Effects of cancer mortality on life expectancy in European high-income countries between 1950 and 2019

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ABSTRACT
This article aims to analyze the effects of cancer mortality on life expectancy at birth in 15 European high-income countries between 1950 and 2019. To establish the 1950–2019 time series of deaths from cancer, mortality data were harmonized from the available datasets of the World Health Organization Mortality database, coded according to the International Classification of Diseases of the 7th, 8th, 9th, and 10th editions. The estimation of the cancer mortality effect on the life expectancy at birth was performed using the algorithm of stepwise replacement for the life expectancy decomposition. The increase in cancer mortality contributed to a decline in overall life expectancy growth until the mid-1990s, coinciding with the aging cohorts of heavy smokers and a long-term reduction in mortality from other non-communicable diseases. Subsequently, since the 1990s, the reduction in cancer mortality has contributed to a significant increase in life expectancy at birth, especially in males. Reduction in cancer mortality was the outcome of various factors, such as alcohol and tobacco control policies, advances in cancer prevention and its treatment, general increase in population well-being, and reduction in risk-factors.

KEYWORDS
cancer mortality; life expectancy; trends; Europe

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1. Introduction

During the 20th century, life expectancy (LE) sharply increased in most countries, while in those developed, it even doubled. This is due to changes in the distribution of cause-specific mortality during this period when a decline in infectious diseases was observed, continued by a cardiovascular revolution (Vallin and Meslé 2004) and a cancer mortality diminution. However, back then, despite the notable increase in LE, cancer mortality sharply increased, especially in males, and decreased in several countries only in the 1990s (DeVita and Rosenberg 2012; Bertuccio et al. 2019). Recently, due to noteworthy changes in mortality structure in developed countries, a shift occurred from cardiovascular diseases to cancer as the leading cause of death (Stringhini and Guessous 2018; Townsend et al. 2016).

Similar mortality trends in most frequent cancer sites were observed in many developed European countries (Hashim et al. 2016), where breast (Carioli et al. 2017; Malvezzi et al. 2019), lung (Islami et al. 2015; Remon et al. 2020), prostate (Baade et al. 2009; Wong et al., 2016), stomach (Balakrishnan et al. 2017), colon and rectal cancer (Araghi et al. 2018; Ait Ouakrim et al. 2015) declined in the last decades. This became possible in the context of reduction in exposure to cancer risk factors, diagnostics and medical care improvements, and enhancement of cancer treatment effectiveness (DeVita and Rosenberg 2012; Proctor 2013). However, despite the visible decline in cancer mortality during the last decades, the impact of the 2020–2021 COVID-19 pandemic may slow down future trends (Englum et al. 2021).

This study aims to describe the long-term trends in LE changes due to cancer mortality in selected European high-income countries and to measure the impact of cancer deaths on these trends. For this, the algorithm of stepwise replacement of the LE decomposition was used. Although cancer mortality trends have already been described previously in the literature, this study quantifies the contribution of cancer mortality trends to life expectancy using data from a large set of European countries.

2. Methods

This study is based on long-term datasets on cancer mortality in selected developed European countries that contain information on the distribution of deaths by sex, age, and cause of death between the 1950s and 2019. The following list of countries with periods of data availability were selected for the research: Belgium (1954–2018), Czechia (1950–2019), Denmark (1952–2018), Finland (1952–2018), France (1950–2017), Hungary (1955–2019), Ireland (1950–2018), Italy (1951–2017), Netherlands (1950–2019), Norway (1951–2016), Poland (1959–2019), Portugal (1955–2018), Spain (1951–2019), Sweden (1951–2018), and Switzerland (1951–2018).

Cancer deaths by sex and age were retrieved from WHO (World Health Organization) Mortality Database (WHO Mortality Database) and included cancer sites that, according to the International Classification of Diseases (ICD), corresponded to the codes 140–205 (ICD7), 140–209 (ICD8), 140–208 (ICD9), and C00–C97 (ICD10). The Human Mortality Database was used as a source for the population exposure data (HMD). To organize a comparable long series of data sets on the cause of death age distribution, ICD7, ICD8, ICD9, and ICD10 classifiers have

Tab. 1 Years of transition between the ICD7, ICD8, ICD9, and ICD10 classifications in analyzed countries.

