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Trends and demographic inequalities in mortality of the Lithuanian population during the COVID-19 pandemic: who suffered most?

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Abstract The aim of the study was to analyze changes and demographic inequalities in the mortality of the Lithuanian population in 2020 and 2021 compared to the period of 2015–2019, assess the major causes of death that contributed to the changes, and identify the groups of the society that suffered most.

Methods Mortality rates for 2015–2021 from all causes, cardiovascular diseases, malignant neoplasms, external causes, diseases of the digestive system, diseases of the respiratory system, and COVID-19 in Lithuania by sex and age were calculated per 100,000 population. Mortality changes compared with the previous year and between the average of 2015–2019 years were calculated. The average annual percentage change was calculated to determine the aggregated 2015–2019 change in mortality from the leading causes of death. Coefficients of linear regression multiplied by 100 were presented as average annual changes, which were statistically significant at $p < 0.05$. Mortality rate differences between 2020 and 2021 years and the average of 2015–2019 years were calculated.

Results Lithuania has recorded 9.4% higher overall mortality among males in 2020 and 18% higher mortality in 2021 compared with a period unaffected by the COVID-19 pandemic ($p < 0.05$). Among females – 10.7% higher mortality in 2020 and 22.6% in 2021 ($p < 0.05$). Male and female mortality from COVID-19 in all age groups in 2021 was higher than that in 2020, and mortality rates increased with an increase in age. Negative changes in mortality from 2015 to 2019 to 2020 among males and females of all age groups were mainly determined by COVID-19. The most significant impact of COVID-19 in 2021 on the overall mortality changes was estimated in the 55–64 and 65–74 male age groups, while female overall mortality was in the 45–54 and 65–74 age groups.

Conclusions Negative changes in mortality from 2015 to 2019 to 2020 among males and females of all age groups were mainly determined by COVID-19. The most significant impact of COVID-19 in 2021 on the overall mortality changes was estimated in the 55–74 male age group, while on female overall mortality in the 45–54 and 65–74 age groups.

Keywords Mortality, Leading causes of death, COVID-19, Excess mortality, Inequalities, Lithuania

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Introduction

COVID-19 was a once-in-generation public health challenge for the entire global community. Lithuania has relatively successfully managed the initial wave of the pandemic. The first quarantine was implemented very early, with multiple restrictions, and resulted in a relatively low seroprevalence and mortality from COVID-19 [1, 2]. However, the second wave (November – December 2020/January – March 2021) was significantly more challenging and caused high morbidity and mortality numbers [3]. To minimize the negative consequences of COVID-19, the Lithuanian Government continued to impose strict non-pharmaceutical measures. Nevertheless, Lithuania appeared in the range of countries that suffered severely in terms of the number of deaths related to COVID-19 [4, 5]. Even before the pandemic, considerably higher mortality rates were reported in Lithuania compared with other European countries [6], especially among low-educated and rural population groups [7, 8]. Therefore, it could be expected that the impact of the pandemic was not uniform across different socioeconomic and demographic groups of the Lithuanian population.

From the public health and healthcare management perspective, it is essential to investigate mortality trends in overall mortality and mortality from the major causes of death, to identify the most vulnerable demographic groups of the population, as well as to evaluate the contribution of the major causes of death to overall changes and inequalities in mortality in the context of COVID-19 pandemic. To the best of our knowledge, there were some efforts to evaluate mortality statistics in Lithuania during the COVID-19 pandemic [9, 10]. However, there is a need to pursue this specific issue in depth. Therefore, this study aimed to analyze changes and demographic inequalities in the mortality of the Lithuanian population in 2020 and 2021, in comparison to the period of 2015–2019, to assess the major causes of death that contributed to the changes and identify the groups of the society, which suffered most.

Methods

Data sources

Information on deaths by age and sex for the period 2015–2021 was obtained from the State Register of Death Cases and Their Causes at the Institute of Hygiene (Lithuania). The Registry systematizes and provides data on the deaths and their causes of persons who died within the territory of the Republic of Lithuania and citizens of the Republic of Lithuania who died abroad. Data on the average annual population in 2015–2021 were obtained from the Database of Indicators of Statistics Lithuania [11].

Statistical analysis

The analysis for this study included all causes (ICD-10 codes A00-Y98) and six leading causes of death in Lithuania: diseases of the circulatory system (I00-I99), malignant neoplasms (C00-C97), external causes (V01-Y98), diseases of the digestive system (K00-K93), diseases of the respiratory system (J00-J99) and COVID-19 (U07.1-U07.2).

Mortality rates (MR) with 95% confidence intervals (CI) by age groups (all ages, 45–54, 55–64, 65–74, 75-year-old and older) and sex for analyzed causes of death were calculated per 100,000 population from 2015 to 2021. Furthermore, the average mortality rates of all analyzed causes of death were calculated for the period 2015–2019. The pandemic period (2020 and 2021) was compared with these averages. The average mortality rate over the period 2015 through 2019 was calculated as the arithmetic mean of the annual rates.

