MORTALITY PATTERNS DURING THE TRANSFORMATION ERA IN CZECHIA 1989–2019

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Abstract
Mortality has decreased during the era of political and socio-economic changes in society since the Velvet Revolution in Czechia in 1989. A reduction in mortality was recorded in the period from 1989 to 2019 among infants and the share of middle and older age groups on the decline has increased. In Czechia, infant mortality has been reduced to one of the lowest at the level of European Union countries. The most common death of an infant occurs in the first days after birth. The reduction in mortality rates also meant an increase in life expectancy at birth. To study the impact of mortality of the different age groups on a change in life expectancy at birth, we used a decomposition method. Moreover, we showed the decrease in a mortality dispersion in life table distribution, nonetheless the greater degree of inequality among men compared to women persists, and deaths have shifted to higher ages. Mortality was further decomposed into senescent and background components based on the logistic model. Senescent mortality, which depends on age, decreased in Czechia during the period of 1989–2019, while background mortality did not show any trend, but rather fluctuations. Mortality from the most common causes of death from diseases of the circulatory system and malignant neoplasms decreased.

Keywords: Mortality, life expectancy, decomposition, cause of death

Demografie, 2020, **62: 211–226**

INTRODUCTION

The mortality of the population of Czechia has improved since 1989, when the most political and socio-economic changes in society began. This process of transformation has generally had a favourable effect on mortality patterns (*Dzúrová*, 2000). The biggest decline in mortality by causes of death is visible in the case of circulatory diseases, where the reduction in cardiovascular mortality at adult and old ages was crucial for the increase in life expectancy after 1991 (*Fihel – Pechholdová*, 2017). The mortality decline was further influenced by political changes and a rapid transition to an open market economy, resulting in better conditions for improvement in population health (*Rychtaříková*, 2004; *Fiala et al.*, 2018). A healthcare reform took place, private health care was developed, and the availability of effective drugs, especially for the treatment of circulatory diseases, greatly improved. Modern medical technology became available, mainly in the field of non-invasive cardiac surgery (*Rychtaříková*, 2004; *Fiala et al.*, 2018),

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contributing to a profound reduction in cardiovascular mortality (*Fiala et al.*, 2018). Furthermore, one of the underlying reasons was significant change in nutritional habits as a result of the abolition of state subsidies and the liberalization of consumer prices (*Dzúrová*, 2000). Changes in the price system increased the demand for vegetable fats as opposed to animal fats, poultry as opposed to pork and beef, and resulted in more affordable prices of fruits and vegetables – all of which helped to advance a healthier dietary regimen (*Dzúrová*, 2000). Generally, the life expectancy has significantly increased since 1989, nonetheless compared to the developed countries of the European Union, Czechia still lags behind in the achieved level of mortality. The population projection until 2100 produced by the Czech Statistical Office (*CZSO*, 2018) expected a continuing growth in life expectancy based on the growth of life expectancy in Czechia and developed European countries[3)] over recent decades. However, as stated by (*CZSO*, 2018), the value currently reported by Czechia was reached in developed European countries on average 20 years ago. Nevertheless, due to the close connection of Czechia to the European area, it is assumed that future development will follow the trajectory of development observed so far in European countries with a high life expectancy (*CZSO*, 2018).

Deaths of infants under one year of age are given special attention. As is well known, infant mortality is one of the crucial characteristics of a country's level of development in connection with the assessment of the level of health care. The change in mortality is not the same in all ages (*CZSO*, 2018): one of the main features of current developments is the increasing influence of older age groups on the mortality decline (the so-called ageing of mortality decline). The decline in infant mortality has led to an increase in life expectancy in recent decades. Due to the currently relatively low values of infant mortality, no further significant reduction in the values can be expected that would have an impact on an increase in life expectancy at birth (*Arltová et al.*, 2013). In order to describe disparities in lifespan between males and females, we computed the median and modal ages at death, which are considered together with life expectancy as appropriate characteristics describing the distribution of life table deaths (*Cannudas-Romo*, 2010).

Decomposing the difference in life expectancy into age groups is useful in estimating how the mortality of a given age group contributes to the overall difference in life expectancy (*Preston et al.*, 2001). In order to evaluate the impact of mortality of the age group on a change in life expectancy at birth between two periods, we used the decomposition method according to Arriaga (1989). We also proposed a decomposition of mortality into senescent and background mortality based on Kannisto's logistic model. Senescent mortality was investigated as it depends on age (increases with age), while background mortality is constant with age, which allows to further assess the development of mortality separately by these two components. The first one, senescent mortality, is the result of biological aging; it can be postponed through medical intervention, but it cannot be avoided because death is inevitable (*Bongaarts*, 2009). The second one, non-senescent or background mortality, refers to deaths unrelated to aging (e.g. accidents, certain infections, etc.), which can be avoided by effective public health and safety measures and through medical intervention (*Bongaarts*, 2009). Senescent and background mortality are evaluated between 1989 and 2019. Furthermore, the development of estimated parameters based on the selected logistic model over the period of 1989–2019 in Czechia was examined. The selected model is based on a logistic curve, which takes into consideration the deceleration in mortality increase with age, and the model generally operates with a continuous definition of mortality, the so-called force of mortality (*CZSO*, 2018). In addition, the logistic model is also used, for example, for mortality modelling at high ages in the construction of life tables by the CZSO or by the Human Mortality Database (HMD). A logistic model including the Makeham parameter for

3) 15 European countries with good and quality mortality data were monitored: Austria, Belgium, Denmark, Finland, France, Great Britain, (former) West Germany, Ireland, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland.

background mortality was used for modelling mortality in several studies (see for example *Horiuchi – Wilmoth*, 1998; *Thatcher,* 1999; *Bongaarts*, 2005). Indeed, among the most common models assuming an exponential increase in mortality with age is the well-known model according to Benjamin Gompertz from 1825, later with the addition of constant expressing age-independent mortality to the formula by William Makeham in 1860.

To assess the development of mortality by cause of death in Czechia, a period was chosen from 1994 after the introduction of a revision of the 10th revision of the International Statistical Classification of Diseases and Related Health Problems (ICD-10) in order to have consistent data for comparison over the period. In Czechia, the ICD-10 is introduced by CZSO Communication No. 495/2003 Coll., on the publication of the International Statistical Classification of Diseases and Related Health Problems (ICD-10), effective from 1 January 2004 with its subsequent updates in 2008, 2011, 2012, 2017 and the latest in 2020. Although the introduced classification complies with international standards, the results may be affected due to the methodological changes. Another reason for choosing this period is the availability of data in the Eurostat database since 1994, with the last available year being 2017. To evaluate the mortality of the population by causes of death in the given period, causes of death were selected that have long been among the most common causes in Czechia. The age-standardized death rates (per 100,000 people) based on the European standard population from 2013 were used for comparability of data on mortality by the selected causes of death according to ICD-10 in the given period. The decomposition method was used to assess the effect of the given group of the cause of death group according to ICD-10 on the change in life expectancy at birth between 1994 and 2017. We followed the procedure to evaluate the effect of changes in mortality by the cause of death on the overall change in life expectancy at birth according to Arriaga's proposal (*Arriaga*, 1984; *Arriaga*, 1989), where in the first step the difference between life expectancies at birth is decomposed by the contribution from each age group, and in the second step the contributions from each separate age group were divided into the contributions from each specific cause of death. Due to the fact that diseases of the circulatory system and neoplasms are among the most common groups of causes of death, specific groups of causes of death were also selected for a more detailed assessment of the mortality trend by cause of death for the period of 1994–2017 in Czechia.

