in the highest educational group, $SRR_{Alcohol}$ = Scenario rate ratio of mortality based on the assumption that the prevalence of alcohol consumption is distributed as in the highest educational group, $SRR_{Smoking}$ = Scenario rate ratio of mortality based on the assumption that the prevalence of smoking is distributed as in the highest educational group, SRR_{BMI} = Scenario rate ratio of mortality based on the assumption that the prevalence of high BMI is distributed as in the highest educational group $SRR_{all factors combined}$ = Scenario rate ratio of mortality based on the assumption that the prevalence of physical activity, alcohol consumption and smoking are all distributed as in the highest educational group.

gian men with a lower education. This amounts to a reduction of excess mortality from 59% ('real RR'-1) to 20% ('scenario RR'-1). Among Norwegian women, this amounts to a reduction from 1.43 to 1.31 or a reduction of excess mortality from 43% to 31%. The graphical presentation confirms the results described above: inequalities in all-cause mortality can potentially be reduced in all countries for both men and women by a redistribution of physical activity, alcohol consumption, smoking and BMI by education, but not sufficiently to eliminate them entirely. Thus, the relative contribution of the four dimensions of health behavior chosen here is limited compared to the underlying social risk factor "low level of education".

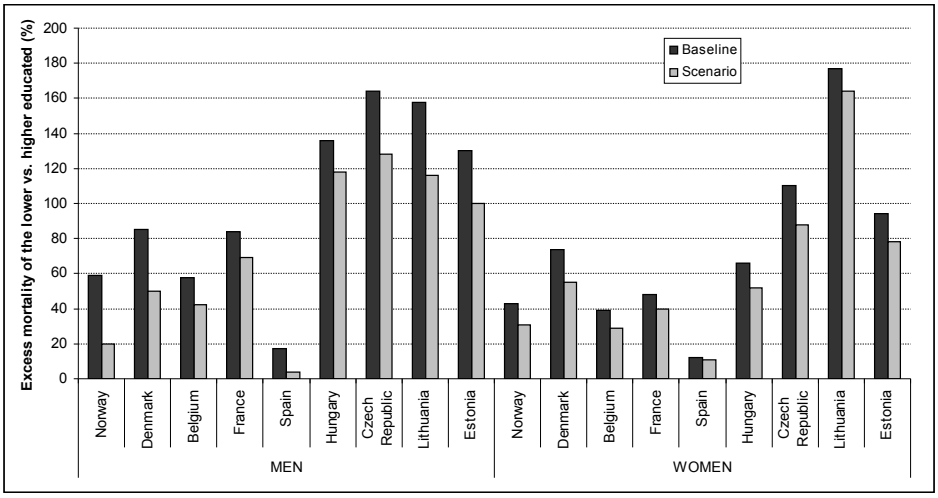

Figure 2: The potential reduction of health inequalities given the that all educational groups have the same behavior as the higher educated (scenario B) in terms of physical activity, alcohol consumption, smoking and BMI

DISCUSSION

In this working document we showed the development and successful implementation of an Excel tool for the application of the "counterfactual" methodology, which has involved a substantial amount of carefully checked data imputation and PAF calculation procedures. As illustrated, the high complexity of the tool allows separate estimations for different countries, men and women, age groups (or for all ages combined), risk factors (separately or combined), and causes of death (or all-cause mortality) in all possible combinations.

We demonstrated that the implemented Excel tool can be used to calculate the PAF given that the exposure to known risk factors is changed according to people's social position in Europe. More generally, our results suggest that the fraction of all-cause mortality preventable by a redistribution of physical activity, alcohol consumption, smoking and BMI to the

level observed among the higher educated is typically about 10% for men, and about 5% for women. However, as we have pointed out, there are large variations between countries, in which Norwegian men are observed with the highest PAF (17%) and Spanish women with the lowest (0%).

