

# BMJ Open Mortality patterns in multimorbid populations: cross-sectional population-wide analysis of Czech national registry data, 2014–2023

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## ABSTRACT

**Objectives** The aim is to (i) examine the evolution of (multi-)morbidity in Czechia, (ii) analyse changes in mortality by (multi-)morbidity between 2014 and 2023 and (iii) analyse factors driving mortality change in these subpopulations, using national health registry data, which is unique among countries of the former Eastern Bloc.

**Design** Cross-sectional population-wide analysis.

**Setting** Czechia.

**Participants** Adult population aged 30 and above (n~7.5 million).

**Outcome measures** 1-year period prevalence proportion by age, age-specific and disease-specific occurrence-exposure mortality rates and their coefficient of variation, contributions of age composition, multimorbidity composition and mortality rates to mortality change.

**Results** Between 2014 and 2023, the prevalence of no or single diseases remained stable at 55%, while complex multimorbidity patterns (3+ diseases) decreased, especially in the 60+ group (from 20% to 16%). Despite additional diagnoses being associated with elevated mortality, especially for those with diabetes and chronic obstructive pulmonary disease (COPD), mortality risks homogenised across (multi)morbid groups, and overall mortality declined (9 pp in neoplasm and COPD, 7 pp in cerebrovascular diseases and 3 pp in diabetes). This decline was primarily due to shifts in multimorbidity composition; without this, mortality in groups with cerebrovascular diseases, diabetes and COPD would have risen.

**Conclusion** The change in mortality over the past decade in Czechia among people with chronic diseases is mainly driven by shifts in multimorbidity composition, rather than pure effects of decline in mortality, contributing to diverging patterns of change between individuals with and without chronic conditions.

## INTRODUCTION

Czechia experienced one of the steepest declines in mortality among European countries from the 1990s to the 2010s.<sup>1</sup> At the end of the 1980s, life expectancy in Czechia was approximately 3–4 years below the EU average. Between 1990 and 2019, life expectancy increased by nearly 7 years for females and 9 years for males, bringing Czechia in

## STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ We use population-wide morbidity data from the Czech healthcare registry.
- ⇒ We study risk stratification by specific disease combinations, not solely by number of diseases.
- ⇒ Diagnosis validation in the data relies on recorded medical visits, which may have been affected by healthcare disruptions during the COVID-19 pandemic.
- ⇒ We only focus on a restricted list of diagnoses, limiting our understanding of comorbidities.

line with the EU average.<sup>2,3</sup> This rapid decline in mortality coincided with the transition to a market economy,<sup>4</sup> which led to substantial investments in the healthcare system. This resulted in improved access to care, an increase in the number of treatments provided by healthcare services,<sup>5</sup> the introduction of modern healthcare techniques and procedures (including highly effective drugs) and the implementation of preventive programmes.<sup>1</sup> Much of the favourable turnover in mortality during the 1990s and 2000s was driven by the untapped potential that had accumulated during the period of stagnation under socialism.<sup>6,7</sup>

The advances in healthcare led to reduced mortality for the most common causes of death, particularly acute myocardial infarction among males and cerebrovascular diseases among females.<sup>8</sup> However, the morbidity burden of treatable diseases remains consistently higher in Czechia.<sup>9</sup> Additionally, Czechia has the highest proportion of people reporting multimorbidity in the EU.<sup>10</sup> Several factors contribute to this phenomenon. First, the long-term health legacy of the socialist era remains significant. Nearly 80% of Czechs living in the 2010s were exposed to associated health risks during their formative or working lives.<sup>11</sup> Second, while advancements in medical care are crucial, they may



represent only one part of the solution for achieving a long-term, sustainable decline in disease burden. Lifestyle factors such as nutrition, physical activity, substance abuse, alcohol consumption and sleep patterns, alongside a growing awareness of health as a personal responsibility and valuable asset, are equally important.<sup>12–15</sup> However, in post-socialist countries like Czechia, such social and behavioural changes appear less pronounced compared with Western Europe, where the prevalence of health risk factors is generally lower. For instance, Czechia has one of the highest obesity rates in Europe,<sup>16</sup> ranks among the top countries for smoking prevalence<sup>16</sup> and considerably exceeds the European average in alcohol consumption.<sup>16</sup> Moreover, only about 7% of Czech adults engage in regular physical activity, which is half the EU average of 14%.<sup>16</sup>

These factors may contribute to the relatively higher mortality rates for treatable diseases and multimorbidity in Czechia compared with Western EU countries. However, major knowledge gaps persist regarding morbidity patterns across EU populations.<sup>17</sup> These gaps arise primarily from inherent differences between national healthcare systems,<sup>18</sup> which hinder the collection of standardised morbidity data. Comprehensive, legally accessible, population-wide patient registries covering all diseases, such as those in the Nordic countries, are rare.<sup>19</sup> Instead, most countries rely on surveys using primarily self-reported morbidity data. This approach has multiple limitations,<sup>20</sup> including potential misreporting of health conditions, selective non-response<sup>21</sup> and reduced validity when comparing across different age groups.<sup>22</sup>

Czechia presents a mixed situation: while the country possesses a population-wide registry recording all patient-healthcare facility contacts, its epidemiological utility may be limited by unreliable diagnostic reporting. As the registry was primarily designed for managing healthcare financial flows, economic incentives may influence disease reporting practices.

Despite these limitations and given the existing evidence of a higher (multi)morbidity burden in the Czech population, coupled with persistent mortality disparities compared with Western Europe, the Institute for Health Statistics and Information (IHIS) of Czechia developed a reliable population-wide polymorbidity dataset based on the National Registry of Reimbursed Health Services (NRRHS). This dataset contains validated data on a range of chronic diseases for the period 2014–2023.<sup>23</sup> Such comprehensive morbidity data are uncommon within the former Soviet bloc and represent a unique resource for understanding the factors driving the enduring East-West health gap, a disparity that persists even 35 years after the fall of the Iron Curtain.