DATA AND METHOD

The main data source was the life tables for Czechia for the period of 1989–2019 produced by the Czech Statistical Office. The Eurostat database containing data on mortality by cause of death for Czechia for the period of 1994–2017 was chosen as another data source. Life expectancy at birth, life expectancy at the age of 65 and the infant mortality rate were selected to examine the development of mortality in Czechia. To decompose the overall change in life expectancy at birth by age groups between two periods, Ponnapalli (2005) listed formulas in life table terms of l_x and e_x with regards to Arriaga's original proposal. The total effect *TE* of each age group on a change in life expectancy at birth can be written in the following form:

$$TE_x = l_x^1\left(e_x^2 - e_x^1\right) - l_{x+n}^1\left(e_{x+n}^2 - e_{x+n}^1\right),$$

where l_x^1 and l_{x+n}^1 is the number of surviving at age x and $x + n$ for period 1; e_x^1, e_x^2 and e_{x+n}^1, e_{x+n}^2 are life expectancies at age x and $x + n$ for periods 1 and 2.

For the open-ended age group, the total effect *TE* is calculated as follows (*Ponnapalli*, 2005):

$$TE_x = l_x^1(e_x^2 - e_x^1)\ .$$

In order to describe the disparities in lifespan among males and females, except for life expectancy representing a mean value, we computed the median and modal ages at death. To obtain median age at death *Md* in time *t*, we followed the formula (*Cannudas-Romo*, 2010) using values of the survival function at two contiguous ages $l(x)$ and $l(x+1)$ assuming a linearity in the interval where $l(Md) = 0.5$ is located.

$$Md\left(t\right) = x + \frac{\left[0.5 - l\left(x,t\right)\right]}{\left[l\left(x+1,t\right) - l\left(x,t\right)\right]}.$$

The modal age at death *M* expresses the age *x*, where the highest number of deaths occurs in the life table at time *t*. The number of deaths *d* at ages *x*, *x*–1 and $x + 1$ are used to fit a quadratic polynomial to the function describing the death distribution (*Canudas-Romo*, 2008).

$$M(t) = $$

$$= x + \frac{\left[d(x,t) - d(x-1,t)\right]}{\left[d(x,t) - d(x-1,t)\right] + \left[d(x,t) - d(x+1,t)\right]}$$

for x > 5.

For the decomposition of background mortality and senescent mortality, Kannisto's logistic model is considered using the continuous mortality rate μ_x, the so-called force of mortality. The model can be written in the following form (*Thatcher et al.*, 1998; *Thatcher*, 1999):

$$\mu_x = \frac{\alpha e^{\beta x}}{1 + \alpha e^{\beta x}} + c,$$

where x is age and α, β are the parameters of the model, c is a constant.

The sum of these two components equals the force of mortality (*Bongaarts*, 2005). For Kannisto's logistic model, the first term on the right-hand side is equal to the senescent force of mortality, and the background force of mortality corresponds to parameter c in the model (*Bongaarts*, 2005). The goodness of fit is tested using the coefficient of determination R^2. The age range of 20–90 years was chosen in order to estimate the values of model parameters due to the low numbers of deaths in old age and the lower reliability of data on the middle-year population in the oldest age. Makeham (1867), for instance, has neglected the ages under 20 and over 80, on account of the comparative insignificance of the numbers at risk at the excluded ages. Similarly, Bongaarts (2009) used as a threshold age a slightly higher age limit to avoid the "accident mortality hump" around age 20, namely the age of 25 years. With a monotonic increase in mortality with age, the following relationship between the force of mortality and mortality rate at a given age applies approximately (*Thatcher et al.*, 1998):

$$m_x \cong \mu_{x+0.5}.$$

According to Arriaga (1989) for calculating age-cause-specific decomposition we observe in the first step the proportion of change in the cause-specific mortality rates as a share of the total mortality change in the specific age interval. In the second step, we distribute the calculated total effect into specific cause contributions according to the proportions calculated in the first step. In formulas (*Auger et al.*, 2014) as follows:

$${}_nC_x^{(i)} = {}_nC_x \cdot \left[\frac{{}_nR_x^{(i,2)} \cdot {}_nm_x^{(2)} - {}_nR_x^{(i,1)} \cdot {}_nm_x^{(1)}}{{}_nm_x^{(2)} \cdot {}_nm_x^{(1)}} \right],$$

where ${}_nR_x^{(i)}$ is the proportion of deaths between ages x and $x + n$ due to cause i, and ${}_nm_x$ is the all-cause mortality rate between ages x and $x + n$.

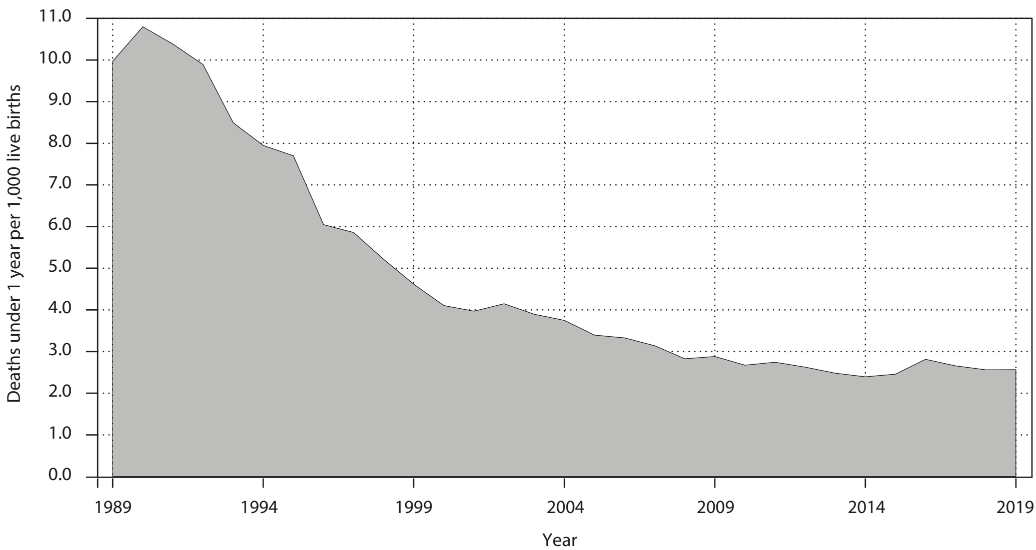
MORTALITY DEVELOPMENT IN CZECHIA IN 1989–2019

Infant mortality

The reduction in infant mortality has continued during the period of 1989–2019 in Czechia. Figure 1 presents the infant mortality rate in Czechia in 1989–2019. The highest number of infant deaths under one year of age per 1,000 live births was in 1990 (10.8‰). In the period of 1990–2019, infant mortality almost gradually decreased with some fluctuations to 2.6‰ in 2019. Infant deaths under the age of one year are not evenly distributed throughout the year; in general, the most deaths occur in the first days after birth.