This working document also represents a first attempt to treat the lack of educational attainment as a risk factor. It is therefore required to carefully evaluate the usefulness of this approach. We showed that the fraction of all-cause mortality preventable by a redistribution of education, where the whole population has high education, is substantial in all countries, except Spain. Typically, the PAF values vary between about 30% and 50%.

Our working document also showed that there is a marked potential for reducing inequalities in mortality in Europe. Inequalities in all-cause mortality can potentially be reduced in all countries for both men and women by a redistribution of physical activity, alcohol consumption, smoking and BMI by education, but only by less than 50% and thus not sufficiently to eliminate them fully.

Another general, but important observation is that the PAFs are larger for men than for women and that the potential for reduction of inequalities in mortality is also larger for men as compared to women.

The results described above demonstrate that the PAF methodology in general and our excel tool in particular is a promising tool for estimating the extent to which health inequalities can realistically be reduced in Europe, by policies and interventions on social determinants as well as on specific risk factors.

We also compared the results of the PAF approach to those obtained through conventional regression. Their equivalence and possible differences are discussed by Hoffmann et al. [21].

Limitations

The results of this study must be interpreted in light of some important limitations that have specific relevance to our illustrative results. Moreover, these limitations are related to the assumptions which have been presented in this working document.

The first limitation concerns the collection of data. Regarding the prevalence data for proximate risk factors, it was not possible to use perfectly comparable data for different countries (assumption 2b). The categories of risk factors in the national health surveys differ and cannot always be regrouped in a way that results in the same groups for each country. The same problem exists for the categories of risk factors for which we found rate ratios by performing

literature reviews. These categories sometimes differ substantially from the categories for which we have prevalence data. Compared to this methodological chapter with only illustrative results, this situation has been improved by further reviews and better input data with comparable categorization in the final data for the Euro-GBD-SE project. The same applies to the rate ratios where, in this chapter, we were not able to use consistently adjusted rate ratios. Some studies provide adjusted rate ratios and others do not and this could have an impact on the estimated effect of the scenarios. Also, here we used risk factor data which were measured at the same time (assumption 2c), and sometimes even after the mortality data were collected (for results of the Euro-GBD-SE project data with an appropriate timeframe have been collected).

Secondly, we assume that the relative risks used in the PAF calculation accurately reflect the causal effects of the risk factors on mortality in the population under consideration (assumptions 1a-b). This may be more problematic for scenario type A as compared to scenario type B. Based on the data we use, we cannot be sure that by providing more education to those with low education, we will obtain an improvement in health corresponding to that observed in highly educated groups.

Third, the risk ratio estimates come from other studies than the prevalence rates (assumption 2a), as it is usually not possible to find both data sources for each population of a large number of European countries.

Fourth, sub-scenario three of scenario A "gives" the whole population higher education and thereby represents a theoretical limit of what can be achieved. However, we should question whether the importance of education as a social stratification indicator would possibly be reduced in this hypothetical case (assumption 1f). If everyone in the population has the same educational level, then the health returns to education would presumably diminish, because having higher education does not buy a higher position in the hierarchy. Furthermore, it is difficult to think of an intervention that would increase the education of the lower educated by more than one level. Both of these concerns have been met in this exercise by also presenting a scenario that redistributes those in the middle education category (sub-scenario 2, Table 8). We should perhaps also note that the most extreme scenario, in which everyone has been given the education of the highest educational group, is mainly a theoretical assumption, which represents another way to estimate the impact of education on mortality.

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Those who know me know that I like to travel, and this dissertation has been quite a remarkable journey. One that I did not initially plan on taking when first arriving at Erasmus MC's Department of Public Health (MGZ). But sometimes travel plans change and result in unexpected discoveries. It has been a journey I have greatly enjoyed and it is always nice to have a whole group of like-minded people to share the experience with. And, no matter how prepared one seems to be, there is nothing better than an experienced guide.