The mortality changes compared to the previous year and between the average of the 2015–2019 years were calculated:

$$(\mathrm{MR}_{\text{analyzed year}} - \mathrm{MR}_{\text{previous year(s)}})/\mathrm{MR}_{\text{previous year(s)}} \times 100(\%)$$

A joinpoint regression analysis was applied to evaluate changes in annual mortality from the leading causes of death by gender and to identify critical periods of change between 2015 and 2021. The joinpoint regression is a Windows-based statistical software program that facilitates the analysis of the direction of change without predetermining cut points [12, 13]. It identifies the cut-points in the mortality curves and determines statistical significance using a Monte Carlo Permutation test. The analysis begins with the fewest cut-points and seeks to identify additional statistically significant cut-points by gradually incorporating them into the model. Cut-points separated the mortality curve into periods. The minimum number of cut-points in the regression fit is 0, and the maximum is 1. The short duration of the analyzed period led to selecting a single regression fit cut-point.

The change in mortality rates for each period between the cut points and the period between 2015 and 2019 was evaluated by applying a logarithmic (*joinpoint*) regression coefficient, which was used to calculate the average annual percentage change (AAPC). AAPCs are used to represent the average increase or rate of change of mortality over a specified period. The AAPC value denotes the percentage annual change (increase, decrease, or no change). This change was considered statistically significant with a p-value of less than 0.05. The AAPC was calculated using the following formula:

$$AAPC = \left\{ \exp\left(\frac{\sum w_i b_i}{\sum w_i} \right) - 1 \right\} \times 100$$

The w_i represents the length of each segment in the range of years, and the b_i denotes the slope coefficients for each segment in the desired range of years.

The differences in mortality rates (RD) for 2020 and the average of 2015–2019, as well as for 2021 compared to the average of 2015–2019, were calculated:

$$MR_{analyzed\ year} - MR_{average\ 2015-2019}\ (per\ 100,000\ population)$$

To assess the impact of leading causes of death on mortality differences, the methodology developed by I. M. Joung was applied [14]. The effect of differences in mortality from the leading causes of death on differences in all-cause mortality was calculated:

$$(\mathrm{RD}_{\text{cause of death}} \times 100)/\mathrm{RD}_{\text{allcauses}}$$

Results

During 2015–2021, 292,172 people died in Lithuania, including 158,001 from diseases of the circulatory system, 56,570 from malignant neoplasms, 19,023 from external causes, 14,419 from diseases of the digestive system, 9,284 from COVID-19, and 8,861 from diseases of the respiratory system. The population size dropped from 2.9 to 2.8 million during the study period [9].

Our analysis suggests that the average annual number of male deaths from all causes for the period 2015 to 2019 was 19,532 and that the mortality rate was 1488.3 (95% CI: 1467.6–1509.0) per 100,000 population (Table 1). Between 2015 and 2019, mortality from all causes (AAPC −2.0%), diseases of the circulatory system (AAPC −2.3%), and especially from external causes of death (AAPC −7.6%) among males decreased significantly ($p < 0.05$). During the study period, there was a non-significant decrease in male mortality from malignant neoplasms and both diseases of the digestive and respiratory systems.

However, Lithuania experienced a 9.4% higher overall mortality among males in 2020 and 18% higher mortality in 2021 compared with a period unaffected by the COVID-19 pandemic ($p < 0.05$). Comparing the average of 2015–2019 years, male mortality from diseases of the circulatory system significantly increased by 4.9% and 5.9% in 2020 and 2021, whereas mortality from external causes decreased by −13.5% and −17.1% in 2020 and 2021 ($p < 0.05$). Only in 2020, male mortality from diseases of the digestive system increased significantly compared with the pre-pandemic period (+14.5%, $p < 0.05$). There was a significant increase in male mortality from COVID-19 in 2021 compared to 2020 (+177.6%, $p < 0.05$).

The trends in female mortality in Lithuania during 2015–2021 are presented in Table 2. For the period from 2015 to 2019, the average annual number of female deaths from all causes was 20643.8, and the mortality rate was 1351.5 (95% CI: 1333.2–1369.8.2.8) per 100,000 population. The period 2015–2019 saw a not statistically significant decrease ($p > 0.05$) in female mortality from all causes (AAPC −0.3%), diseases of the circulatory system (AAPC −1.6%), diseases of the digestive system (AAPC −0.9%), and external causes of death (AAPC −3.5%). There was a statistically significant decrease in mortality from malignant neoplasms among females (AAPC 0.5%, $p < 0.05$)) during the study period.

Lithuania recorded a 10.7% higher female overall mortality in 2020 and 22.6% in 2021 compared with a pre-COVID-19 period ($p < 0.05$). The mortality of females from circulatory system diseases increased by +3.7% in 2020, compared to the 2015–2019 period average. In the year 2021, the rate remained stable. Female mortality from malignant neoplasms increased in 2020, although not statistically significant. However, from 2020 to 2021, it experienced a considerable decline of −6.8%. The female mortality from COVID-19 increased by +243.3% in 2021 compared to 2020 ($p < 0.05$).