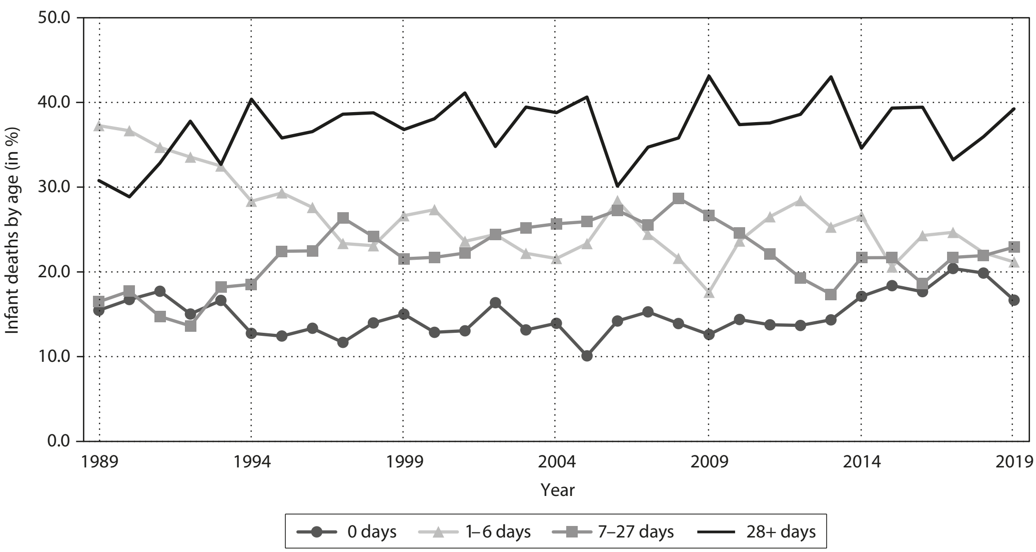
Among infant deaths in Czechia in 1989–2019 (Figure 2), the highest share of deaths was from 28 days to one year of life (36.9%), then the share of deaths between the first and sixth day of life followed (26.2%). Deaths between the seventh to 27th day of life accounted for 22.0% and the remaining 14.9% were deaths within 24 hours. Given the range of the category over the 28th day of life to one year of life, it is not surprising that it represented the highest part of the total number of infant deaths. The majority of infant deaths occurred under 24 hours together with deaths between the first and sixth day after birth. The lowest value of share of deaths under one day in the given period was recorded in 2005 (10.1%) and, conversely, the highest value was registered in 2017 (20.4%). In 2014–2019, the share of children who died during the 24 hours after birth was slightly above average. The share of deaths between the first and sixth day of life decreased slightly in the period of 1989–2019. By 2019, the share of deaths between the first and sixth day after birth had fallen by 16.1 percentage points to 21.2% since the year 1989. By 2008, the share of deaths from the seventh to the 27th day of life had increased to 28.7% since the year 1989, followed by a decline to 17.4% (in 2013) and again a slight increase to 22.9% in 2019. Moreover, the share of deaths occurring from 28 days after birth increased from 30.8% in 1989 to 39.2% in 2019.

Figure 1 **Infant mortality rate in Czechia 1989–2019 (in ‰)**



Source: Czech Statistical Office (2020a), author's processing.

Figure 2 **Infant deaths by age in Czechia 1989–2019 (in %)**



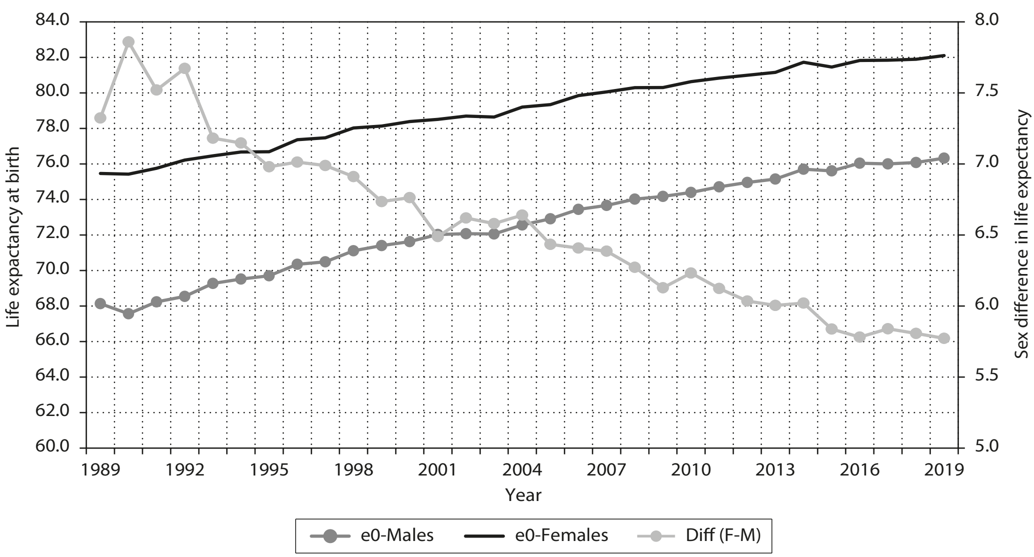
Source: Czech Statistical Office (2020a), author's processing.

Life expectancy

Life expectancy is one of the most used indicators in the study of mortality due to its comparability based on the model of a stationary population. The indicator reflects mortality in all age groups with no dependency on the age structure of the current population. As seen in Figure 3, the length of human life measured by life expectancy at birth increased during the period of 1989–2019 for both men and women in Czechia. Male life expectancy at birth has increased during 30 years by 8.2 to 76.3 years. Female life expectancy at birth increased less than for males, by 6.6 to 82.1 years in 2019. The male excess mortality decreased between the years 1989 and 2019. The highest value of the difference between the sexes was recorded in 1990 (7.9 years). On the other hand, the lowest difference in life expectancy at birth between men and women was in 2019 (5.8 years).