I am very lucky to have found such a guide in my promoter Prof. Johan Mackenbach. Johan, given my background in Economics and Demography, you led the way through and introduced me to the realm of Public Health. I cannot thank you enough for all of your support and inspiration, especially with your busy schedule. I admire your sheer endless knowledge of this field of research and your ability to pragmatically tackle any unforeseen bump in the road. You always saw the bigger picture, even if I sometimes still had to turn the corner to admire the view.

Terje (Eikemo), my co-promoter, thank you for joining this journey during my second Rotterdam-based project, Euro-GBD-SE, which you were leading, and for helping to combine my research there with my previous work within the DYNAMO-HIA project, both now forming this dissertation. You were always keeping up the spirits (even from distant Norway) and helped me develop a degree of determination that I did not even know I was capable of.

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National Institute for Public Health and the Environment (RIVM) in Bilthoven for the duration of DYNAMO-HIA. Thank you also to Pieter van Baal and Alet Wijga and to all other colleagues for making me part of RIVM's Center for Prevention and Health Services Research (PZO), although I was only an occasional visitor.

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ABOUT THE AUTHOR

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Margarete C. Kulik was born in Katowice, Poland on April 26th 1976. She spent her childhood growing up in Katowice, in Geithain (then still part of now former East Germany) and in Belgrade (then still the capital of now former Yugoslavia). In 1985 she and her parents came to Moers (then still part of now former West Germany). She was a senior at Oak Ridge High School in Oak Ridge, TN, USA in 1993/94 and obtained her Abitur at Gymnasium Rheinkamp in Moers, Germany in 1996. Having spent many of her school years close to the Dutch border she enrolled at Maastricht University and majored in International Economic Studies, graduating in 2000. Her master's thesis was entitled: "Germany's Troubled Pension System – Time for a Radical Reform?" Her interest in population aging and migration issues led her to obtain her MA in Demography at the University of California at Berkeley, USA in 2002.

Margarete then returned to Germany to investigate family and fertility dynamics in Eastern European countries at the Max Planck Institute for Demographic Research in Rostock. In 2006 she became a research associate at the IGES Institut in Berlin, an institute specialized in health and social research. In 2008 she was appointed researcher at the Department of Public Health (MGZ) of the Erasmus Medical Center in Rotterdam. There she has been involved in two European research projects which had the goal to develop and apply quantification tools to assess the impact of policies and interventions on risk factor prevalence and on health and inequalities. Her work on the particular applications to smoking resulted in this thesis. She remains interested in tobaco control issues and continues her research work at MGZ. There she is now also investigating the health, socioeconomic and equity impacts of neglected tropical diseases.

LIST OF PUBLICATIONS

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Papers in this thesis

Kulik MC, Eikemo TA, Regidor E, Menvielle G, Mackenbach JP for the Euro-GBD-SE Consortium. Does the pattern of socioeconomic inequalities in smoking in Western Europe depend on the choice of survey? (submitted)

Kulik MC, Menvielle G, Eikemo TA, Bopp M, Jasilionis D, Kulhánová I, Leinsalu M, Martikainen P, Östergren O, Mackenbach JP for the EURO-GBD-SE Consortium. Educational inequalities in three smoking-related causes of death in 18 European populations
Accepted for publication in "Nicotine & Tobacco Research"

Kulik MC, Nusselder WJ, Boshuizen HC, Lhachimi SK, Fernandez E, Baili P, Bennett K, Mackenbach JP, Smit HA. (2012) Comparison of tobacco control scenarios: quantifying estimates of long-term health impact using the DYNAMO-HIA modeling tool. PLoS One 7: e32363.