Country	ICD7	ICD8	ICD9	ICD10
Belgium	until 1967	1968–1978	1979–1997	since 1998
Czechia	until 1967	1968–1978	1979–1993	since 1994
Denmark	until 1968	1969–1993	–	since 1994
Finland	until 1968	1969–1986	1987–1995	since 1996
France	until 1967	1968–1978	1979–1999	since 2000
Hungary	until 1968	1969–1978	1979–1995	since 1996
Ireland	until 1967	1968–1978	1979–2006	since 2007
Italy	until 1967	1968–1978	1979–2002	since 2003
Netherlands	until 1968	1969–1978	1979–1995	since 1996
Norway	until 1968	1969–1985	1986–1995	since 1996
Poland	until 1968	1969–1979	1980–1996	since 1997
Portugal	until 1970	1971–1979	1980–2001	since 2002
Spain	until 1967	1968–1979	1980–1998	since 1999
Sweden	until 1968	1969–1986	1987–1996	since 1997
Switzerland	until 1968	1969–1994	–	since 1995

Source: WHO Mortality Database

been harmonized. Tab. 1 shows the years of transition between classifications in the countries studied.

The age-standardized mortality rate was calculated using the direct standardization method, where the New European Standard Population (Eurostat 2013) with a 5-year age group and the last open-ended age interval 85+ was applied as a population standard.

LE calculation was based on an abridged life table construction with the last open-ended age interval of 85+. Therefore, LE decomposition was performed using the algorithm of stepwise replacement (Andreev et al. 2002), where the age components of LE were compared between time periods and measured the contribution of cancer mortality to the LE change. These calculations were made in two steps:

1. LE decomposition was performed based on a 5-year age group interval by using the following formula:

$$\delta_x^{2-1} = l_x^2(e_x^2 - e_x^1) - l_{x+1}^2(e_{x+1}^2 - e_{x+1}^1) \quad (1)$$

Where δ_x is the difference in LE between two populations within age interval x; l_x is the number of life table survivors to age x; and e_x is the LE at the beginning of age interval x.

2. For measuring the contribution of cancer mortality to the LE change, was applied formula expressed as:

$$\Delta e_{i,x} = (m_{i,x}^2 - m_{i,x}^1) \div (m_x^2 - m_x^1) \times \delta_x^{2-1} \quad (2)$$

Where $\Delta e_{i,x}$ is the contribution of cause-specific mortality to the life expectancy change within age interval x; and m_x and $m_{i,x}$ are age-specific and age-cause-specific mortality rates in the age interval x.

For a graphic presentation of the contribution of cancer mortality to the life expectancy change, the results have been assembled into more extended age groups: 0–34, 35–54, 55–74, and 75+, respectively.

3. Results

3.1 Cancer mortality trends

Since the 1950s, cancer mortality has continuously increased for both sexes in most European countries, reaching its peak in the late 1980s (Fig. 1). Such an increase in cancer mortality was evident in most countries despite the initial gap between them. Thus, in males in the 1950s, the age-standardized cancer mortality rate ranged between 200 deaths per 100 thousand population (in Ireland, Italy, Poland, and Portugal) and above 400 deaths per 100 thousand population in Finland and Switzerland. By the end of the 1980s (in Hungary, Poland, and Portugal by the end of the 1990s), cancer mortality in males grew by 25–200%. After reaching its peak, cancer mortality in males started to decline at a pronounced pace.

In females, between 1950–2019, cancer mortality levels out mainly reaching a plateau, with the highest values of mortality rate noted in the mid of the 1990s. A different situation was observed for females in Belgium, Denmark, the Netherlands and Switzerland, where the highest cancer mortality rates were recorded during the 1950s.

3.2 Contribution of cancer mortality to the life expectancy change

Between 1950 and 1990, in Norway, Czechia, Portugal, Spain, Poland, and Hungary, cancer mortality contributed with −0.2 years, −0.6 years, −0.6 years, −1.1 years, −1.2 years, and −1.4 to the overall LE growth. In the rest of the countries, except Finland, a peak in male cancer mortality was observed in the 1980s – deaths that from 1950 diminished the growth in LE in Switzerland (−0.2 years), Sweden (−0.3 years), Denmark (−0.5 years), Ireland (−0.5 years), Belgium (−0.6 years), France (−0.8 years), the Netherlands (−0.8 years), and Italy (−1.0 years). In Finland, due to cancer mortality, a slight decline in overall male LE change was found only between 1950–1960.