In 2020, the overall mortality rate for males increased by 140.2 (95% CI: 139.2–141.2.2.2) per 100,000 pop. and for females by 144.6 (95% CI: 143.4–145.8.4.8) per 100,000 pop. compared to the average mortality rate from 2015 to 2019 (Table 3). This increase was primarily driven by mortality from COVID-19, which accounted for 64.8% of the rise in males and 50.1% in females' mortality. Additionally, deaths due to diseases of the circulatory system contributed to 24.5% of the increase in male and 21.9% in female' mortality. In 2021, the mortality rate rose further, with an increase of 268.3 (95% CI: 266.5–270.1.5.1) per 100,000 pop. for males and 305.8 (95% CI: 303.7–307.2.7.2) per 100,000 pop. for females, again compared to the average rates from 2015 to 2019. In 2021, COVID-19 was responsible for 93.9% of the increase in deaths among males and 81.4% among females. Mortality from diseases of the circulatory system contributed to a 15.5% increase in male and 8.7% in female' mortality in 2021.

All age groups experienced a statistically significant increase in overall male mortality during the COVID-19 pandemic, particularly in individuals aged 75 years and older, with a rate of 23.3% ($p < 0.05$) (Table 4).

Mortality from external causes of death decreased significantly among males aged 45–54 years (19.7% in 2020 and 25.1% in 2021; $p < 0.05$) and among males aged 55–64 years in 2021 (20.7%; $p < 0.05$). Mortality from malignant neoplasms decreased significantly among males aged 65–74 years in 2021 (by 10.9%; $p < 0.05$). Additionally, mortality from respiratory system diseases decreased significantly among males aged 75 years or older in 2021

Table 1 Mortality changes among males in Lithuania from 2015 to 2021 (per 100,000 population)

Year	Diseases of the circulatory system		Malignant neoplasms		External causes		Diseases of the digestive system		Diseases of the respiratory system		COVID-19		All causes	
	MR (95% CI)	%[a]	MR (95% CI)	%[a]	MR (95% CI)	%[a]	MR (95% CI)	%[a]	MR (95% CI)	%[a]	MR (95% CI)	%[a]	MR (95% CI)	%[a]
2015	728.9 (714.5–743.3)		346.8 (336.8–356.8)		179.5 (172.3–186.7)		83.7 (78.8–88.6)		66.7 (62.3–71.1)		0.0		1534.4 (1513.6–1555.2)	
2016	735.6 (721.0–750.2)	0.9	342.6 (332.6–352.6)	−1.2	175.5 (168.4–182.6)	−2.2	92.6 (87.4–97.8)	10.6	63.3 (59.0–67.6)	−5.1	0.0		1539.0 (1518.0–1560.0)	0.3
2017	711.7 (697.3–726.1)	−3.2	336.4 (326.5–346.3)	−1.8	156.1 (149.3–162.9)	−11.1	79.5 (74.7–84.3)	−14.1	66.5 (62.1–70.9)	5.1	0.0		1478.1 (1457.4–1498.8)	−3.95
2018	693.7 (679.4–708.0)	−2.5	341.2 (331.2–351.2)	1.4	144.9 (138.4–151.4)	−7.2	78.7 (73.9–83.5)	−1.0	70.2 (65.6–74.8)	5.6	0.0		1467.4 (1446.7–1488.1)	−0.7
2019	669.1 (655.1–683.1)	−3.5	340.8 (330.8–350.8)	−0.1	135.2 (128.9–141.5)	−6.7	77.8 (73.0–82.6)	−1.1	59.5 (55.3–63.7)	−15.2	0.0		1422.6 (1402.2–1443.0)	−3.1
Average 2015–2019	707.8 (693.5–722.1)	−2.3*[b]	341.6 (331.6–351.6)	−0.4	158.2 (151.4–165.0)	−7.6*[b]	82.4 (77.5–87.3)	−3.1[b]	65.2 (60.8–69.6)	−1.2[b]	0.0		1488.3 (1467.6–1509.0)	−2.0*[b]
2020	742.2 (727.5–756.9)	10.9* (4.9*[c])	344.4 (334.4–354.4)	1.1 (0.8[c])	136.9 (130.6–143.2)	1.3 (−13.5*[c])	89.1 (84.0–94.2)	14.5* (8.1[c])	61.8 (57.5–66.1)	3.9 (−5.2*[c])	90.8 (85.6–96.0)		1628.5 (1606.8–1650.2)	14.5* (9.4*[c])
2021	749.4 (734.6–764.2)	0.97 (5.9*[c])	327.4 (317.6–337.2)	−4.9 (−4.2[c])	131.1 (124.9–137.3)	−4.2 (−17.1*[c])	91.4 (86.2–96.6)	2.6 (10.9[c])	52.5 (48.6–56.4)	−15.0* (−19.5*[c])	252.1 (243.5–260.7)	177.6*	1756.6 (1734.1–1779.1)	7.9* (18.0*[c])

MR, mortality rate per 100,000 population; CI, confidence interval; *$p < 0.05$; [a]changes compared with the previous year; [b]average annual percentage change (AAPC); [c]changes compared with the average in 2015–2019 years

(28.5%; $p < 0.05$). Mortality from other causes of death in 2020 and 2021, compared to the 2015–2019 average, showed trends of either an increase or a decrease.