Kulik MC, Hoffmann R, Judge K, Looman C, Menvielle G, Kulhánová I, Toch M, Östergren O, Martikainen P, Borrell C, Rodríguez-Sanz M, Bopp M, Leinsalu M, Jasilionis D, Eikemo TA, Mackenbach JP for the Euro-GBD-SE Consortium. Smoking and the potential for reduction of inequalities in mortality in Europe
Provisionally accepted for publication in the "European Journal of Epidemiology"

Lhachimi SK, Nusselder WJ, Smit HA, van Baal P, Baili P, Bennett K, Fernandez E, **Kulik MC**, Lobstein T, Pomerleau J, Mackenbach JP, Boshuizen HC. (2012) DYNAMO-HIA-A Dynamic Modeling Tool for Generic Health Impact Assessments. PLoS One 7: e33317.

Hoffmann R, Eikemo TA, Kulhánová I, **Kulik MC**, Mackenbach JP & the Euro-GBD-SE Consortium. Development of methods to assess the potential for reduction of health inequalities. Parts of this paper have been published as Chapter 3 of the Euro-GBD-SE Final Report, available at: http://www.euro-gbd-se.eu/fileadmin/euro-gbd-se/public-files/EURO-GBD-SE_Final_report.pdf

Other contributions to the DYNAMO-HIA project

Lhachimi SK, Nusselder WJ, Lobstein TJ, Smit HA, Baili P, Bennett K, **Kulik MC**, Jackson-Leach R, Boshuizen HC, Mackenbach JP. (2013) Modelling obesity outcomes: reducing obesity risk in adulthood may have greater impact than reducing obesity prevalence in childhood. Obesity Reviews. doi: 10.1111/obr.12029.

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Toch M, Menvielle G, Eikemo TA, Kulhánová I, **Kulik MC**, Jasilionis D, Mackenbach JP for the Euro-GBD-SE Consortium. Occupational class inequalities in all-cause and cause-specific mortality among middle aged men in 14 European populations during the early 2000s (submitted)

Hoffmann R, Eikemo TA, Kulhánová I, **Kulik MC**, Looman C, Menvielle G, Mackenbach JP for the Euro-GBD-SE Consortium. Obesity and the potential reduction of inequalities in mortality in 20 European populations (submitted)

Kulhánová I, Menvielle G, Hoffmann R, Eikemo TA, **Kulik MC**, Toch M, Mackenbach JP for the Euro-GBD-SE Consortium. The potential for reduction of inequalities in ischemic heart disease mortality in Europe: The role of lifestyle risk factors (submitted)

Eikemo TA, Hoffmann R, **Kulik MC**, Kulhánová I, Toch M, Menvielle G, Mackenbach JP for the Euro-GBD-SE Consortium. The potential for reduction of health inequalities in 21 European populations (submitted)

Eikemo TA, Hoffmann R, Kulhánová I, **Kulik MC**, Toch M, & Mackenbach JP. Euro-GBD-SE Final Report, Chapter 1: General introduction to the EURO-GBD-SE project. Available at: http://www.euro-gbd-se.eu/fileadmin/euro-gbd-se/public-files/EURO-GBD-SE_Final_report.pdf

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Other published work

Hagenmeyer EG, Gothe H, Landgraf W, **Kulik MC**, Schiffhorst G, Häussler B. Ressourcen-Inanspruchnahme und Kosten der Behandlung von Typ 2 Diabetikern unter Insulin glargin- oder Insulin detemir-Therapie: Anlyse von Krankenkassen-Routinedaten mittles Propensity Score Matching (Comparison of Utilisation and Costs of Treatment for Patients with Type 2 Diabetes Using Insulin glargin or Insulin detemir: a Claims Data Analysis using the Propensity Score Matching Method). Gesundheitsökonomie & Qualitätsmanagement, 2010, 15:121-126.

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Häussler B, Reschke P, **Kulik MC**, Höer A (2006) Arzneimittel: Analogpräparate sind nicht der Grund für Mehrausgaben. Deutsches Ärzteblatt 103(38): A 2456-8. incl.: Methodische und gesundheitspolitische Probleme des Konzeptes der Strukturkomponente im Arzneiverordnungs-Report (Methodological Appendix).