From 1980 to 1990, a decrease in males cancer mortality has led to a considerable gain in LE with a cumulative contribution by 2019 of 0.2 years in Portugal, 1.1 years in Ireland, Norway and Poland, 1.2 years in Hungary and Sweden, 1.4 years in Spain, 1.5 years in Denmark, 1.9 years in Finland, France and Italy, 2.0 years in the Netherlands and Czechia, and 2.2 years in Belgium.

Between 1950 and 1960, in most countries, LE slightly declined among females due to cancer mortality, except for Ireland, Italy, and Spain, where a decrease in LE was more pronounced by 0.1, 0.2, and 0.4 years, respectively. Among females in Norway, the Netherlands, Finland, Belgium, and Switzerland, cancer mortality has continuously decreased since the 1950s. This mortality trend increased LE to 2019 by 1.0, 1.2, 1.4, 1.5, and 1.8 years. In the period 1960–2019, female LE rose in Portugal (0.5 years), Spain (0.8 years), Italy (0.9 years), France (1.0 years), Ireland (1.0 years), Sweden (1.2 years), and Denmark (1.4 years) as a result of cancer mortality decline. In Poland, Hungary, and Czechia, female cancer mortality started to decline after the 1990s, increasing LE by 0.4, 0.6, and 1.2 years.

3.3 Age components of cancer mortality in the life expectancy change

In most countries, cancer mortality among males and females younger than 35 years contributes only negligibly to increase in LE in the period analyzed (Fig. 2). A significant decrease in LE due to cancer mortality was observed in males in the period 1950–1990,