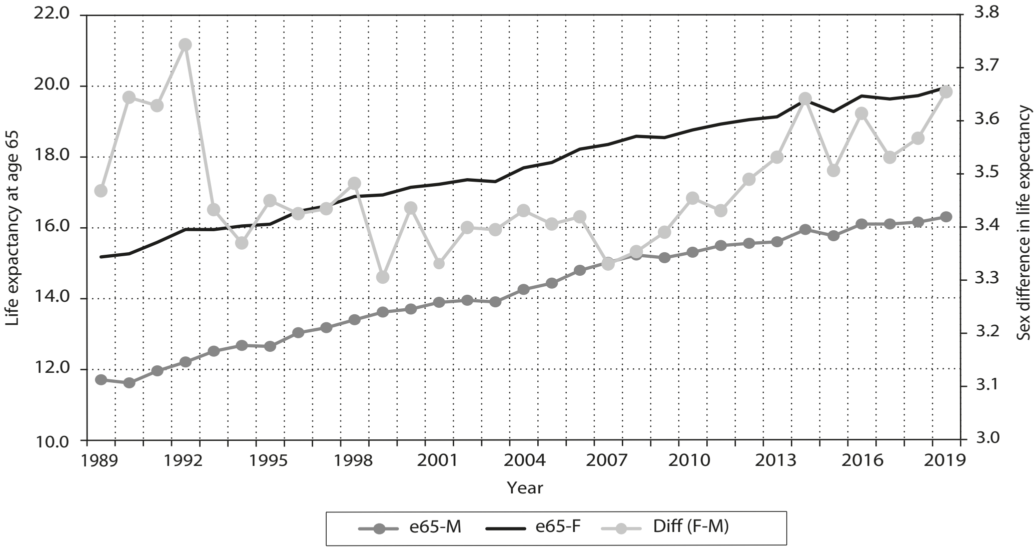
Compared to men, women tend to live longer, but on the other hand they suffer from greater morbidity, especially at an older age. This mortality-morbidity paradox is reported in connection with the longer life expectancy of women (*Austad – Fisher*, 2016). Male excess mortality is one of the recent demographic phenomena that have occurred in connection with the reduction of infections and the increase in mortality from neoplasms and cardiovascular diseases (*Beltrán-Sánchez et al.*, 2015). Male excess mortality has both biological and non-biological origins (*Sundberg et al.*, 2018). Given the generally higher mortality of men, it is interesting to observe the differences in mortality at older ages. Life expectancy at the age of 65 is most often stated, which expresses the length of a person's remaining life at a given age. The advantage of such an indicator is its better assessing of the mortality at a given age, because the person has already "survived" some causes of death occurring in younger ages, for example some of the external causes, and some of the infectious and chronic diseases, etc. Figure 4 shows that male life expectancy at the age of 65 increased between 1989 and 2019 by 4.6 years to 16.3 years. Female life expectancy at the age of 65 increased more compared to men, by 4.8 years to 19.9 years. At the beginning of the period in 1989, the difference in life expectancy between men and women at the age of 65 was around 3.5 years. It can be observed that the difference in the period fluctuated around this value. In particular, lower numbers of deaths at higher ages and the methodology used to model mortality rates may

Figure 3 **Life expectancy at birth by sex in Czechia, 1989–2019**



Note: Diff (F-M) – Female life expectancy minus male life expectancy (at birth).
Source: Czech Statistical Office (2020b), author's processing.

Figure 4 **Life expectancy at age 65 by sex in Czechia, 1989–2019**



Note: Diff (F-M) – Female life expectancy minus male life expectancy (at the age of 65).
Source: Czech Statistical Office (2020b), author's processing.

account for the fluctuations in the time series. The highest difference was recorded in 1992 (more than 3.7 years). On the contrary, the lowest difference was in 1999 (3.3 years). In 2019, the difference was equal to almost 3.7 years.

We calculated the contributions to the overall change in life expectancy at birth by age groups for males and females in the period from 1989 to 2019 (Table 1). The tempo of an increase in life expectancy gradually decreased mostly as a result of a reduction

Table 1 **Contributions to difference in life expectancy at birth by age group and sex, Czechia in 1989–2019**

Age Group	**1989–1999**		**1999–2009**		**2009–2019**		**1989–2019**	
	m	**f**	**m**	**f**	**m**	**f**	**m**	**f**
0	0.48	0.28	0.13	0.14	0.01	0.04	0.66	0.47
1–24	0.15	0.07	0.22	0.08	0.06	0.04	0.44	0.19
25–44	0.29	0.20	0.33	0.09	0.20	0.05	0.86	0.36
45–64	1.08	0.66	0.98	0.45	0.99	0.41	3.19	1.62
65–84	1.19	1.35	1.08	1.27	0.76	0.97	2.89	3.61
85+	0.07	0.11	0.03	0.14	0.14	0.30	0.14	0.38
Total	**3.26**	**2.67**	**2.77**	**2.17**	**2.16**	**1.80**	**8.19**	**6.64**
				%				
0	14.84	10.62	4.70	6.35	0.64	2.02	8.11	7.15
1–24	4.58	2.64	7.87	3.47	2.70	2.16	5.41	2.86
25–44	8.74	7.46	12.00	4.15	9.15	2.64	10.51	5.38
45–64	33.13	24.71	35.33	20.95	46.00	22.90	38.89	24.47
65–84	36.58	50.38	39.06	58.63	35.08	53.74	35.34	54.42
85+	2.13	4.19	1.04	6.45	6.43	16.55	1.73	5.73
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

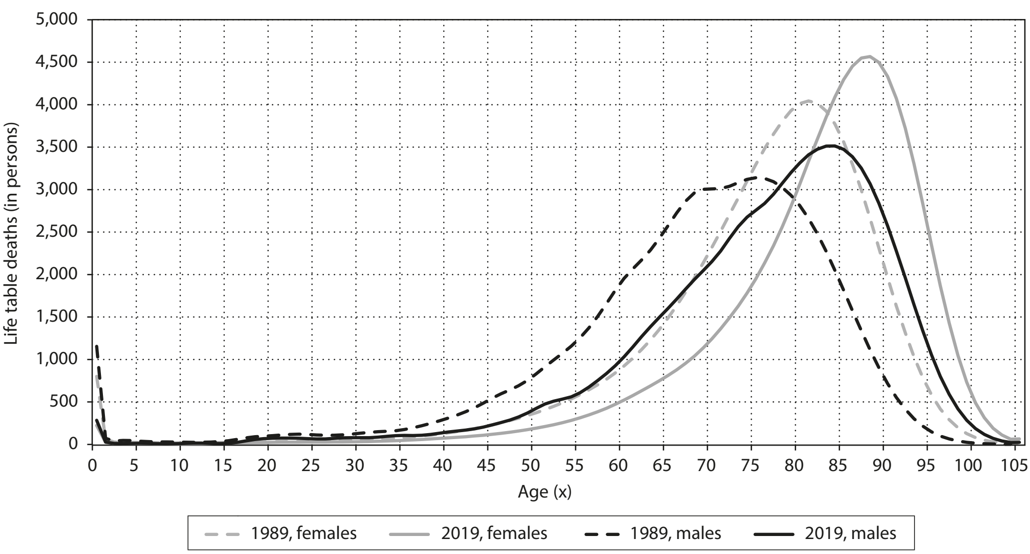
Source: Czech Statistical Office (2020b), author's calculations.

in the contribution of the age group 0 years to the overall change in life expectancy at birth. Since 1989, due to the decrease in infant mortality, life expectancy at birth has increased by 0.66 years for men and 0.47 years for women. The highest contribution was recorded for men in the age group 45–64 years (3.19) and 65–84 years (2.89). Female life expectancy at birth increased the most thanks to the contribution of the age group 65–84 years (3.61) and 45–64 years (1.62). Male life expectancy increased faster than female life expectancy between 1989 and 2019. The difference in life expectancy at birth between 1989 and 2019 equals the total contribution that was calculated at 8.19 years for men and 6.64 years for women. The contributions of the age groups of men exceeded the contributions of the age groups of women up to the age of 65, from which higher contributions were recorded for women. In relative terms, women had a significantly higher contribution of the age group 65–84 than contributions for the other age groups (higher than 50%). The value of contributions for women in the age group of 85 years and above gradually increased. On the contrary, male mortality improved in the younger and middle-aged groups. The contribution of men in the age group 45–64 years increased relatively.