Using this polymorbidity dataset derived from Czech health registries, we examine (i) the evolution of (multi) morbidity in Czechia and (ii) changes in mortality rates across subpopulations stratified by (multi)morbidity between 2014 and 2023 and (iii) factors driving mortality change in these subpopulations. This study represents

**Table 1** Frequency of validated chronic conditions in the studied population, Czechia, 2022–2023

	Frequency	
	%	N
Chronic obstructive pulmonary disease	12.9	2 793 692
Diabetes	12.3	2 663 063
Neoplasm	5.8	1 243 787
Cerebrovascular diseases	5.0	1 075 364
Liver disease	4.6	989 232
Peripheral artery disease	4.2	908 794
Heart failure	3.2	695 544
Renal disease	2.4	523 883
Rheumatic diseases	2.2	467 788
Dementia	1.4	312 151
Myocardial infarction	1.4	298 719
Peptic ulcer	1.3	272 762
Hemiplegy	0.6	138 260
Authors' calculations, based on data from Kučerová <i>et al.</i> <sup>23</sup>		

the first analysis bridging morbidity and mortality using reliable medical data from Czechia.

## METHODS

### Data and study variables

At the individual level, the polymorbidity dataset by IHIS contains information on the presence or absence of leading chronic conditions, as well as sociodemographic characteristics such as age, sex and vital status. The data cover the period from 2014 to 2023.

This dataset is based on data collected in the NRRHS. The registry collects data from insurance companies on all contacts between healthcare providers and the insured Czech population.<sup>24</sup> By law, every person with permanent residence in Czechia is required to have health insurance, regardless of their nationality. Therefore, the polymorbidity data are population-based<sup>25</sup> and include healthcare from all providers, as both public and private facilities are mandated to report to IHIS.

Diagnosis validation within the polymorbidity dataset relied on 5-year patient healthcare utilisation histories.<sup>23</sup> For these histories, IHIS developed disease-specific rules to verify each diagnosis listed in [table 1](#). The diagnosis list aligns with those used in the Charlson Comorbidity Index,<sup>26 27</sup> an established tool for predicting in-hospital mortality. For our analysis, we selected the four most frequent diagnoses from [table 1](#) and identified the four most common co-occurring diseases for each. While other conditions listed in [table 1](#) are not explicitly analysed individually, they are included in the analysis of subpopulations with 'complex disease patterns of three or more conditions'. Therefore, we also include these conditions in the descriptive analysis.

**Table 2** Frequencies (%) of co-occurring conditions within the populations by morbidity (in rows), Czechia, 2022–2023

	<b>COPD</b>	<b>Diabetes</b>	<b>Neoplasm</b>	<b>Cerebrovascular disease</b>	<b>Liver disease</b>
COPD	–	19.1	9.4	9.1	7.3
Diabetes	20.0	–	14.2	14.7	9.5
Neoplasm	21.2	30.4	–	14.5	9.5
Cerebrovascular disease	23.6	36.4	16.8	–	9.4
Liver disease	20.6	25.6	12.0	10.2	–
CVD	22.0	34.4	14.9	20.2	8.2
Renal disease	25.6	45.9	21.9	23.3	12.3
Rheumatic disease	25.6	23.6	11.9	12.4	9.5
Dementia	21.4	40.8	17.6	45.0	8.0
Peptic ulcer	25.0	28.5	16.4	16.9	15.1
	<b>CVD</b>	<b>Renal disease</b>	<b>Rheumatic disease</b>	<b>Dementia</b>	<b>Peptic ulcer</b>
COPD	15.0	4.8	4.3	2.4	2.4
Diabetes	24.6	9.0	4.1	4.8	2.9
Neoplasm	22.7	9.2	4.5	4.4	3.6
Cerebrovascular disease	35.7	11.3	5.4	13.1	4.3
Liver disease	15.8	6.5	4.5	2.5	4.2
CVD	–	11.9	4.5	7.3	3.7
Renal disease	43.2	–	6.0	9.0	5.3
Rheumatic disease	18.2	6.7	–	3.0	3.3
Dementia	44.4	15.1	4.5	–	5.2
Peptic ulcer	26.0	10.2	5.7	6.0	–

Note: For instance, almost 24% of people who had cerebrovascular disease also had COPD. COPD, chronic obstructive pulmonary disease; CVD, cardiovascular disease.

The four most common diseases—chronic obstructive pulmonary disease (COPD), diabetes, cerebrovascular diseases and neoplasms—affected approximately 38% of the total population. The most frequent co-occurring diseases alongside these four include renal diseases, liver diseases, cerebrovascular diseases and cardiovascular diseases (CVD) (comprising myocardial infarction, heart failure and peripheral artery disease). We do not specify ICD-10 codes for the diseases, as this information is not available in the polymorbidity dataset metadata.

