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Cause-specific mortality in Spain during the pandemic: educational differences and its impact on life expectancy

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Background: Life expectancy in Spain fell by 1 year between 2018/19 and 2020. Yet, little is known on the impact on cause-of-death (COD) dynamics and educational inequalities therein. **Methods:** We use individual-level death counts data by age, sex, education and multiple causes of death (MCOD) and the corresponding population exposures from national registers in Spain. Deaths were examined both as underlying cause of death (UCOD) and as contributory cause. We estimated life expectancies and lifespan inequalities by subpopulation groups and decomposed life expectancy differences between 2018/19 and 2020 by age groups and COD to assess the impact of COVID-19 (as MCOD) and major UCOD. **Results:** COVID-19 contributed to a decline in male and female life expectancy in Spain between 2018/19 and 2020 (respectively, −1.7 and −1.4 years). Conversely, cancer, respiratory and circulatory system diseases and ill-defined causes as UCOD contributed to life expectancy increases. Life expectancy declines equalled −1.4 years among the low-educated in both sexes (population 30+), −1.0 and −0.7 years among middle-educated and −1.1 and −0.9 years among high-educated men and women. Without COVID-19, educational inequalities in life expectancy would have remained at similar levels, whereas lifespan variation would have been lower (−22% for women and −8% for men). **Conclusions:** Life expectancy declines in Spain in 2020 were mainly driven by COVID-19, with possible substitution effects, especially for respiratory system diseases (fewer deaths compared to 2018/19 when coded as UCOD but more as contributing cause). We therefore advocate analysing MCOD when studying changing COD patterns during the pandemic.

Background

During 2020–21, Spain was hit hard by COVID-19 pandemic, costing the lives of 90 035 persons according to official statistics.[1] Research on the impact of COVID-19 on excess deaths[2–4] and life expectancy[5] is already well-covered. In Spain, the first wave of the pandemic led to a 0.9-year decline in life expectancy at birth,[6] while annual estimates for 2020 suggest a 1.2-year decline compared to the previous year[7,8] or 1.5 years when compared to the average yearly change between 2015 and 2019.[5]

COVID-19 mortality risks are known to be associated with morbidity trajectories.[9,10] Most studies on cause-of-death (COD) mortality dynamics focus on the assessment of the principal or so-called underlying cause of death (UCOD). However, in a context of ageing societies and mortality shifts towards older ages, there is a growing concern regarding the assessment of mortality using only the UCOD.[11–13] The COVID-19 pandemic is not an exception as almost all COVID-19 deaths recorded as UCOD in 2020 had other conditions mentioned on the death certificate (e.g. 92% in the USA[14] and 98.4% among 30- to 69-year olds living in three Brazilian capitals[15]). This implies a high prevalence of comorbidity among people who died from COVID-19.[15–17] Moreover, the UCOD approach underestimates the mortality burden from diseases that are not commonly selected as the UCOD but nevertheless contribute to the sequence of causes in the death process, as is known to occur with diabetes, influenza and pneumonia, or hypertension.[18] The use of multiple causes of death (MCOD) should therefore aid the understanding of mortality dynamics, particularly in exceptional situations such as the COVID-19 pandemic.[15]

However, cause-specific mortality research during the pandemic years is still scarce. Exceptions include Fedeli et al.[19] who observed not only the emergence of COVID-19 mortality in the Veneto region (Italy) during the first months of the pandemic but also related respiratory conditions, diabetes mellitus, hypertensive heart disease, cerebrovascular diseases and ill-defined causes as the underlying cause. Concurrently, when MCOD were analysed, sharp increases were also found for dementia and Alzheimer's and chronic lower respiratory diseases.[19] A Brazilian study assessing COD from an MCOD perspective revealed that hypertension and diabetes were the most common contributory causes associated with COVID-19.[15] Thus, assessing the COD dynamics in COVID-19 times from an MCOD perspective seems particularly insightful. COVID-19 infection and mortality rates are also known to differ according to individual-level demographic and socioeconomic characteristics, including age, sex and educational attainment.[20–22] Educational attainment is a frequently used indicator of socioeconomic status in health and mortality research.[23–25]

In this article, we aim to analyse the impact of COVID-19 deaths alongside all other COD reported on the death certificate on the life expectancy in 2020 in Spain, one of the most affected countries in Europe by the pandemic.[5] In doing so, we account for deaths that had COVID-19 mentioned on the death certificate as underlying or contributing cause. In addition, we assess other COD frequently mentioned on the death certificate in the presence of COVID-19,

ascertain any differences in the relative risks of having died from other diseases compared to the average for the two preceding years (2018–19) and explore the (change in) educational inequalities in mortality during this period.