Median and modal age at death

In general, mortality increases with age, which is also sometimes called the law of mortality. In addition, around the age of 20 a so-called "adult mortality hump", or increased mortality, can be observed especially due to external causes of death in young people, particularly for men compared to women. It is known that women have lower mortality compared to men and die at an older age. In Figure 5, we show a comparison of the distribution of male and female life table deaths for Czechia in 1989 and 2019. The change of mortality in the period of 1989 to 2019 showed that deaths shifted to higher ages, both in men and women. In 1989, the modal age at death was calculated at 75.7 years for males and 80.4 years for females. Over the 30 years in 2019, the modal ages are closer to each other (84.0 years for males and 88.2 for females); nonetheless, the greater number of female deaths persists at high ages. The further change of mortality refers to lower mortality dispersion in 2019 compared with 1989. The median age at death was calculated at 70.8 years for males and at 78.2 years for females in 1989. Then in 2019, the median age at death was slightly closer to the life expectancy at birth, with the values of 79.0 years for males and 84.8 years for females in 2019.

Figure 5 **Life table deaths, males and females, Czechia in 1989 and 2019**



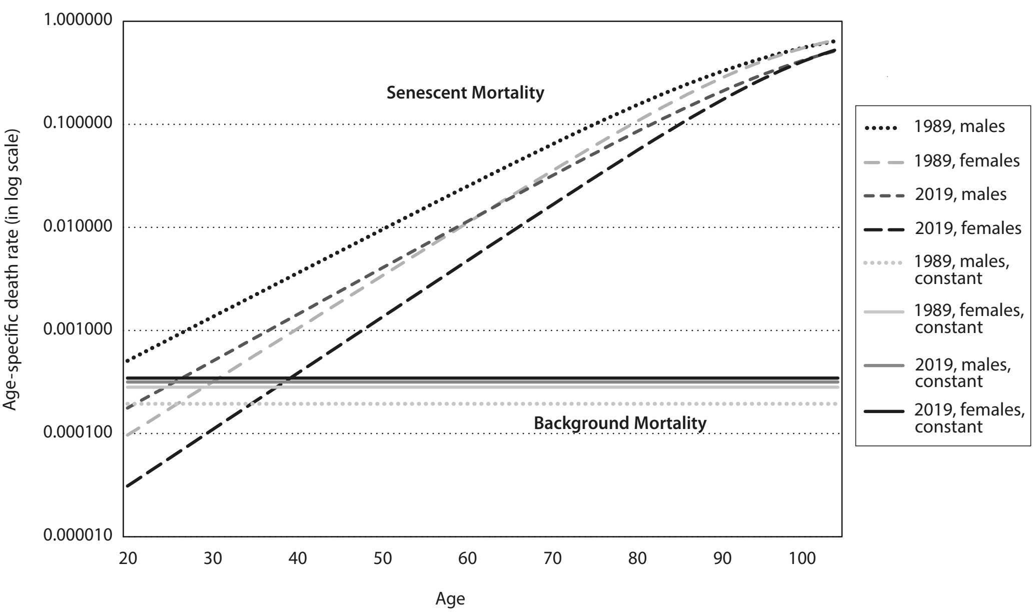
Source: Czech Statistical Office (2020b), author's processing.

Senescent and Background Mortality

The model estimates of senescent and background age-specific death rates in the age group 20–105 years for males and females in Czechia in 1989 and 2019 based on Kannisto's logistic model are shown in Figure 6. The goodness of fit of the model was tested using the R^2 statistic with the following results: 0.9961 (for males in 1989); 0.9988 (for females in 1989); 0.9945 (for males in 2019); and 0.9936 (for females in 2019). Based on the values of R^2, the model can be considered appropriate as the chosen model explained almost 100% of the variability. The estimate of senescent mortality decreased when comparing the years 1989 and 2019, both in men and women. The decrease of senescent mortality is more significant at lower ages as well. The shape of the curves of the estimated senescent mortality showed a slowing increase in the intensity of mortality towards the end of human life (so-called deceleration). The estimated background mortality slightly increased over the period, where the increase was higher for men compared to women.