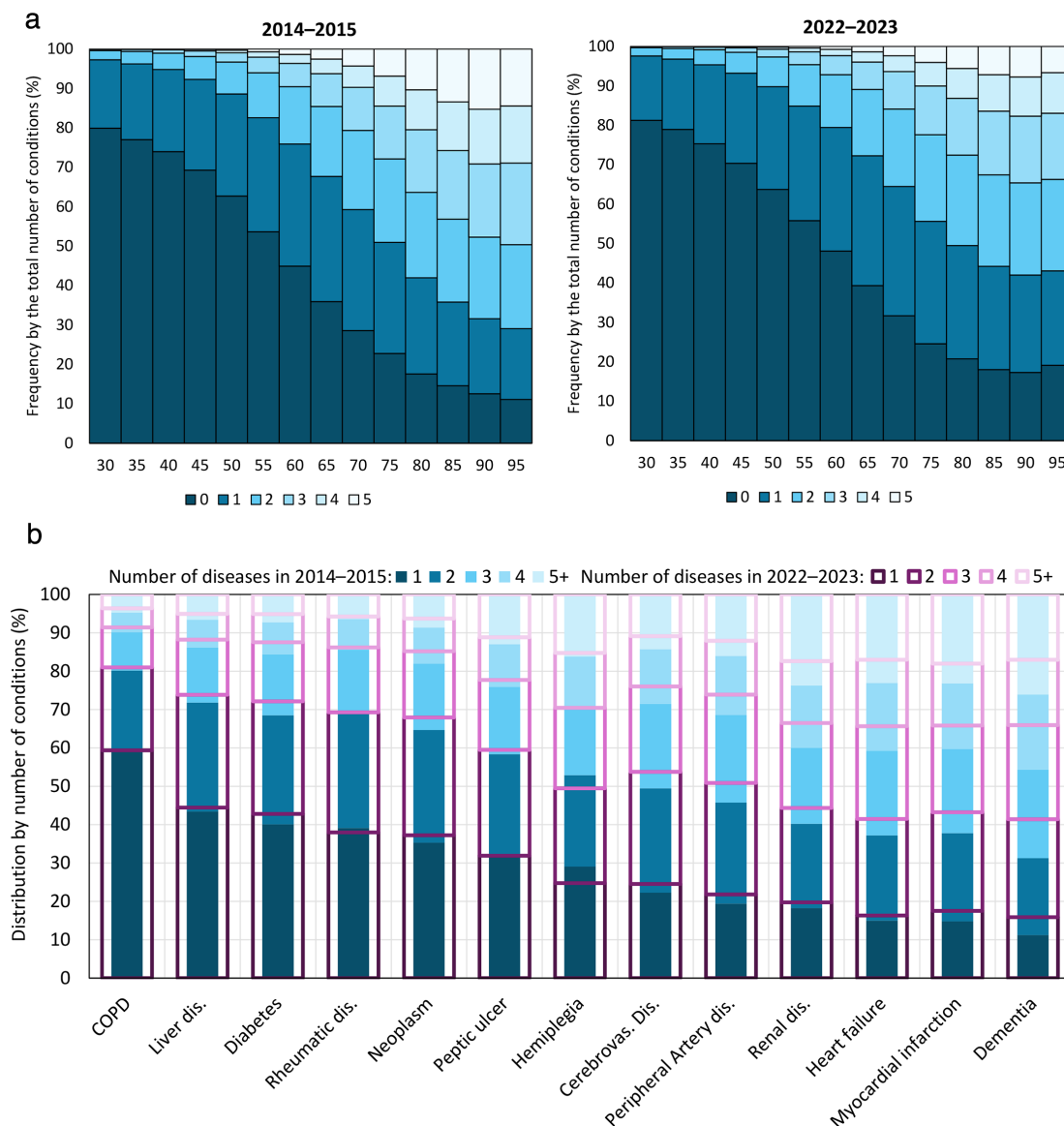
#### Statistical analysis

This analysis focuses on three key aspects: first, we present descriptive findings using prevalence data; second, we examine disparities in mortality within subgroups defined by morbidity; and finally, we explore factors contributing to changes in mortality among individuals with chronic conditions over the past decade. While the prevalence analysis included individuals aged 30 and above, the mortality analyses were restricted to those aged 45 and older because of the limited number of deaths in younger age groups.

To measure changes in disease burden, we used a 1-year period prevalence proportion by age,<sup>28</sup> calculated as the ratio

of the total number of individuals living with a condition at age  $x$  in year  $t$  to the corresponding person-years at risk. Prevalences are calculated for individual chronic conditions, as well as by the total number of reported diagnoses within subgroups defined by chronic diseases.

For the analysis of mortality disparities, age-specific and disease-specific mortality rates were used. These rates, representing demographic rates of the first type (occurrence exposure rates),<sup>29</sup> are calculated by dividing the number of deaths of individuals with disease  $i$  at age  $x$  in year  $t$  by the person-years lived by individuals with disease  $i$  at age  $x$ . For broader age and time intervals, mortality rates are calculated by pooling deaths and exposures before calculating the rates. The raw mortality rates were smoothed across age using one-dimensional P-splines.<sup>30</sup> Due to the non-parametric nature of these P-splines, we ensured that the smoothing process did not distort estimates of mortality risk or any other analysed quantities. To assess the relative change in age-specific mortality rates, we computed the ratio between age-specific mortality rates in 2022–2023 and those in 2013–2014. Furthermore, we use age-specific coefficients of variation to assess changes in the variability of mortality across comorbid conditions within the morbidity groups. These



**Figure 1** Distribution by number of chronic conditions and age (a) and distribution by number of chronic conditions and diseases (b), comparison of 2014–2015 and 2022–2023. COPD, chronic obstructive pulmonary disease. Source: Authors' calculations, based on data from Kučerová *et al.*<sup>23</sup>