Methods

Data

We used individual-level mortality and aggregated population level data for 2018–20 for Spain that was requested from the Spanish National Statistics Institute (INE) (www.ine.es). Both datasets consist of secondary data of public sources, which did not have any individual identifiers. As such, no ethical approval for human subject research from the Institutional Review Board of the respective institutions was required. The datasets contain age, sex and education and, regarding the mortality dataset, also all COD listed on the death certificate. We used a detailed COD list of 33 COD including COVID-19 (suspected or diagnosed) (Supplementary table S1). Information on the COD data production process, death certificates and coding methods can be found elsewhere (see Supplementary references S1 and S2). Regarding the educational attainment of the deceased and population at risk, INE estimated this through data linkage from multiple datasets, including censuses, municipal population registers (*Padrón*), data on enrolment and university and non-university diplomas from the Ministry of Education. For the 0.2% that this was not possible, INE probabilistically imputed a value based on the 2011 Census and considering the person's province of residence and age (see Supplementary reference S3 and figure S1 for the distribution of the Spanish population according to age, sex and educational attainment). Based on the mortality and population data sources, we created three educational attainment categories: low (primary education or less, ISCED-2011 0–1), middle (lower and upper secondary education and lower vocational training, ISCED-2011 2–3) and high (postsecondary vocational training and university, ISCED-2011 4+).

Analytical approach

First, we compare the distribution of the main UCOD (traditional view on COD analyses) and any mention of a selected COD in the death certificate (MCOD) in 2020 with the 2018/19 average. Herewith, we obtain an indication of the magnitude of both COVID-19 mortality and any changes in the patterns of other important, frequently reported conditions, especially during the initial stages of the pandemic, including flu and pneumonia and other respiratory system diseases (see also[19]), dementia/Alzheimer, cardiovascular diseases and external causes.

Secondly, we define COVID-19-related deaths as those with a COVID-19 cause on the death certificate, irrespective of their position within the death certificate. For the remaining deaths, the UCOD was used. Using conventional life table methods, we estimated life expectancies at birth by sex and according to educational attainment at age 30.[26] Life expectancy gaps between 2018/19 and 2020 were estimated and differences decomposed into (i) age- and cause- and (ii) education- and cause-specific components using the decomposition derived by Horiuchi using the DemoDecomp package in R.[27,28]

Lastly, we estimated the contribution of COVID-19 to life expectancy and lifespan variation at age 30 (measured as the standard deviation in age at death) by sex and educational group by comparing the corresponding values for the whole population and excluding COVID-19-related deaths, defined as potential gains in life expectancy (PGLE).[29] This method was recently applied to estimate the contribution of alcohol to life expectancy and lifespan variation in Spain.[30]

Results

In 2020, 74 839 deaths had COVID-19 as the UCOD (15.2% of all deaths) and 8275 additional deaths (1.9% of all deaths) had COVID-19 mentioned elsewhere on the death certificate (table 1). While deaths from COVID-19 occurred at all ages, there is a clear positive age gradient: 18.2% of the 85+ who died had COVID-19 mentioned on their death certificate, compared to <1% among infants.