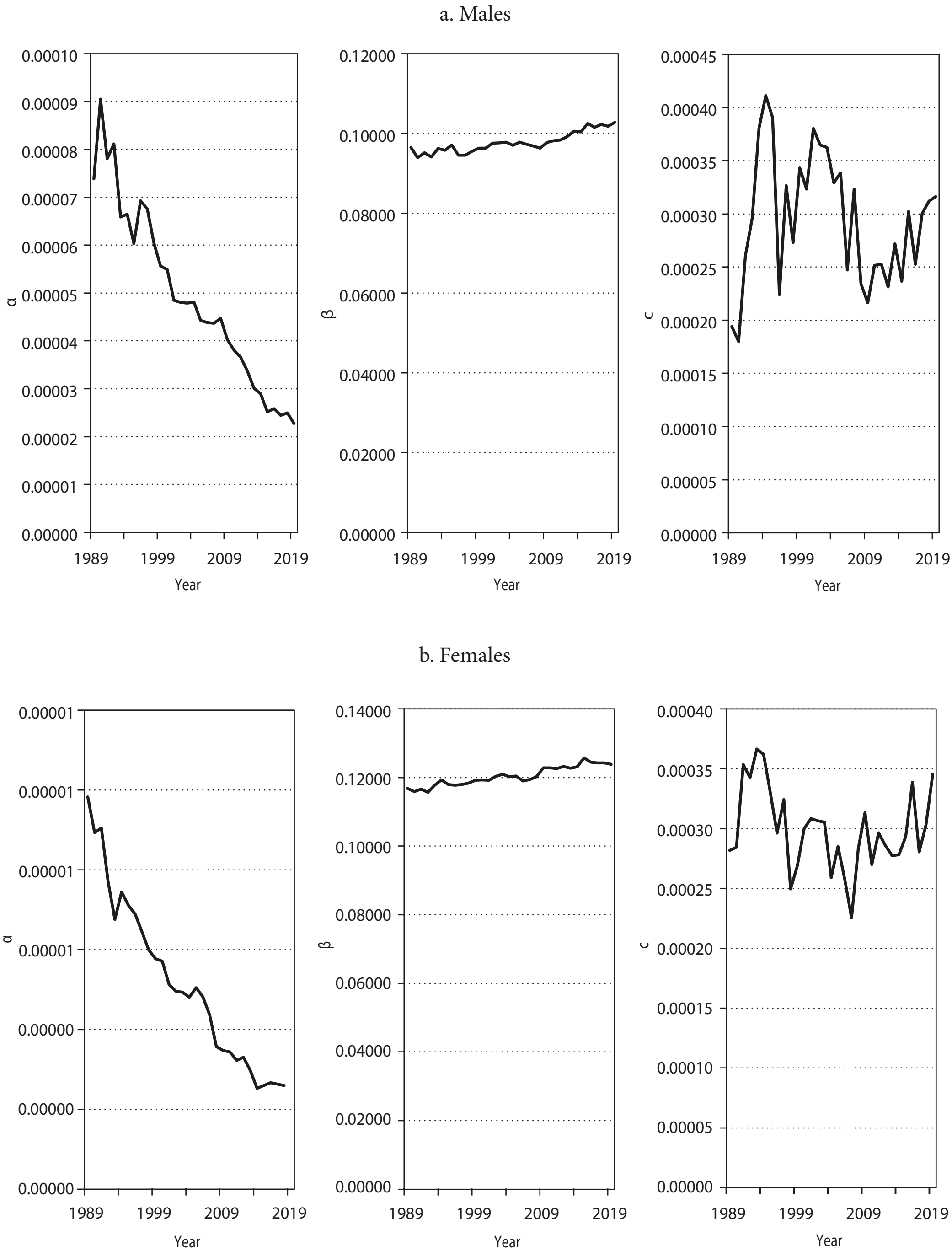
To show trends in mortality over the period of 1989–2019 for Czechia, we used the estimated parameters of Kannisto's logistic model within the age range from 20 to 90 years (Figure 7). The level parameter decreases during the period, both in men and women. As seen in Figure 7, the slope parameter seems to be nearly constant over time with a slightly upgoing trend. Similar findings were found in (*Bongaarts*, 2005; *Gavrilov – Gavrilova*, 1991; *Thatcher*, 1999). The decline in the value of the level parameter implies a decline in senescent mortality (*Bongaarts*, 2005). The constancy of the slope parameter implies that the senescent component of the force of mortality shifts to higher or lower ages as mortality conditions improve or deteriorate (*Bongaarts*, 2005). Although background mortality increased slightly between 1989 and 2019 (Figure 6), the estimated values of parameter for the period 1989–2019 (Figure 7) showed a higher variability of values over time, while no trend is shown except the fluctuations. Given the nature of background mortality, which is mainly related to external causes of death such as accidents, etc., fluctuations are not unexpected.

Figure 6 **Model estimates of senescent and background age-specific death rates in the age group 20–105 years, males and females, Czechia in 1989 and 2019**



Source: Czech Statistical Office (2020b), Bongaarts (2005), author's calculations.

Figure 7 **Estimates of parameters of the Kannisto logistic model for Czechia 1989–2019**

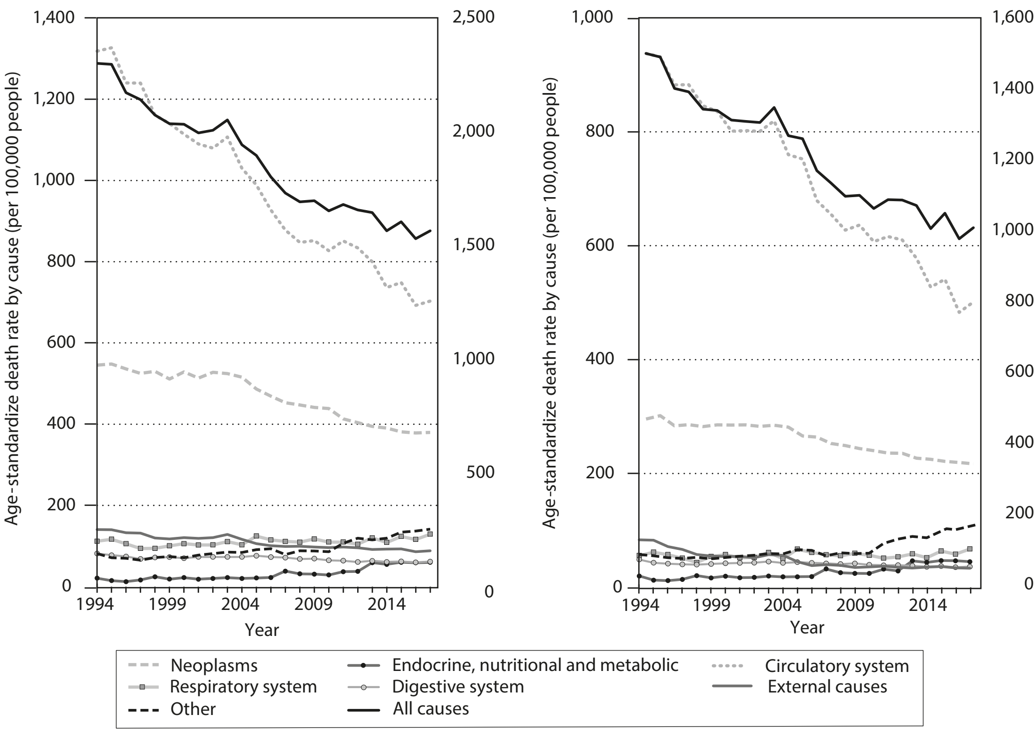


Source: Czech Statistical Office (2020b), Bongaarts (2005), author's calculations.

Mortality by Causes of Death

The following causes of death were selected according to ICD-10: Circulatory system (I00–I99); Neoplasms (C00–D48); Endocrine, nutritional and metabolic (E00–E90); Respiratory system (J00–J99); Digestive system (K00–K93) and External causes (V01–Y89). In Figure 8, we show the age-standardized death rate (per 100,000 people) based on the European standard population from 2013. The overall standardized mortality rate decreased in Czechia in the period of 1994–2017. Circulatory diseases and neoplasms predominate among the causes of death, both in men and women. However, in this period there was a reduction in mortality from the most common causes of death, which was also more significant in men compared to women. Mortality from diseases of the circulatory system as the most common cause of death has dropped from 1,318 deaths in 1994 to 703 deaths (per 100,000) in 2017 for males and from 938 to 501 deaths (per 100,000) for females. In 1994, mortality according to the second most common cause of death from neoplasms amounted to 546 deaths for males and 296 deaths for females per 100,000, while in 2017 a total of 380 male deaths and 217 female deaths were recorded. There was also a slight decrease in mortality due to diseases of the digestive system, both in men and women. In contrast, endocrine, nutritional and metabolic diseases slightly increased in mortality in the period of 1994–2017, in men from 21 to 60 deaths and in women from 20 to 45 deaths, per 100,000. Diseases of the respiratory system developed constantly in the given period with occasional fluctuations. Although the death of men from external causes of death was higher than that of women, the development of the mortality had a gradually declining trend in both sexes.