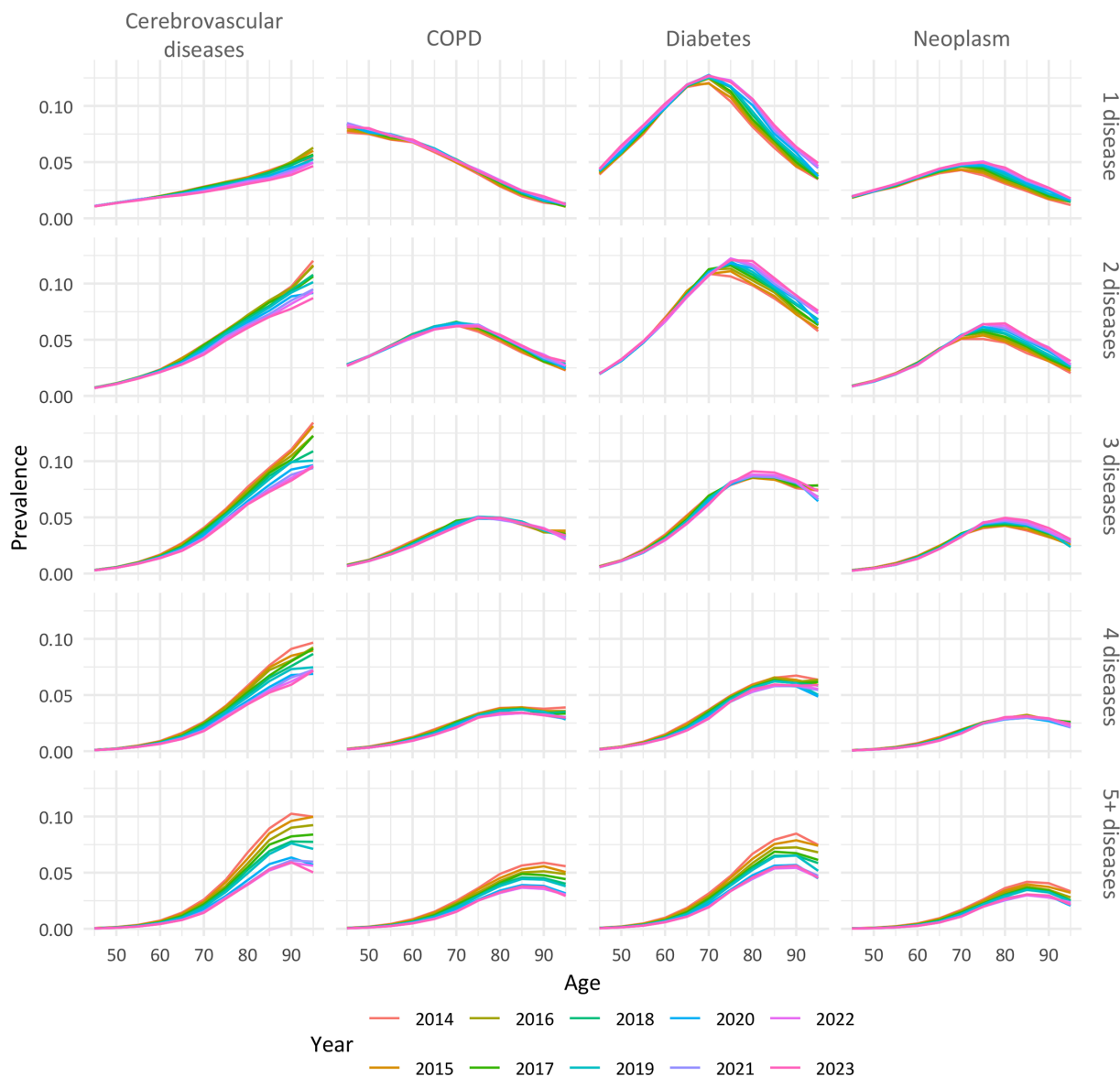
coefficients are calculated as the ratio of the SD to the mean of mortality rates by age.

To explore factors contributing to mortality changes in the last decade, we use Das Gupta decomposition.<sup>31–33</sup> We break down the overall change in the crude mortality rate within populations with chronic diseases between 2014 and 2023 into the (i) rate effect, (ii) age effect and (iii) multimorbidity effect. The rate effect reflects the change between age-adjusted and multimorbidity-adjusted mortality rates and is therefore primarily attributed to changes in mortality rates. Throughout the paper, we use the terms 'mortality rate' and 'mortality intensity' interchangeably. The age effect reflects changes in mortality resulting from shifts in the age composition of the (multi)morbid population. The multimorbidity effect measures how changes in the composition by number of

comorbidities contribute to shifts in mortality within the morbidity groups.

Additionally, we analysed changes in mortality rates after standardising for the age effect to assess mortality differences between multimorbid groups that were not biased by age composition. We used the Czech mortality schedule as the standard population.

Further technical details of the Das Gupta decomposition and standardisation are available in online supplemental appendix 1. Although our main focus is on the decomposition between 2014 and 2023, we conducted a sensitivity analysis comparing the periods of 2014 with 2018–2019 and 2020–2021 to explore the potential disruptions during the COVID-19 pandemic (online supplemental appendix 5). The analysis was conducted using SAS V.9.4M8 and RStudio V.2024.03.0+492 with R V.4.4.0.



**Figure 2** Age-specific prevalences of leading chronic diseases by number of additional conditions, Czechia, 2014–2023. COPD, chronic obstructive pulmonary disease. Source: Authors' calculations, based on data from Kučerová *et al.*<sup>23</sup>