The changes in female mortality in different age groups from 2015 to 2019 to 2020 and 2021 were similar to changes in male mortality (Table 5). In 2021, female mortality increased significantly in all age groups. The most notable increase in female all-cause mortality was estimated in the 75 years and older and 55–64 years age groups (25.1% and 20.5%, respectively; $p < 0.05$). However, female mortality changes from major causes of death were not statistically significant in different age groups.

In females aged 75 years and older, mortality significantly increased from diseases of the circulatory system in 2021 (5.3%, $p < 0.05$) and decreased from diseases of the respiratory system in 2021 (21.4%, $p < 0.05$). Mortality from other causes of death in 2020 and 2021, compared to the average of 2015–2019, demonstrated trends of either an increase or a decrease.

Further detailed indicators of mortality from the leading causes of death are presented in the Supplementary material (Table S1 – S3).

Discussion

The current study revealed that in Lithuania, all-cause mortality increased in 2020 and 2021 compared with the previous five-year period unaffected by the pandemic. Deaths from COVID-19 caused most of this increase. In addition, the rise in mortality from diseases of the circulatory and digestive systems was observed.

Previous studies highlighted that excess mortality caused by the pandemic varied significantly across countries and was higher than reported COVID-19 deaths [4, 15, 16]. Factors contributing to the differences between countries might include (1) population-level differences in sociodemographic and health-related factors, (2) healthcare system preparedness for public health emergencies, and (3) COVID-19 vaccination policy. We would like to explore these factors more thoroughly.

Population-level differences in sociodemographic and health-related factors. Our study demonstrated the highest mortality rates for 75-year-olds and older males and females. Existing evidence suggests that older age remains the most decisive risk factor for severe COVID-19 outcomes, including deaths [15–17]. Lithuania is an aging country. During the last decade, the proportion of older people in Lithuania has steadily increased to 20.8% at the beginning of 2022 [18]. The older population experiences higher morbidity, especially from chronic noncommunicable diseases and disease complexity. The presence of one or multiple underlying medical conditions, including chronic kidney, lung, liver, cardiovascular diseases, obesity, and immunodeficiency, was associated with an increased risk of COVID-19 death [16, 17, 19, 20]. In 2017, only 44.0% of the Lithuanian population reported perceiving themselves in good health – the lowest rate in the European Union (EU) countries [21]. Before the pandemic (2019), Lithuania had one of the highest all-cause mortality and mortality from chronic noncommunicable diseases among EU countries [22, 23]. The study by Urashima et al. demonstrated that increased mortality before the pandemic was associated with the most tremendous increase in excess deaths during the pandemic [24]. A similar correlation is observed between pre-pandemic life expectancy and excess mortality rate [25]. The possible explanation for this association is that baseline life expectancy serves as a proxy of 'initial conditions' reflecting different aspects related to population health, such as the quality and accessibility of health care, the level of socioeconomic development, the prevalence of risk factors, and disease burden, environmental conditions, etc [25]. Hajdu et al. (2024) has measured that a one-year lower pre-pandemic life expectancy was associated with 521 more excess deaths per million inhabitants throughout the three years of 2020–2022 [26]. Life expectancy in Lithuania in 2020 was the third lowest in the European Union (EU) and 5.5 years below the EU average [27]. It is important to note that excess deaths attributed to causes other than COVID-19 may have resulted from undiagnosed or unrecognized coronavirus infections. A recent study from Lithuania suggests that deaths contributing to COVID-19 constituted 31.0% of the excess non-coronavirus deaths in Lithuania [28].