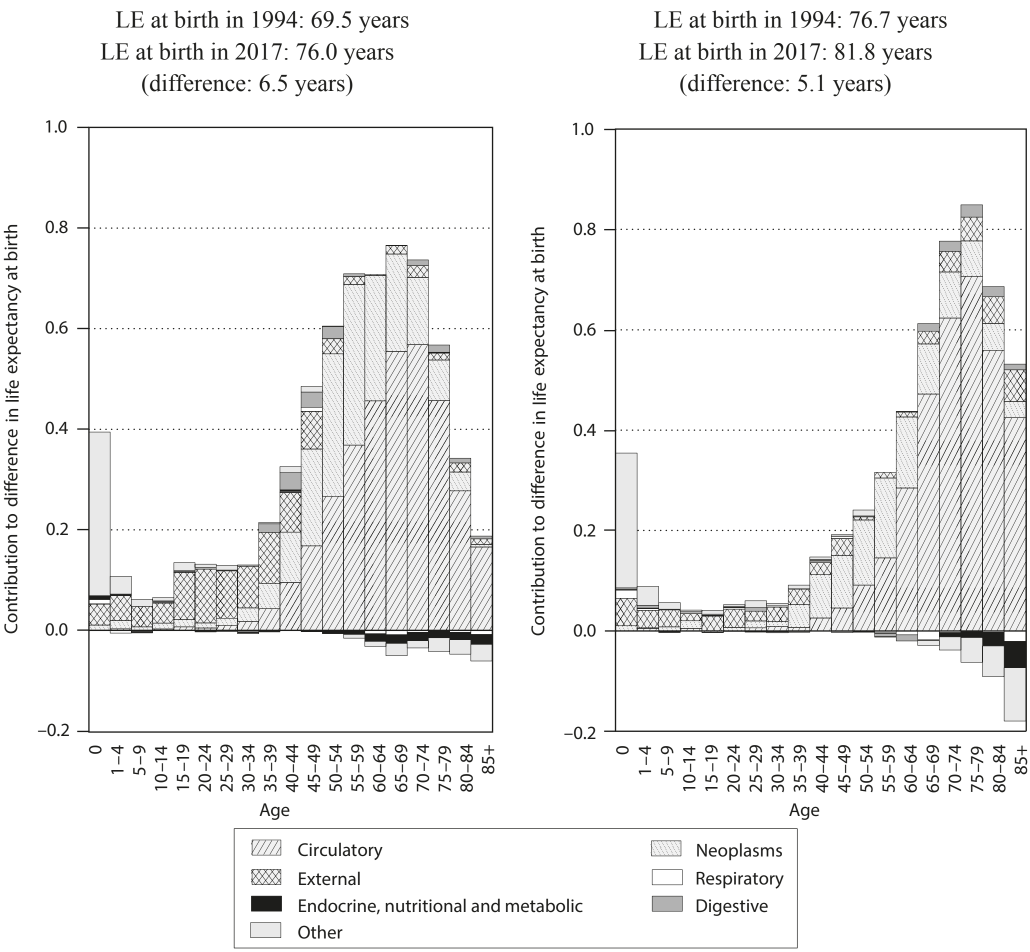
Figure 8 **Age-standardized death rate by selected cause* (per 100,000 people), males (left panel) and females (right panel), Czechia in 1994–2017**



Note: * Right axis: all causes of death (A00–Y89); Left axis: Neoplasms (C00–D48), Endocrine, nutritional and metabolic (E00–E90), Circulatory system (I00–I99), Respiratory system (J00–J99), Digestive system (K00–K93), External causes (V01–Y89), other causes of death.
Source: Eurostat (2020a and 2020b), author's processing.

As seen in Figure 9, a reduction in mortality from diseases of the circulatory system had a substantial impact on the increase of life expectancy at birth in Czechia in 1994–2017, both in men and women. In addition, life expectancy increased in this period due to the improvement in mortality from neoplasms, with this improvement being more noticeable for men. Male life expectancy has increased due to the improvement in mortality from external causes, especially in childhood and adulthood. Also, female life expectancy at birth has increased due to the reduction of mortality from external causes, but more at an older age compared to men. Diseases of the respiratory system, on the other hand, have contributed to a reduction in life expectancy at birth, both in men and women. Endocrine, nutritional and metabolic diseases have also contributed to a slight decrease in life expectancy at birth, in men and women, especially in older age groups. The reduction in mortality from digestive diseases has contributed to a slight increase in life expectancy at birth, in men in the middle and older age groups, and in women in the older age groups.

Figure 9 **Contributions to difference in life expectancy at birth by age group and by cause of death, males (left panel) and females (right panel), Czechia in 1994–2017**

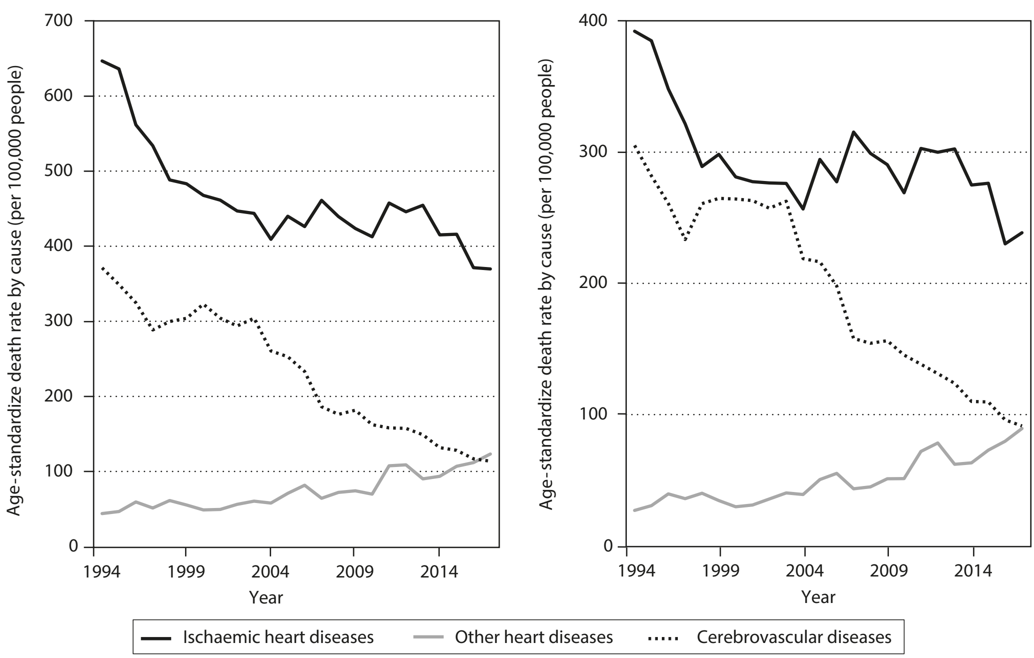


Source: Eurostat (2020c and 2020d), author's calculations.