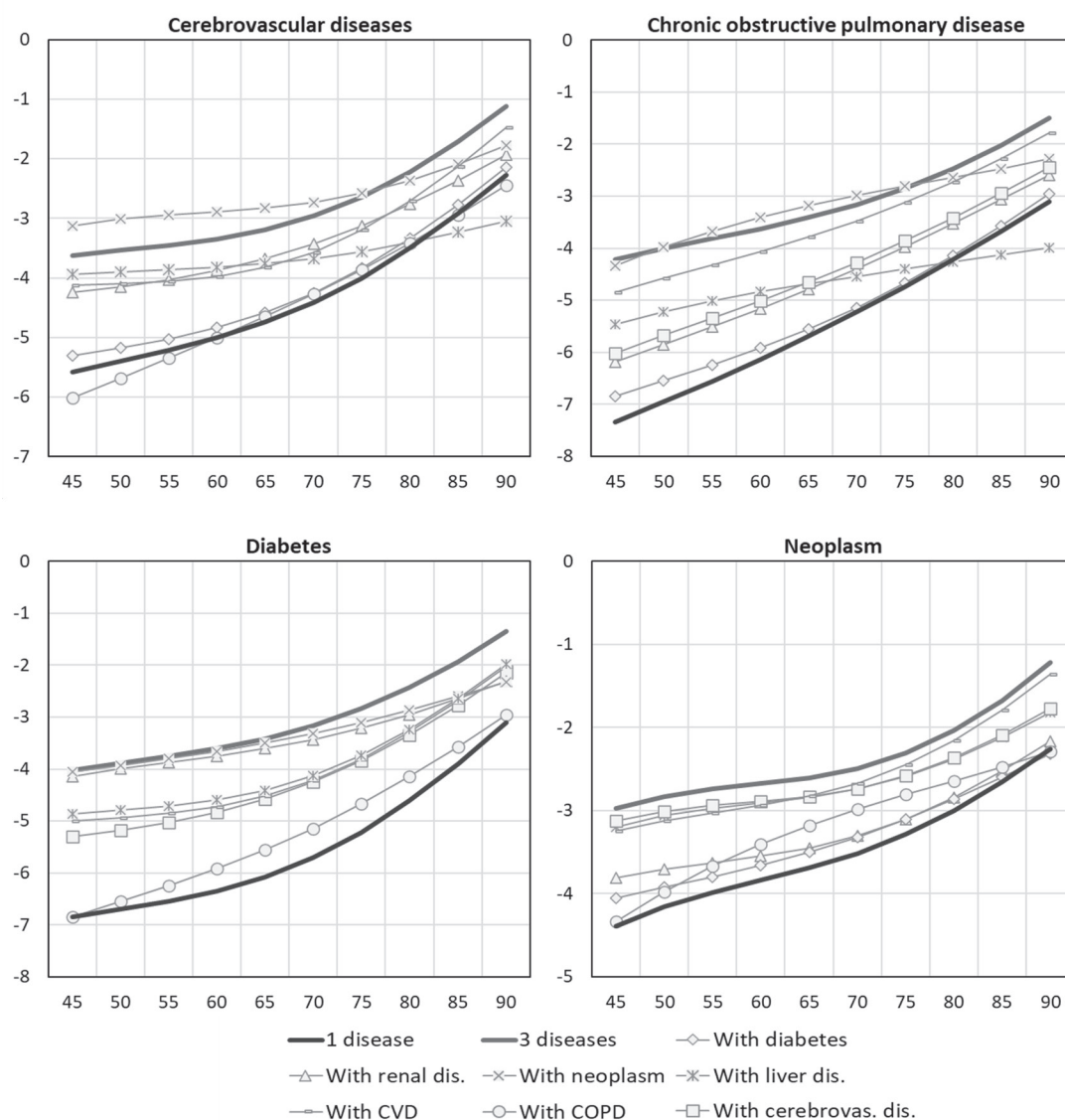
## RESULTS

### Prevalence of multimorbidity

More than one-third of the Czech population—approximately 10.5 million people—were diagnosed with one or more of the leading chronic diseases listed in [table 1](#), with prevalence rates of 34% in 2014–2015 and 35% in 2022–2023. [Table 2](#) shows the distribution of people by their additional diagnosis, providing justification for the selection of disease pairs. In Czechia, the most common comorbidities associated with validated chronic diseases are CVD—comprising myocardial infarction, heart failure and peripheral artery diseases—and diabetes. For instance, nearly half of the individuals with renal disease or dementia have CVD or diabetes as well (around 43% and 44% or 46% and 41%, respectively). COPD, liver diseases and neoplasms are more evenly distributed across subpopulations by morbidities. In each subpopulation by morbid condition, around 20%

are diagnosed with COPD as well. This is similar for neoplasms, which occur in around 15% of cases in all subpopulations by morbidities, except for the population with renal disease. In the population affected by renal disease, neoplasms occur slightly more often (20%). It is important to note that the results shown in [table 2](#) are influenced by the actual sizes of the populations differentiated by morbidities.

As expected, there is a strong age dependence with the prevalence of morbidity ([figure 1a](#)). Among individuals aged 60 and older, nearly half present at least one chronic condition in both 2014–2015 and 2022–2023. At age 80+, most individuals were multimorbid. However, there have been notable changes in the distribution of the number of conditions within the multimorbid populations between 2014 and 2023. In the first period, the proportion of individuals aged 80+ with two or more conditions was notably higher than in the second period.