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PHD PORTFOLIO

PHD PORTFOLIO: MARGARETE C. KULIK

Academic degrees obtained	YEAR	WORKLOAD ECTS
Doctoraal Examen Economische Wetenschappen (Master of Science in Economics) Maastricht University, Netherlands	2000	
Master of Arts in Demography, University of California at Berkeley, USA	2002	
Classes taken at Erasmus Medical Center, Rotterdam (NIHES)		
Methods of Health Services Research	2011	0.7
Health Economics	2011	0.7
Social Epidemiology	2010	0.7
Medical Demography	2010	1.1
Introduction to Global Public Health	2009	0.7
Methods of Public Health Research	2009	0.7
Principles of Epidemiologic Data-Analysis	2009	0.7
English Biomedical Writing and Communication	2011	4
Multistate-models and models for competing risks	2009	0.6
Other classes taken		
Maastricht Graduate School of Governance, Maastricht University		
Governance and Political Science	2008	1
International Max Planck Research School for Demography, Max-Planck-Institute for Demographic Research, Rostock, Germany (IMPRSD)		
Advanced Event History Analysis	2003/04	9
Family Dynamics: Theories and Methods	2003	3.6
General Theory of Pure Demography	2002/03	3.2
Introduction to Event History Analysis	2002/03	8
Research Tools and Presentation Skills	2002/03	1.5

Teaching activities	YEAR	WORKLOAD ECTS
Introducing the topic of "PAF and health inequalities" within the course "Public Health Research: Analysis of Determinants", NIHES Course at Erasmus MC, Rotterdam	2013	0.6
Supervising public health community project of 3rd year medical students, part of the education theme 3.C "Arts en volksgezondheid" at Erasmus MC, Rotterdam	2011	0.8
Teaching Assistant for the IMPRSD class: "Introduction of Event History Analysis", Max-Planck-Institute for Demographic Research, Rostock, Germany	2003/04, 2004/05	2.8
Presentations at Project Meetings		
Euro-GBD-SE Steering Committee/Consortium Meetings: Stockholm, Paris, Turin, Rotterdam	2010-2012	5.6
DYNAMO-HIA Steering Committee Meetings: London, Amsterdam	2008-2010	2.8
Health Equity 2020 Project Workshop: Brussels	2012	0.5
IMCA II, 3rd Group Meeting: Barcelona	2010	1
Research Meetings of the Department of Public Health and of the Social Epidemiology Section, Erasmus MC	2008-2013	1.4
Presentations at Conferences		
Oral presentation at the Congress of the Nederlands Netwerk voor Tabaksonderzoek, Utrecht, Netherlands	2013	1
Paper Presentation and Session Moderation at the Congress of the ESHMS and the DGMS Hannover, Germany	2012	1.4
Poster Presentation at WEON 2012, Rotterdam, Netherlands	2012	1.4
WEON 2012 conference organization: annual conference of the Dutch Epidemiological Society (VvE), successful grant applications, poster jury		
DYNAMO-HIA workshop at EUPHA 2010, Amsterdam, Netherlands	2010	1.4
Poster Presentation at EUPHA 2009, Lodz, Poland	2009	1.4
Seminars/Symposia		
Attendance of Research Seminars of the Public Health Department, Erasmus MC	2008-2013	3
Attendance of Network for Studies on Pensions, Aging and Retirement (NETSPAR) Symposia:		
Health expenditures a cause of increasing life expectancy?	2012	0.3
Projective future life expectancy: an interdisciplinary perspective.	2011	0.3
Attendance: From before the cradle to the grave - methodological challenges in life course epidemiology (Pre-Conference Workshop at WEON Conference, Rotterdam)	2012	0.1
Attendance: Social inequalities in health - research status and new challenges (Symposium, Trondheim, Norway)	2011	1
Attendance: Introduction to Health Impact Assessment (Pre-Conference Workshop at HIA-Conference, Rotterdam)	2009	0.2