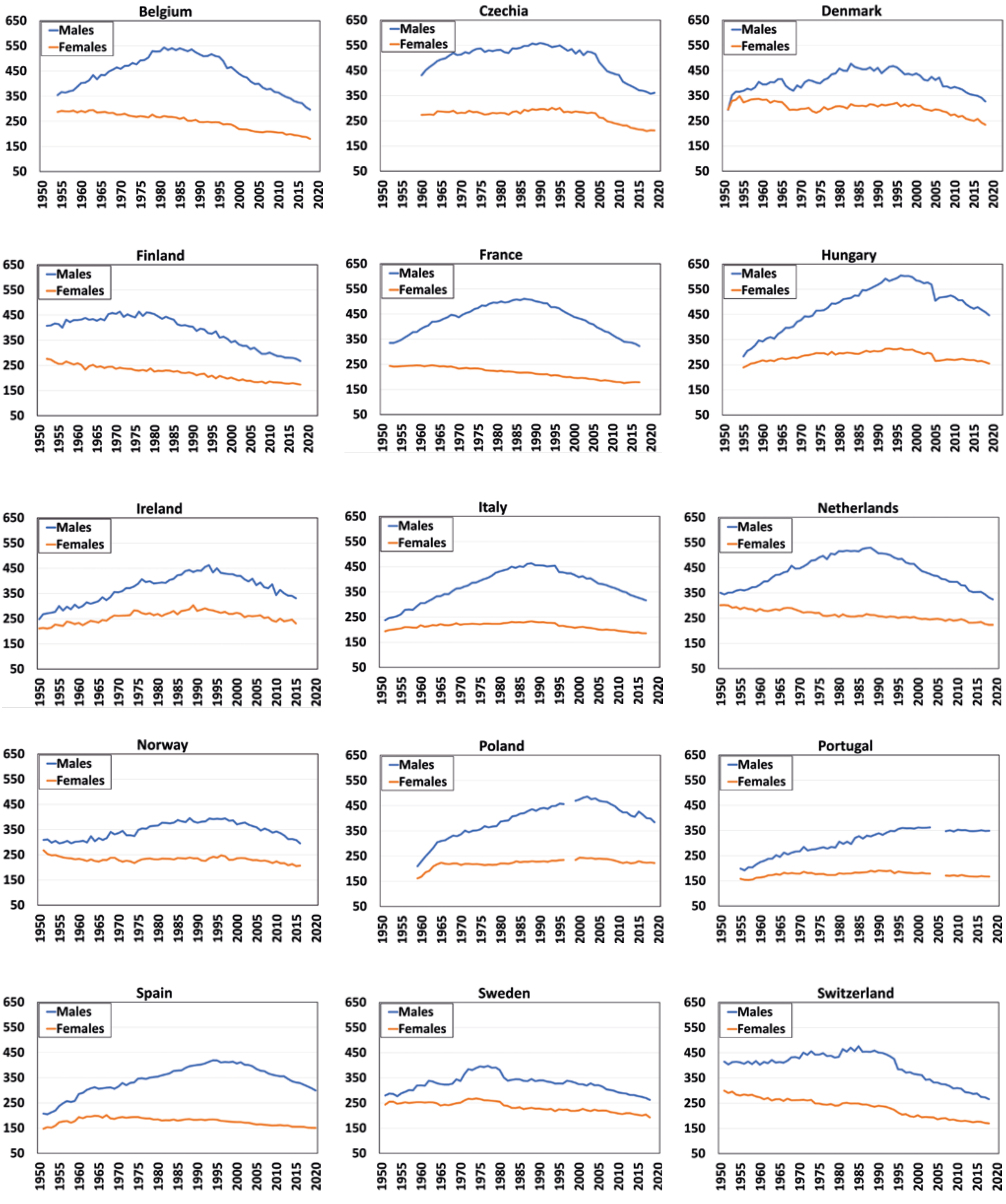

Fig. 1 Age-standardized cancer mortality rate (per 100,000 population) in 15 European high-income countries for males (A) and females (B), 1950–2019.
Source: WHO Mortality Database and Human Mortality Database

mainly in the age groups above 35, while in females, this decline was specific only to a few countries (Czechia, Hungary, Ireland, Italy, Poland, Portugal, and Spain). A considerable increase in females' LE for the 1950–1990 period was found in Belgium, the Netherlands, Switzerland and Nordic countries due to cancer mortality decline in all age groups.

After 1990 LE increase due to cancer mortality reduction was evident for males and females in all countries analyzed. This was mainly assured by the

Tab. 2 Contribution (in years) to the change in life expectancy by cancer mortality for males and females, 1950s–2019*.

	Years						
Country	**1950s–1960**	**1960–1970**	**1970–1980**	**1980–1990**	**1990–2000**	**2000–2010**	**2010–2019***
Males							
Belgium	−0.28	−0.14	−0.19	0.25	0.56	0.64	0.77
Czechia	−0.15	−0.24	−0.12	−0.12	0.45	0.85	0.70
Denmark	−0.19	−0.03	−0.26	0.01	0.27	0.62	0.63
Finland	−0.07	0.09	0.26	0.44	0.44	0.31	0.37
France	−0.28	−0.21	−0.33	0.07	0.53	0.79	0.57
Hungary	−0.20	−0.27	−0.45	−0.52	−0.05	0.49	0.68
Ireland	−0.23	−0.20	−0.06	0.02	0.22	0.78	0.39
Italy	−0.36	−0.27	−0.34	0.08	0.64	0.64	0.49
Netherlands	−0.28	−0.31	−0.16	0.23	0.42	0.52	0.80
Norway	0.04	−0.16	0.05	−0.10	0.13	0.45	0.51
Poland	–	−0.56	−0.33	−0.29	0.12	0.49	0.53
Portugal	−0.18	−0.17	−0.14	−0.10	−0.01	0.09	0.10
Spain	−0.42	−0.16	−0.22	−0.30	0.10	0.59	0.66
Sweden	−0.17	0.04	−0.13	0.23	0.23	0.41	0.35
Switzerland	0.18	−0.05	0.04	0.12	0.65	0.63	0.53
Females							
Belgium	0.03	0.15	0.14	0.22	0.36	0.22	0.41
Czechia	−0.06	0.04	−0.01	−0.05	0.24	0.58	0.36
Denmark	−0.01	0.14	−0.06	0.04	0.13	0.55	0.62
Finland	0.17	0.27	0.17	0.07	0.24	0.24	0.24
France	−0.04	0.18	0.12	0.18	0.19	0.25	0.07
Hungary	−0.09	0.01	−0.11	−0.07	0.01	0.33	0.26
Ireland	−0.10	−0.16	0.03	0.04	0.15	0.62	0.26
Italy	−0.15	0.03	0.06	0.04	0.32	0.25	0.19
Netherlands	0.16	0.06	0.34	−0.04	0.09	0.16	0.38
Norway	0.20	0.06	0.11	−0.07	0.09	0.26	0.31
Poland	–	−0.31	−0.06	−0.02	0.00	0.27	0.17
Portugal	−0.07	−0.11	0.04	0.02	0.20	0.22	0.06
Spain	−0.36	0.02	0.12	0.07	0.19	0.22	0.19
Sweden	−0.08	0.17	0.04	0.29	0.14	0.29	0.26
Switzerland	0.24	0.10	0.26	0.11	0.44	0.37	0.24

Source: WHO Mortality Database and Human Mortality Database
* Last available year

age groups between 35 and 74 years, while in countries with the highest LE, a decline in cancer mortality was observed in the ages above 75.