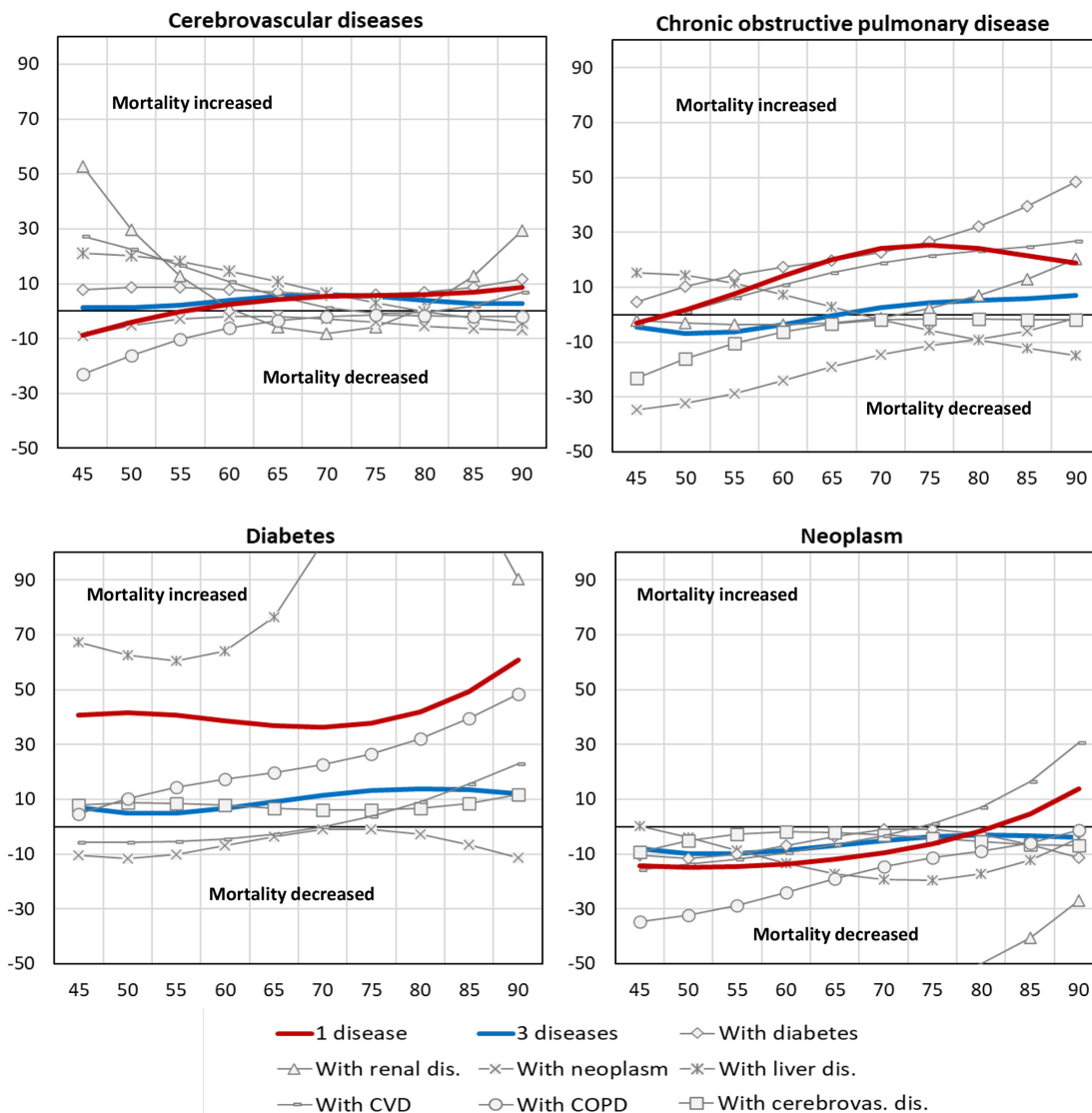


**Figure 3** Age-specific and disease-specific mortality rates in subpopulations defined by (multi)morbidities, Czechia, 2022–2023. COPD, chronic obstructive pulmonary disease; CVD, cardiovascular disease. Source: Authors' calculations, based on data from Kučerová *et al.*<sup>23</sup>

The proportion of the population varies by the number of additional conditions across different disease groups (figure 1b). Individuals with COPD most commonly live with only one condition, whereas this is rare for those with dementia, myocardial infarction, heart failure or renal disease. Approximately 60% of individuals with liver disease, diabetes, rheumatic diseases and neoplasms typically have at least one additional condition. This pattern has remained stable over time for most diseases. However, in dementia, myocardial infarction, peripheral artery disease and cerebrovascular diseases, the multimorbidity decreased between 2014 and 2023, as illustrated with the purple bars on figure 1b.

Figure 2 illustrates age-specific prevalences of the leading chronic diseases from 2014 to 2023, stratified by total number of conditions. Results for all conditions

listed in table 1 are provided in online supplemental appendix 2. Prevalence profiles across age groups vary by disease. For instance, cerebrovascular diseases do not exhibit the sharp decline in prevalence at older ages seen in diabetes, COPD and neoplasms. Figure 2 also depicts temporal changes in prevalence over the past decade, which differ according to the number of co-occurring conditions. The most pronounced prevalence decreases among older individuals occurred in populations with cerebrovascular disease, regardless of the number of additional conditions. Conversely, in subpopulations with diabetes, or diabetes combined with one other disease, prevalence increased over time, paralleling changes observed in populations with neoplasms.



**Figure 4** Relative change in age-specific and disease-specific mortality rates between 2014–2015 and 2022–2023 in subpopulations defined by multimorbidity, Czechia. COPD, chronic obstructive pulmonary disease; CVD, cardiovascular disease. Source: Authors' calculations, based on data from Kučerová *et al.*<sup>23</sup>

#### Mortality by multimorbidity

Figure 3 shows the age-specific and disease-specific mortality rates in 2022–2023. A gradient in the by the number of conditions is evident: mortality from the single disease typically represents the lower boundary, while mortality from three diseases marks the upper boundary. There is considerable variability in mortality rates among groups with two conditions. Generally, the rates are higher if one of the diseases is neoplasm or cerebrovascular disease. Within these two groups, especially for individuals under the age of 70, there is a distinct gap in mortality between combinations with COPD or diabetes at one end (lower mortality rate) and combinations with either neoplasms or cerebrovascular diseases at the other end (higher mortality rate).

The mortality differences between (multi)morbid groups presented in figure 3 were similar as early as 2014–2015. Since then, changes occurred in variability of mortality rates, as reflected by the coefficient

of variation (detailed in the online supplemental appendix 3). Specifically, heterogeneity in mortality among groups with different (multi)morbidity patterns decreased within the 45–60 age group. During 2014–2015, this age group exhibited the highest relative variation in mortality compared with the average, but by 2022–2023, these pronounced differences had largely diminished. Moreover, within the neoplasm subgroup, mortality variation remained consistently lower across different disease combinations. Conversely, among individuals with COPD and diabetes, the mortality variation remained higher, as evidenced by elevated coefficients of variation. This suggests that additional comorbid conditions might strongly modify mortality risk, especially in these groups.

In addition to mortality variability by disease combinations, we examine changes in overall mortality rates in (multi)morbid populations. The relative change in mortality by

**Table 3** Contributions of intensity of mortality, age composition and multimorbidity composition to the change in crude death rates between 2014–2015 and 2022–2023 in populations by leading morbidities

	Cerebrovascular disease	COPD	Diabetes	Neoplasm
CDR 2014–2015 (%)	95.04	36.70	41.11	85.86
CDR 2022–2023 (%)	89.24	33.47	40.14	78.94
Difference	–5.80	–3.24	–0.97	–6.93
Rate effect	2.77	0.68	3.50	–2.82
Multimorbidity effect	–8.78	–5.55	–7.02	–8.61
Age effect	0.20	1.63	2.55	4.51

Authors' calculations, based on data from Kučerová *et al.*<sup>23</sup>  
CDR, Crude Death Rate; COPD, chronic obstructive pulmonary disease.

(multi)morbidity, expressed as a percentage change in mortality rates by age between 2014 and 2023, is illustrated in [figure 4](#). This figure highlights changes within a two-fold range of increase or decrease, even if some combinations involving renal diseases exceeded this range.