From the most common group of causes of death from diseases of the circulatory system, more specific causes of death were selected, namely Ischaemic heart diseases (I20–I25), Other heart diseases (I30–I51) and Cerebrovascular diseases (I60–69). Figure 10 shows age-standardized death rate by selected Circulatory diseases (per 100,000 people) for males (left panel) and females (right panel) in Czechia in 1994–2017. Among the most common causes of death from Circulatory diseases were Ischaemic heart diseases, followed by Cerebrovascular diseases and Other heart diseases, both in men and women. Mortality from Ischaemic heart diseases decreased, especially from 1994 to 2004, with fluctuations and a slight decrease in the following years until 2017. While the decrease in mortality from Ischaemic heart diseases was more significant in men than in women, Cerebrovascular diseases showed a rapid decrease for women compared to men, where the mortality decreased gradually. Other heart diseases increased slightly in this period, in both men and women.

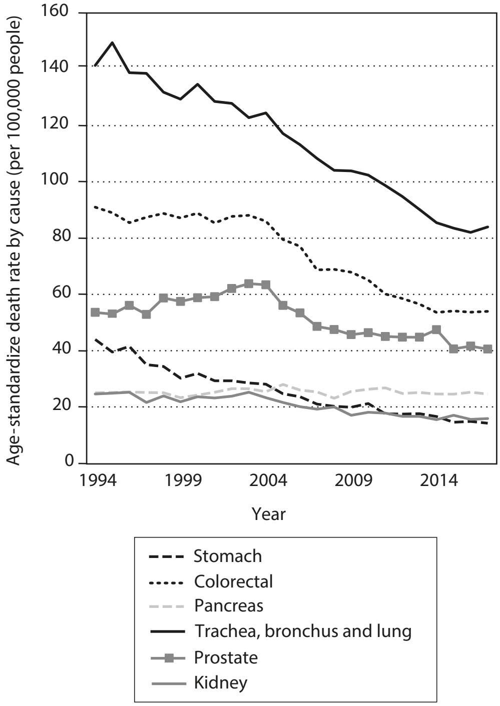
From the second largest group of the cause of death from neoplasms, more detailed causes of death were selected, namely Stomach (C16); Colorectal (C18C21); Pancreas (C25); Trachea, bronchus and lung (C33 and C34); Prostate – males (C61); Kidney, except renal pelvis (C64); Breast – females (C50); Ovary – females (C56). Figure 11 shows the age-standardized death rate by selected Neoplasms (per 100,000 people) for males (left panel) and females (right panel) in Czechia in 1994–2017. Among the most common cancer in men belonged trachea, bronchus and lung, prostate and colorectal. Male mortality from cancer related to trachea, bronchus and lung, and prostate has greatly decreased. However, mortality from prostate neoplasms in men increased slightly from 1994 to 2004, and subsequently decreased in the following years. The mortality of men from neoplasms of the stomach and kidney also decreased. The development of male mortality from neoplasms of the pancreas fluctuated during this period. Breast, colorectal and trachea, bronchus

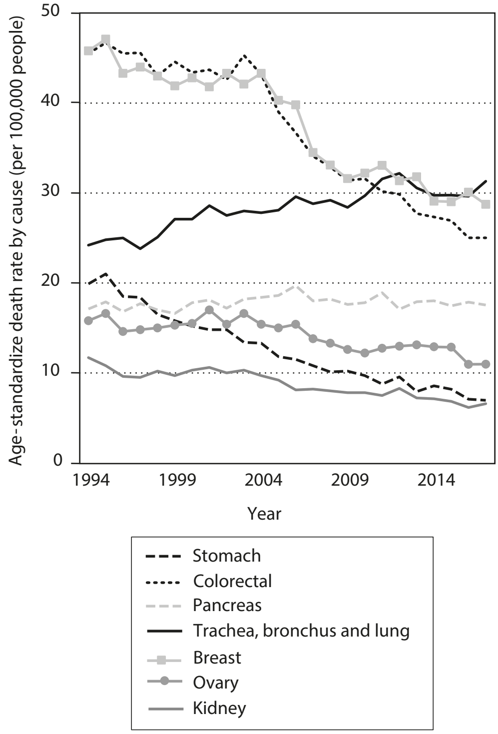
Figure 10 **Age-standardized death rate by selected circulatory diseases* (per 100,000 people), males (left panel) and females (right panel), Czechia in 1994–2017**



Note: * Ischaemic heart diseases (I20–I25); Other heart diseases (I30–I51); Cerebrovascular diseases (I60–I69).
Source: Eurostat (2020a and 2020b), author's processing.

Figure 11 **Age-standardized death rate by selected neoplasms* (per 100,000 people), males (left panel) and females (right panel), Czechia in 1994–2017**





Note: * Stomach (C16); Colorectal (C18–C21); Pancreas (C25); Trachea, bronchus and lung (C33 and C34); Prostate – males (C61); Kidney, except renal pelvis (C64); Breast – females (C50); Ovary – females (C56).
Source: Eurostat (2020a and 2020b), author's processing.

and lung cancer were among the most common groups of neoplasms in women. Colorectal and trachea, bronchus and lung cancer slightly decreased with fluctuations in the years 1994–2004, in the following years there was a rapid decrease in mortality from these neoplasms in women by 2017. While mortality from trachea, bronchus and lung cancer dropped rapidly in men, there was a slight increase in mortality in women. There was also a reduction in women's mortality from the neoplasms of the ovary, kidney and stomach. As with men, the development of neoplasms of the pancreas fluctuated during this period.

CONCLUSION

To summarize, this study confirmed a mortality decline during the transformation era in Czechia in the period of 1989–2019. This conclusion was also confirmed in several studies examined for Czechia, see for example (*Fiala et al.*, 2018; *Lustigova et al.*, 2019; *Nepomuceno – Canudas-Romo*, 2019; *Fiala – Langhamrova*, 2020). Given that the mortality rate does not reach the level of mortality in developed European countries, we can expect a further reduction in mortality in the future in Czechia. However, no further significant reduction in infant mortality can be expected due to the fact that infant mortality has reached the level of one of the lowest at the European level. The reduction in mortality in Czechia in 1989–2019 also meant an increase in life expectancy. We showed also an increase in life expectancy for older men and women, namely at the age of 65. With regard to the reduction in mortality at age 65, the pressure on the social and pension systems in Czechia is expected to increase. The projection of the Czech Statistical Office from 2018 also expects to see further growth in life expectancy, both for men and women. In addition, we showed a decrease in mortality dispersion.

Despite the fact that a greater degree of inequality among men and women persists, the sex difference in life expectancy at birth declined over this period. In life table distribution, deaths move towards higher ages. Based on Kannisto's logistic model, we observed a decline in senescent mortality during this period, while background mortality remained almost unchanged. Given that background mortality can be influenced by the intervention of national policies in connection with prevention, mortality could decrease in the future due to this component, but as it turned out for Czechia in the period of 1989 to 2019, fluctuations can also be expected. In addition, the logistic model proved to be suitable for modelling mortality in Czechia on the basis of the share of explained variability, especially in the decomposition into components of mortality. Mortality from the most common causes of deadly diseases of the circulatory system and malignant neoplasms has decreased.

Acknowledgements

The article was supported by the Internal Grant Agency of the Prague University of Economics and Business No. 35/2020 *Decomposition analysis of mortality* and by the Czech Science Foundation No. GA CR 19-03984S under the title *Economy of Successful Ageing*.

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