4. Discussion

The results highlighted a considerable impact of cancer mortality on LE change during the last 70 years. The increase in cancer mortality observed until the end of the 1980s corresponds with the period of the aging cohorts of heavy smokers (Janssen and Van Poppel 2015) and occurred after a continuous decline in mortality from cardiovascular diseases (Vallin and Meslé 2004). Even though mortality from certain types of cancer (such as stomach, uterus, etc.) decreased since the 1950s, the cancers directly connected to smoking registered a visible increase until the end of the 1980s (Meslé 2002). Nevertheless, the age- and sex-differentiation in cancer mortality contribution to the LE change relied on divergence in the risk factors and predominant types of cancer in males and females (Radkiewicz et al. 2017; McCartney et al. 2011).

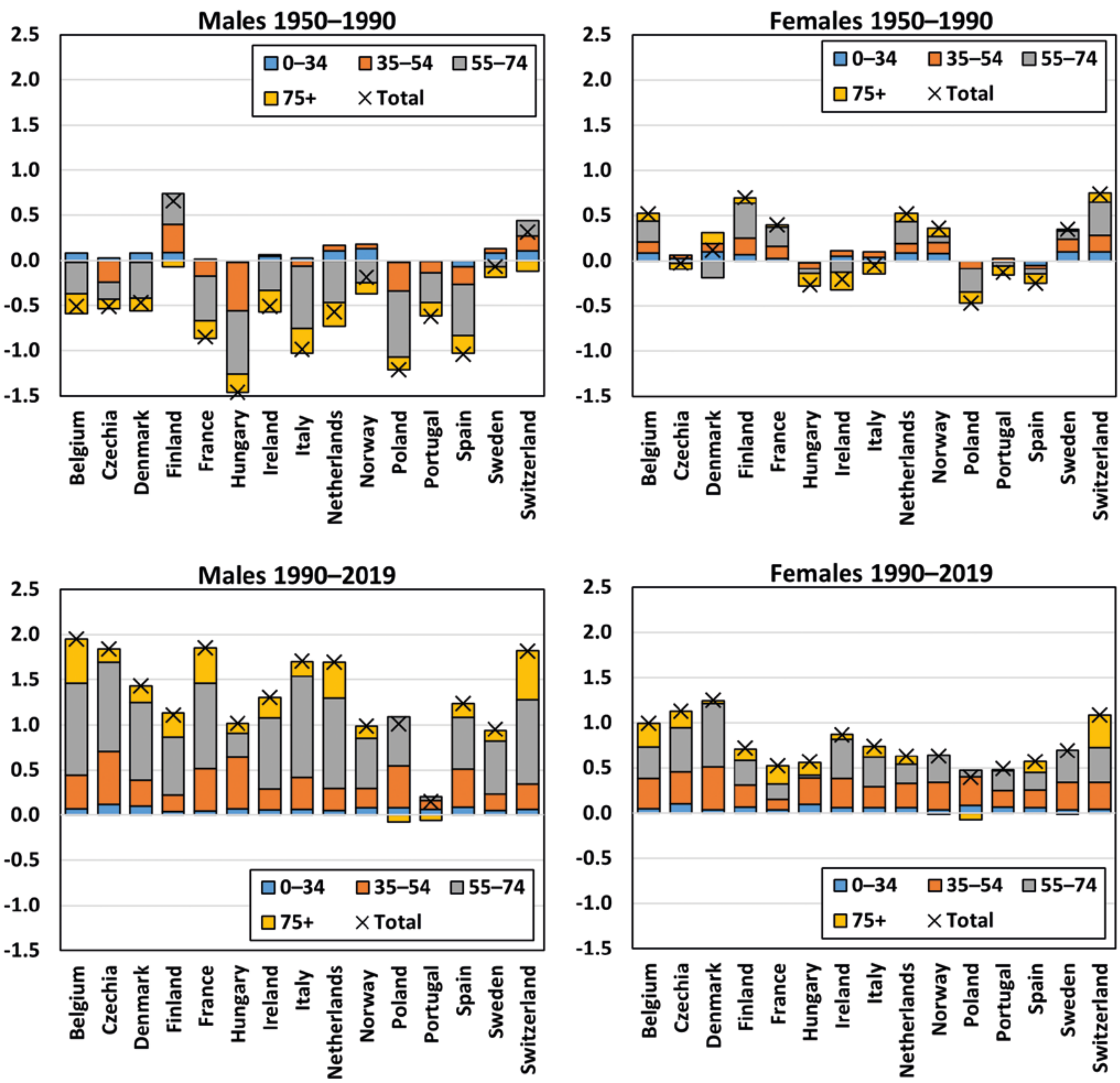

Fig. 2 Contribution (in years) of cancer mortality to the increase in life expectancy by age groups and sex, 1950–1990 and 1990–2019*.
Source: WHO Mortality Database and Human Mortality Database
* Last available year

In the 1990s, cancer mortality began to fall, which resulted from the mutual influence of cancer-preventive policies and significant improvements in cancer treatment. An outstanding contribution to reducing cancer mortality has been made by discovering new cancer treatment methods, including surgery, chemotherapy and radiation therapy (DeVita and Rosenberg 2012), introducing alcohol and tobacco control policies (Gredner et al. 2021), vaccination against hepatitis B (Lee et al. 1998) and efficient treatment of hepatitis C. An important contribution to cancer prevention and risk-factors reduction is made by a general increase in population education and welfare (Arık et al. 2021). However, such results in cancer mortality reduction were possible under an efficient bureaucratic system and high population responsiveness towards the health policies implemented in European countries (Mackenbach and McKee 2015).

The role of birth cohorts in determining cancer mortality trends has been distinctly described in earlier studies (La Vecchia et al. 1998). Consequently, the changes in behavioural factors that contribute to cancer mortality increase (e.g. high prevalence in alcohol and tobacco consumption), or the influence of cancer preventive policies and improvement in its treatment, will contribute to the changes in cancer mortality trends via cohort and period effects.