Healthcare system preparedness for public health emergencies. The Lithuanian healthcare system's emergency response preparedness was low due to an under-resourced budget and health workforce shortage [2]. Lithuania spends a lower gross domestic product share on health care (7.9% in 2021) and has lower nurses per 1000 population rates than the EU average [27]. Lithuanian healthcare system demonstrated some positive development during the independence period; however, it was not among the most effective in the European Region [27, 29]. The COVID-19 pandemic caused some disruption for essential healthcare services in Lithuania as well as in other countries [30–32]. In response to the pandemic, the Lithuanian government implemented restrictive measures relatively early to prevent the transmission of infection and ensure the healthcare system's capacity, including a decrease in hospital overloads. Remote consultations, instead of face-to-face services, were introduced, and routine services and non-urgent procedures were canceled or postponed for a later time [2, 31]. Both cardiovascular outpatient care visits and hospitalizations decreased dramatically in 2020 [30]. In addition, fear of accessing healthcare institutions might be associated with declining healthcare utilization during

Table 2 Mortality changes among females in Lithuania from 2015 to 2021 (per 100,000 population)

Year	Diseases of the circulatory system		Malignant neoplasms		External causes		Diseases of the digestive system		Diseases of the respiratory system		COVID-19		All causes	
	MR (95% CI)	%[a]	MR (95% CI)	%[a]	MR (95% CI)	%[a]	MR (95% CI)	%[a]	MR (95% CI)	%[a]	MR (95% CI)	%[a]	MR (95% CI)	%[a]
2015	882.9 (868.3–897.5)		236.6 (229.0–244.2)		51.4 (47.9–54.9)		62.4 (58.5–66.3)		29.7 (27.0–32.4)		0.0		1355.9 (1337.8–1374.0)	
2016	865.1 (850.5–879.7)	−2.0	237.3 (229.6–245.0)	0.3	48.1 (44.6–51.6)	−6.4	60.9 (57.0–64.8)	−2.4	29.5 (26.8–32.2)	−0.7	0.0		1342.8 (1324.7–1360.9)	−0.97
2017	868.0 (853.3–882.7)	0.3	236.7 (229.0–244.4)	−0.3	50.7 (47.1–54.3)	5.4	62.7 (58.7–66.7)	2.9	31.3 (28.5–34.1)	6.1	0.0		1368.8 (1350.4–1387.2)	1.94
2018	858.9 (844.2–873.6)	−1.0	239.5 (231.7–247.3)	1.2	49.2 (45.7–52.7)	−2.95	58.5 (54.6–62.4)	−6.7	31.8 (29.0–34.6)	1.6	0.0		1365.4 (1346.9–1383.9)	−0.2
2019	816.7 (802.3–831.1)	−4.9	241.7 (233.8–249.6)	0.9	42.6 (39.3–45.9)	−13.4	60.9 (56.9–64.9)	4.1	29.0 (26.3–31.7)	−8.8	0.0		1324.4 (1306.1–1342.7)	−3.0
Average 2015–2019	858.3 (843.7–872.9)	−1.6[b]	238.4 (230.7–246.1)	0.5*[b]	48.4 (44.9–51.9)	−3.5[b]	61.1 (57.2–65.0)	−0.9[b]	30.3 (27.5–33.1)	0.3[b]	0.0		1351.5 (1333.2–1369.8)	−0.3[b]
2020	890.0 (874.9–905.1)	8.97* (3.7*[c])	249.1 (241.1–257.1)	3.1 (4.5[c])	48.1 (44.6–51.6)	12.9 (−0.6[c])	66.9 (62.7–71.1)	9.8 (9.5[c])	26.9 (24.3–29.5)	−7.2 (−11.2[c])	72.5 (68.2–76.8)		1496.1 (1476.6–1515.6)	13.0* (10.7*[c])
2021	884.9 (869.9–899.9)	−0.6 (3.1[c])	232.2 (224.5–239.9)	−6.8* (−2.6[c])	47.7 (44.2–51.2)	−0.8 (−1.4[c])	66.1 (62.0–70.2)	−1.2 (8.2[c])	25.3 (22.8–27.8)	−5.9 (−16.5[c])	248.9 (240.9–256.9)	243.3*	1657.3 (1636.9–1677.0)	10.8* (22.6*[c])

MR, mortality rate per 100,000 population; CI, confidence interval; *$p < 0.05$; [a]changes compared with previous year; [b]average annual percentage change (AAPC); [c] changes compared with average 2015–2019 years

Table 3 Differences in male and female mortality from major causes of death in 2020 and 2021 compared to 2015–2019

Causes of death	Males				Females			
	2020		2021		2020		2021	
	RD (95% CI)	%[a]	RD (95% CI)	%[a]	RD (95% CI)	%[a]	RD (95% CI)	%[a]
Diseases of the circulatory system	34.4 (34.0–34.8)	24.5	41.6 (41.1–42.1)	15.5	31.7 (31.2–32.2)	21.9	26.6 (26.2–27.0)	8.7
Malignant neoplasms	2.8 (2.8–2.8)	2.0	−14.2 (−14.0- −14.4)	−5.3	10.7 (10.4–11.0)	7.4	−6.2 (−6.2- −6.2)	−2.0
External causes	−21.3 (−20.8- −21.8)	−15.2	−27.1 (−26.5- −27.7)	−10.1	−0.3 (−0.3- −0.3)	−0.2	−0.7 (−0.7- −0.7)	−0.2
Diseases of the digestive system	6.7 (6.5–6.9)	4.7	9.0 (8.7–9.3)	3.3	5.8 (5.5–6.1)	4.0	5.0 (4.8–5.2)	1.6
Diseases of the respiratory system	−3.4 (−3.3- −3.5)	−2.4	−12.7 (−12.2- −13.2)	−4.7	−3.4 (−3.2- −3.6)	−2.4	−5.0 (−4.7- −5.3)	−1.6
COVID-19	90.8 (85.6–96.0)	64.8	252.1 (243.5–260.7)	93.9	72.5 (68.2–76.8)	50.1	248.9 (240.9–256.9)	81.4
All causes	140.2 (139.2–141.2)	100	268.3 (266.5–270.1)	100	144.6 (143.4–145.8)	100	305.8 (303.7–307.2)	100