Overall, mortality rates among individuals with diabetes and additional comorbidities generally increased, similar to the COPD group, particularly in older ages. In contrast, mortality among individuals with cancer developed in the opposite direction. The magnitude of change in mortality between 2014 and 2023 is very different across (multi)morbid groups, particularly in the case of diabetes. In neoplasms and cerebrovascular diseases, mortality remained relatively consistent in (multi)morbidity groups, placing the relative change in mortality rates near to zero. The results in [figure 4](#) also indicate that mortality among individuals with renal diseases combined with diabetes nearly doubled between 2014 and 2023. When renal diseases are combined with cerebrovascular conditions, change in mortality follows a U-shaped pattern, rising in early adulthood, declining in middle age and increasing again in older age. Conversely, for individuals with only COPD, the sharpest rise in mortality occurs between the ages of 65 and 80.

#### Factors contributing to mortality change

Over the past decade, crude mortality rates in groups with leading chronic diseases declined, as shown in [table 3](#). This change was largely driven by shifts in multimorbidity composition. The multimorbidity effect reached a substantial 8% for neoplasms and cerebrovascular diseases, meaning that the decline in mortality would have been even greater if age and rate composition had remained constant ([table 3](#)).

In contrast, the age effect was positive across all disease groups, suggesting that mortality would have increased if multimorbidity composition and mortality intensity had remained unchanged throughout the study period. This finding is expected in an ageing population.

The rate effect was also positive in groups with cerebrovascular diseases, COPD and diabetes, indicating increased mortality intensity between 2014 and 2023, assuming constant age and multimorbid composition. Overall, the positive rate effects in these groups were

offset, and even surpassed, by the negative effect of changes in multimorbidity profiles, resulting in declines in crude death rates. As shown in [figure 1](#), the primary change in multimorbidity composition was the decreased frequency of complex multimorbidity patterns following the COVID-19 pandemic.

To clarify the decomposition results, we calculated changes in age-standardised mortality rates within disease-specific subpopulations, stratified by number of conditions and standardised against the national mortality rate in Czechia. The results (provided in the online supplemental appendix 4) demonstrate that mortality increased over the past decade in populations with cerebrovascular disease, COPD or diabetes, with the most pronounced increase observed in those with a single disease. Conversely, subpopulations with neoplasms showed decreasing mortality of approximately 5%–10%. Detailed age-standardised results are presented in the online supplemental appendix 4.

#### DISCUSSION AND CONCLUSION

Using population-wide health registry data from Czechia, we analysed the changes in multimorbidity prevalence, mortality rates across disease burden subpopulations and the factors driving mortality changes.

Regarding the prevalence trends, we found that between 2014 and 2023, the proportion of individuals with no or only a single disease stabilised, but the frequency of complex multimorbidity patterns declined (3+ diseases). In 2014, one-fifth of people aged 60 and older had three or more chronic diseases; by 2023, this was 14%. Age-specific prevalences of diabetes, as well as neoplasms alone or with one additional condition, increased over time among those aged 70 and older, while prevalences of more extensive disease combinations remained stable or declined. In contrast, the prevalence of cerebrovascular diseases continued to decline regardless of the number of comorbidities.

Morbidity data are known to exhibit substantial variability depending on the data source,<sup>34</sup> so we compared disease prevalences of leading diseases

in the most recent IHIS period with estimates from other data sources. While diabetes is generally estimated to affect around 7%–9% of the Czech population,<sup>35–38</sup> the IHIS dataset<sup>23</sup> indicates a prevalence of approximately 12%. This is similar to COPD, which is typically estimated at 4.5%–6%<sup>39–41</sup>—though some sources suggest rates as high as 14%<sup>42</sup>—in the IHIS the prevalence was nearly 12%. For both diseases, studies repeatedly highlight the large number of undiagnosed cases, with estimates suggesting up to 250 000 undiagnosed individuals for diabetes.<sup>38</sup> For COPD, research indicates that the actual prevalence could be nearly twice as high as reported.<sup>43</sup> In contrast, prevalence estimates for neoplasms align closely between the IHIS dataset and other sources.<sup>44–46</sup> However, for cerebrovascular diseases, the polymorbidity dataset shows a higher prevalence (4.6%) compared with general estimates of 1%–3%.<sup>47 48</sup>

The discrepancies may arise from differences in the methodologies used to produce the estimates. As previously mentioned, the polymorbidity data are derived from population-wide healthcare utilisation records, whereas, for instance, Eurostat estimates of prevalence are based on the European Health Interview Survey.<sup>49</sup> Alternatively, these discrepancies could also reflect most recent shifts in morbidity patterns within the Czech population, likely as a result of the COVID-19 pandemic. Most of the above-cited estimates come from the pre-pandemic period. However, when we calculated prevalence rates for 2018–2019, we found no substantial changes in any of the four leading chronic conditions.

In contrast to that, when it comes to multimorbidity, survey-based estimates often exceed those derived from administrative data. For instance, according to the Survey of Health, Ageing and Retirement (SHARE) study, the prevalence of multimorbidity among Czech individuals aged 50+ ranged from 35% to 45% across all seven SHARE Waves conducted between 2004 and 2017.<sup>50</sup> In comparison, IHIS data show a lower prevalence of 27% for the same age group. Many other examples of significant inconsistencies in multimorbidity estimates can be found, as evidenced by Nguyen *et al.*<sup>51</sup> Studies using SHARE data consistently show higher prevalences, which is expected given the survey question phrasing: “*Has a doctor ever told you that you had (specific condition)?*”<sup>52</sup> In contrast, the IHIS dataset identifies individuals with diseases based on patient-healthcare facility contacts, potentially capturing only those actively receiving treatment.