A substantial increase in LE due to a decrease in cancer mortality in the Central European countries of the former socialist bloc might be explained by the so-called low base effect when in previous years, in Czechia, Hungary, and Poland, cancer mortality was significantly higher compared to Western European countries. Catching up economies of these countries allowed for adjusting cancer prevention and treatment standards, which contributed to a convergence in cancer mortality in the 15 European countries investigated (Bremberg 2017).

In recent years, during the COVID-19 pandemic, a decrease in the number of planned cancer treatments and screening procedures was observed (Englum et al. 2021; Mayo et al. 2021). This disruption might have a long-term impact on cancer mortality. However, continuous improvements in cancer treatment and early detection significantly contribute to cancer mortality reduction (DeVita and Rosenberg 2012).

5. Limitations

The study is based on WHO long-term data on age, sex, and cause-of-death mortality distribution, which primarily was provided by the national authorities, that not necessarily have an identical approach in codifying deaths according to the ICD classification (e.g. in diagnosing the underlying diseases that caused a fatal outcome). Additionally, the countries studied had different transition periods between the ICD classifications, which may affect the comparability results between the countries and periods analysed.

The method of decomposition used to measure the impact of cancer mortality on the LE change, in fact, measures the contribution of cause-specific mortality in the overall LE indicator. Thus, a decline in violent, infectious or non-communication disease mortality could contribute to an increase in exposure of cancer fatality, and, on the contrary, a decline in cancer mortality would increase in later ages mortality.

6. Conclusions

Cancer mortality continuously increased in 15 European countries until the late 1980s and mid-1990s, which coincided with a long period of growth in the population's lifespan, the aging of cohorts of heavy smokers, and an increase in behavioral and risk-factors incidence. After reaching its peak in the 1990s, cancer mortality has significantly declined, contributing to a considerable increase in LE, especially in males.

Recent decline in cancer mortality is one of the leading resources for increasing LE in most high-income countries. As cancer is nowadays one of the leading causes of death, understanding of past and future trends in cancer mortality and its contribution to the LE may be of importance for policymakers in order to set up preventive strategies.

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