CI, confidence interval; RD, rate difference = $MR_{analyzed\ year} - MR_{average\ 2015–2019}$ (per 100,000 population)

[a]the effect of differences in mortality from the leading causes of death on differences in all-cause mortality was calculated: $(RD_{cause\ of\ death} \times 100)/RD_{all\ causes}$

the pandemic [31]. These factors may have contributed to the increased mortality not only from COVID-19 but also from other diseases, including circulatory and digestive diseases, as was observed in our study.

COVID-19 vaccination policy. There is clear evidence that vaccines effectively reduce hospitalization rates, disease severity, and mortality from COVID-19 [33–35]. Excess all-cause mortality in countries was related to vaccination coverage [36]. Unfortunately, Lithuania's vaccination rate among the most vulnerable groups was only moderate. The complete primary course vaccination rate among Lithuanian adults aged 60 or older was lower compared with European countries' average, 78.2%, and 91.2%, respectively [37]. Nevertheless, there are estimations that vaccination averted 3420 deaths in the Lithuanian population 60 years and older during weeks 51/2020-45/2021 [38]. The link between excess deaths and the percentage of people fully vaccinated by the end of 2021 is confirmed by other studies [10].

We would also like to stress some methodological issues regarding the usage of mortality statistics (i.e., excess deaths) to evaluate the impact of the COVID-19 pandemic and propose some considerations for further research development. Excess deaths are an essential indicator for assessing the burden of the COVID-19 pandemic but have some limitations for international comparisons [39]. Firstly, we must stress the quality of internationally available and national official statistical information [40]. Secondly, the accuracy of results depends on the choice of the mortality index, the number of years included in the reference period, the method, and the time unit of the death series. Nepomuceno (2022) showed that excess mortality can differ nearly four times for Lithuania depending on the used model [41]. This suggests that the volume of excess deaths is under intensive discussion in the academic community. In calculating excess deaths, factors influencing mortality should also be adequately assessed, including heat waves and other natural disasters (many of which are accentuated by climate change) [42]. It was also noticed that determining excess mortality requires the estimation of mortality under non-pandemic conditions. However, the often-used method of averaging the 5-year historical weekly mortality, however, ignores the trend in mortality of the first weeks of 2020 by estimating the population average and may be influenced by recent excess mortality in the past [43].

We want to draw attention to another methodological error that we noticed in the case of Lithuania. In most mortality assessment studies [42, 43], the standard period for analysing Lithuanian mortality data is the last 3 or 5 years. Since the mortality rate has been steadily decreasing in Lithuania since 2015, it is unsurprising that many mathematical models that relied on data from

Table 4 Mortality changes from 2015–2019 to 2020 and 2021 by age groups among males in Lithuania (per 100,000 population)