With respect to mortality patterns, we found that while mortality rates varied by disease combinations and number of conditions, a shift toward homogenisation of mortality risks emerged within the 45–60 age group from 2014 onwards. Generally, additional diagnoses were associated with increased mortality, with this gradient being more pronounced among individuals with diabetes and COPD. This may reflect both the systemic nature of these conditions and their complex interactions with other

diseases, as well as potential challenges in clinical management when treating multiple conditions simultaneously.

We repeatedly observed discrepancies in mortality and prevalence developments between populations with complex multimorbidity (three or more diseases) and the rest of the population. This may be attributable to the COVID-19 pandemic from two perspectives. First, COVID-19 may have had a disproportionate impact on individuals with different multimorbidity profiles—specifically, higher excess mortality among those with complex multimorbidity during the pandemic, followed by their reduced contribution to population-level mortality in subsequent years. Second, restricted access to health services may have affected the reconstruction of patient treatment histories and, consequently, the identification of individuals with diseases (online supplemental appendix 5).

Finally, regarding the drivers of mortality change, we found that the observed mortality declines were primarily driven by changes in multimorbidity composition. In the absence of this effect, mortality among individuals with cerebrovascular diseases, diabetes and COPD would have shown an upward change, as confirmed by separate analyses stratified by number of diseases and adjusted for age composition. Conversely, the neoplasm subgroup consistently exhibited decreasing mortality not attributed to age or multimorbidity composition throughout the study period. This indicates improvements in cancer-specific mortality, likely reflecting advances in cancer detection, treatment and survival over the past decade. This finding aligns with broader European trends showing sustained reductions in cancer mortality during this period.<sup>53 54</sup>

Complex multimorbidity prevalence declined slightly (5 percentage points) between 2014–2015 and 2018–2019. During the pandemic, this decline accelerated to 10 percentage points. Decomposition analyses between 2014–2015 and 2018–2019 also indicated decreased mortality driven by the multimorbidity effect; however, this effect was weaker and balanced out by the rate and age effects. When comparing 2014–2015 with the pandemic period 2020–2021, mortality increased in the population with chronic diseases, primarily attributable to the rate effect. Although multimorbidity’s contribution to mortality reduction grew during this time, it was no longer sufficient to offset the substantial rise in mortality associated with excess deaths. Similar patterns emerged when comparing 2018–2019 and 2022–2023: multimorbidity’s mitigating effect persisted, while the slightly positive influence of the overall mortality rate was insufficient to counterbalance it, resulting in an overall decline in crude mortality. In summary, multimorbidity composition positively influenced mortality development even before the pandemic, but the pandemic further strongly accelerated these changes.

This study has several limitations. First, as highlighted above, some diseases might be underdiagnosed, especially



diabetes or COPD. Consequently, individuals with these conditions who are not treated are excluded from the analysis. This introduces a bias, as the higher mortality expected among untreated individuals is not captured in the results. We also observed the opposite extreme—a more than twofold increase in mortality rate related to renal diseases among individuals with diabetes. This may reflect data issues, most likely stemming from changes in the classification of what constitutes a diabetic complication vs a standalone disease.

Second, we used a restricted set of diagnoses in the comorbidity analysis. While these represent the most prevalent diseases, the spectrum of diseases that can co-occur is much broader and unobserved in this analysis. The analysis could also benefit from differentiating disease severity, as it is likely that this factor, rather than the mere presence or absence of a chronic condition, drives survival and progression towards disease accumulation. Not only does the scope of included diagnoses affect the results, but also the level of detail in the disease list; for example, aggregating diseases from the Charlson list into broader categories, such as ICD chapters, would alter the leading diagnoses, with CVD—appearing multiple times in the original list—likely taking the lead. However, we have not explicitly analysed this group of diseases in the paper, even though the diseases from the list are among the most prevalent comorbidities when considered collectively. We acknowledge that other important conditions such as CVD merit examination; however, their inclusion would have further increased the complexity of the analysis and results interpretation.

Third, in the decomposition analysis by number of diseases, individuals are not distinguished by primary or secondary diagnoses, leading to overlapping subpopulations. This likely explains why differences between groups diminish with an increasing number of diagnoses. Unfortunately, a more sophisticated analysis was not possible with the current dataset, as individual disease trajectories cannot be reconstructed and no additional information on the clinical significance of diagnoses is available. However, our approach aligns with the study's aim of monitoring multimorbidity, which does not necessarily require identifying a central diagnosis.<sup>55</sup>

Fourth, we omitted an important differentiating factor: sex. Men and women naturally differ in (multi)morbidity patterns and associated mortality risk. However, the size of the available data and analysis scope did not permit this additional level of granularity. Nonetheless, we calculated mortality rates by sex, indicating that, for most diseases and multimorbidity groups, males experience higher mortality, which converges towards female rates around the age of 60. However, this requires further examination.

Future research should incorporate the temporal dimension of disease accumulation, as the severity of disease combinations partly depends on how long individuals have been living with them. An international comparison could also enhance interpretation. Additionally, distinguishing specific diseases within complex

multimorbidity patterns is important, as the particular conditions that co-occur influence mortality risk estimates. Overall, stratifying mortality risk by disease profile is crucial: multimorbidity is common and expected to increase, making the multimorbid population increasingly significant in overall mortality estimates. As demonstrated here, mortality risks among individuals with multimorbidity are highly heterogeneous and influenced by various compositional factors, highlighting the need for further investigation. Accurate quantification of multimorbidity through administrative registers provides essential evidence for policymakers to understand the scale and impact of these complex conditions. Our findings emphasise the necessity for healthcare systems to move beyond single-disease management approaches and adopt integrated care models that address specific disease combinations, since treatment requirements for multimorbid patients can differ significantly from those for individual conditions.

In conclusion, our analysis provides novel insights into the shifts of multimorbidity prevalence and associated mortality patterns in Czechia. We present unique evidence that mortality in these subpopulations may be diverging from the overall declining tendency in general population mortality. These findings may contribute to understanding the factors underlying the persistent health gap between Czechia and Western countries and have relevance for the Czech public health sector. We also contribute by highlighting potential inconsistencies in the Czech registry data.

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