Causes of death	45–54 years					55–64 years					65–74 year					75 years and older				
	Average 2015–2019	2020	%[a]	2021	%[a]	Average 2015–2019	2020	%[a]	2021	%[a]	Average 2015–2019	2020	%[a]	2021	%[a]	Average 2015–2019	2020	%[a]	2021	%[a]
Diseases of the circulatory system	285.4 (261.9–308.9)	309.1 (284.3–333.9)	8.3	294.7 (270.4–319.0)	3.3	774.8 (734.0–815.6)	806.7 (766.1–847.3)	4.1	788.3 (749.1–827.5)	1.7	1959.2 (1875.4–2043.0)	2069.5 (1984.9–2154.1)	5.6	1919.1 (1840.3–1997.9)	−2.0	6328.3 (6160.2–6496.4)	6529.9 (6358.1–6701.7)	3.2	6660.4 (6486.4–6834.4)	5.2
Malignant neoplasms	172.7 (154.4–191.0)	166.8 (148.5–185.1)	−3.4	162.6 (144.5–180.7)	−5.8	563.2 (528.4–598.0)	545.3 511.9–578.7)	−3.2	492.1 (461.0–523.2)	−12.6	1279.1 (1211.1–1347.1)	1205.1 (1140.3–1269.9)	−5.8	1140.1 (1079.1–1201.1)	−10.9*	2102.2 (2003.1–2201.3)	2221.9 (2119.4–2324.4)	5.7	2008.0 (1910.1–2105.9)	−4.5
External causes	221.3 (200.6–242.0)	177.8 (158.9-196.7)	−19.7*	165.8 (147.5–184.1)	−25.1*	259.4 (235.7–283.1)	227.7 (206.1–249.3)	−12.2	205.7 (185.6–225.8)	−20.7*	248.5 (218.4–278.6)	251.7 (221.9-281.5)	1.3	223.2 (196.1–250.3)	−10.2	306 (267.9–344.1)	341.2 (300.6–381.8)	11.5	331.5 (291.4–371.6)	8.3
Diseases of the digestive system	108.0 (93.5–122.5)	129.3 (113.2–145.4)	19.7	129.5 (113.4–145.6)	19.9	149.3 (131.3–167.3)	162.3 (144.0–180.6)	8.7	160.9 (143.1–178.7)	7.8	196.3 (169.5–223.1)	213.1 (185.7–240.5)	8.6	204.2 (178.3–230.1)	4.0	316.2 (277.4–355.0)	282 (245.1–318.9)	−10.8	294.7 (256.9–332.5)	−6.8
Diseases of the respiratory system	33.2 (25.2–41.2)	36.5 (28.0–45.0)	9.9	34.7 (26.3–43.1)	4.5	78.6 (65.6–91.6)	76.6 (64.0–89.2)	−2.5	57.6 (47.0–68.2)	−26.7	187.7 (161.5–213.9)	194.7 (168.5–220.9)	3.7	153.4 (130.9–175.9)	−18.3	514.8 (465.4–564.2)	429.3 (383.8–474.8)	−16.6	368.3 (326.0–410.6)	−28.5*
COVID-19	0	28.7 (21.1–36.3)		108.4 (93.6–123.2)		0	106.1 (91.3–120.9)		262.2 (239.5–284.9)		0	279.2 (247.9–310.5)		686.8 (639.3–734.3)		0	776.7 (715.7–837.7)		2138.8 (2037.9–2239.9)	
All causes	938.7 (896.2–981.2)	985.2 (941.0–1029.4)	5.0	1046.1 (1000.4–1091.8)	11.4*	2001.2 (1936.0–2066.4)	2137.3 (2071.7–2202.9)	6.8*	2141.1 (2076.9–2205.3)	7.0*	4168 (4047.1–4288.9)	4609.2 (4484.6–4733.8)	10.6*	4664.7 (4543.5–4785.9)	11.9*	10291.7 (10081.9–10501.5)	11516.3 (11294.3–11738.3)	11.9*	12688.3 (12456.1–12920.5)	23.3*

*$p < 0.05$; [a]changes compared with average 2015–2019 years

Table 5 Mortality changes from 2015–2019 to 2020 and 2021 by age groups among females in Lithuania (per 100,000 population)

Causes of death	45–54 years					55–64 years					65–74 years					75-years and older				
	Average 2015–2019	2020	%[a]	2021	%[a]	Average 2015–2019	2020	%[a]	2021	%[a]	Average 2015–2019	2020	%[a]	2021	%[a]	Average 2015–2019	2020	%[a]	2021	%[a]
Diseases of the circulatory system	65.4 (54.6–76.2)	70.4 (58.9–81.9)	7.6	67.2 (56.0–78.4)	2.8	197.9 (179.4–216.4)	205.0 (186.4–223.6)	3.6	207.3 (188.9–225.7)	4.7	744.2 (703.5–784.9)	763.3 (722.4–804.2)	2.6	712.1 (673.0–751.2)	−4.3	5774.9 (5671.1–5878.7)	5783.9 (5680.1–5887.7)	0.2	6078.3 (5970.0–6186.6)	5.3*
Malignant neoplasms	123.8 (109.0–138.6)	121.5 (106.4–136.6)	−1.9	109.7 (95.4–124.0)	−11.4	271.7 (250.0–293.4)	258.5 (237.7–279.3)	−4.9	254.8 (234.4–275.2)	−6.2	506.8 (473.2–540.4)	512.1 478.6–545.6))	1.0	463.5 (431.9–495.1)	−8.5	914.7 (872.4–957.0)	968.4 (924.8–1012.0)	5.9	931.2 (887.7–974.7)	1.8
External causes	45.1 (36.2–54.0)	35.9 (27.7–44.1)	−20.4	34.3 (26.3–42.3)	−23.9	54.1 (44.4–63.8)	49.1 (40.0–58.2)	−9.2	45.3 (36.7–53.9)	−16.3	65.6 (53.5–77.7)	58.1 (46.8–69.4)	−11.4	60.2 (48.8–71.6)	−8.2	150.5 (133.3–167.7)	178.1 (159.3–196.9)	18.3	184.7 (165.2–204.2)	22.7
Diseases of the digestive system	41.2 (32.7–49.7)	60.0 (49.4–70.6)	45.6	58.5 (48.1–68.9)	42.0	60.7 (50.4–71.0)	67.5 (56.8–78.2)	11.2	70.5 (59.8–81.2)	16.1	84.5 (70.7–98.3)	81.0 (67.6–94.4)	−4.1	82.7 (69.3–96.1)	−2.1	262.8 (240.0–285.6)	272.4 (249.2–295.6)	3.7	252.7 (229.9–275.5)	−3.8
Diseases of the respiratory system	8.7 (4.8–12.6)	8.9 (4.8–13.0)	2.3	6.8 (3.2–10.4)	−21.8	15.4 (10.2–20.6)	15.8 (10.6–21.0)	2.6	13.7 (9.0–18.4)	−11.0	40.4 (30.9–49.9)	37.4 (28.3–46.5)	−7.4	45.6 (35.7–55.5)	12.9	167.6 (149.4–185.8)	134.9 (118.6–151.2)	−19.5	131.7 (115.3–148.1)	−21.4*
COVID-19	0	13.8 (8.7–18.9)		63.8 (52.9–74.7)		0	42.5 (34.0–50.9)		136.4 (121.4–151.3)		0	79.9 (66.6–93.2)		349.9 (322.5–377.3)		0	414.5 (385.9–443.1)		1391.2 (1338.1–1444.3)	
All causes	321.9 (298.1–345.7)	361.6 (335.5–387.7)	12.3	376.4 (350.0–402.8)	16.9*	670.6 (636.6–704.6)	722.4 (687.7–757.1)	7.7	808.4 (772.1–844.7)	20.5*	1613.4 (1553.7–1673.1)	1724.4 (1663.2–1785.6)	6.9	1916.9 (1853.2–1980.6)	18.8*	7829.3 (7709.8–7948.8)	8465.8 (8341.9–8589.6)	8.1*	9794.5 (9659.8–9929.2)	25.1*

*$p < 0.05$; [a]changes compared with average 2015–2019 years

the 2015–2019 period continued to predict a decrease in mortality in 2020–2022 under non-pandemic conditions [44]. However, we have observed a constant trend of mortality growth with several fluctuations in Lithuania since 1960, when mortality decreased for several years (for example, 1994–2000, 2007–2009, and 2015–2019). It happened that the last period of mortality decrease in 2015–2019 coincides with the period of the previous 3 or 5 years, which is used in the standard methodologies of mathematical mortality modelling. This caused the predicted non-pandemic mortality in Lithuania for the period of 2020–2021 to turn out to be much lower than could be expected if the long-term mortality trend since 1960 was considered. Accordingly, the excess mortality for 2020–2022 based on the long-term mortality trend since 1960 was much lower than the excess mortality estimated from the short-term trends for 2015–2019.

In our understanding, a method for estimating excess mortality cannot be automatically applied to different countries. Adapting the methodology to specific mortality dynamics in a particular country is essential. However, due to the phenomenon's complexity, the incompleteness and unreliability of the data, the ambiguity of their evaluation, and frequent bias, it is complicated to compare excess mortality among different countries. Incorrect assessment of the results of the pandemic does not allow an adequate evaluation of the effectiveness, benefits, burden appropriateness, and legality of the measures to prevent the pandemic. Therefore, we believe that it is necessary to develop a more universal and reliable methodology for assessing excess mortality, which would help to avoid incompletely justified and controversial conclusions in such a sensitive public context as pandemic management and help to choose adequate management measures in future pandemics.

Conclusions

Our study has revealed that COVID-19 is the leading cause of the increase in mortality in Lithuania in 2020–2021. The impact of COVID-19 on mortality rates across all age groups, both male and female, showed an increase in 2021 compared to 2020.

The most significant impact of COVID-19 in 2021 on the overall mortality changes was estimated in the 55–74 male age group, while on female overall mortality in 45–54 and 65–74 age groups. Relatively low vaccination rates among the elderly, poor general health status of the Lithuanian population, insufficient health system preparedness for managing emergencies, and different challenges in managing the COVID-19 pandemic in Lithuania could be listed as underlying causes.

Supplementary Information

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Supplementary Material 1

Author contributions

MS: conceptualization, methodology, formal analysis, resources, data curation, writing-original draft preparation, writing-review and editing, visualization. OM: conceptualization, methodology, formal analysis, resources, data curation, writing-original draft preparation, writing-review and editing, visualization. SK: conceptualization, methodology, formal analysis, resources, data curation, writing-original draft preparation, writing-review and editing, visualization. SS: conceptualization, methodology, formal analysis, resources, data curation, writing-original draft preparation, writing-review and editing, visualization. JP: conceptualization, methodology, formal analysis, writing-original draft preparation, visualization. RK: conceptualization, methodology, writing-original draft preparation, visualization. RG: conceptualization, methodology, formal analysis, resources, data curation, visualization. JA: conceptualization, methodology, writing-original draft preparation, visualization. AD: conceptualization, methodology, writing-original draft preparation, visualization. All authors contributed to the article and approved the submitted version.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Competing interests

The authors declare no competing interests.

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