Table 1 Number of deaths due to COVID-19 as underlying cause of death (UCOD), contributing cause of death and all-cause mortality in Spain in 2020 according to the age, sex and educational level of the deceased and period of death

	Number of deaths			Ratio (%)	
	All causes	COVID-19		COVID-19 UCOD/all causes	Any mention of COVID-19/all causes
		As UCOD	As contributing		
Total	493 776	74 839	8275	15.2	16.8
Age					
0	890	4	3	0.4	0.8
1–4	188	1	1	0.5	1.1
5–29	2139	81	17	3.6	4.3
30–44	6715	331	96	4.9	6.4
45–64	54 248	4819	857	8.9	10.5
65–84	192 772	30 416	3374	15.8	17.5
85+	236 824	39 192	3927	16.5	18.2
Gender					
Male	249 664	38 917	4264	15.6	17.3
Female	244 112	35 922	4011	14.7	16.4
Education (30+)					
Low	282 731	44 286	4673	15.7	17.3
Medium	149 986	21 666	2575	14.4	16.2
High	50 055	7745	867	15.5	17.2
Missing	11 004	1142	160	10.4	11.8
Month of death					
January–February	79 716	0	4	0.0	0.0
March–May (wave 1)	154 302	45 988	4270	29.8	32.6
June–August (summer)	101 561	2726	1069	2.7	3.7
September–December	158 197	26 125	2932	16.5	18.4

Proportions were relatively similar between men (17.3%) and women (16.4%) and educational categories (low 17.3%; medium 16.2%; high 17.2%). Finally, the proportion of deaths directly due to COVID-19 was highest during wave 1 (29.8%), followed by the last four months of the year (16.5%). Just 2.7% of deaths during the summer months had COVID-19 as UCOD.

Compared to 2018/19, the mean number of causes per death certificate hardly changed in 2020 (3.8 vs. 3.7) (table 2). When specified according to UCOD, increases can be observed for external causes (accidental falls, from 3.6 in 2018/19 to 4.2 in 2020, other accidental threats to breathing, from 3.6 to 4.0, and suicide and self-inflicted injury, from 1.4 to 1.8 causes per death certificate). Regarding the frequency of the different UCOD, deaths from diseases related to the respiratory system declined when they were reported as the underlying cause (flu and pneumonia −16.4%, chronic lower respiratory diseases −10.5% and remaining respiratory system diseases −20.6%). Death from sepsis (blood poisoning) also declined (−7.3%), as well as ill-defined causes (−7.0%), transport accidents (−18.9%) and other accidental threats to breathing (−7.0%). Mortality from different cancer sites remained relatively stable. Conversely, important increases were observed for diabetes (+15.5%), other endocrine, nutritional and metabolic diseases (+11.5%), hypertensive disease (+17.2%), diseases of the genitourinary system (+12.7%), accidental falls (+12.0%) and suicide and self-inflicted injury (+9.3%).

However, the impact of the pandemic on other diseases becomes clearer when analysing MCOD as each COD category analysed appeared more often on the death certificate in 2020 than in 2018/19, except transport accidents (−17.7%). This was particularly the case with flu and pneumonia (+63.0%), but also the endocrine, nutritional and metabolic diseases (diabetes +25.8%; obesity +51.9%; other +21.7%), dementia and Alzheimer (+18.9%), hypertensive diseases (+32.6%), diseases of the genitourinary system (+16.4%) and ill-defined causes (+19.5%). Although less important numerically, accidental falls also saw an increase of 17.2% during 2020. Hence, the MCOD/UCOD ratio increased for most COD, suggesting an increase in co- or multimorbidity during 2020. Finally, COVID-19 co-occurred in all COD categories analysed, ranging from 0.1% when an ill-defined cause was the UCOD to 3.1% in the case of flu, pneumonia and COPD and 3.2% for malignant neoplasm of lymphoid, haematopoietic and related tissue.

Age, education and cause-specific contributions to life expectancy changes

Life expectancy at birth declined by 0.99 years for men and 0.95 years for women between 2018/19 and 2020 (table 3). Most of the decline occurred among the 65- to 84-year age group (−0.65 years among men and −0.53 years among women), followed by the 85+ age group (respectively, −0.22 and −0.34 years). Life expectancy among 45- to 64-year-old men and women declined by −0.12 and −0.09 years, respectively, and among 30- to 44-year olds merely −0.03 and −0.01 years. One- to twenty-nine-year olds even gained 0.02 years, while no change took place in infant mortality (both sexes).

Among all three educational categories, declines in life expectancy at age 30 were observed between 2018/19 and 2020, whereby declines were highest among the lowest educated, with minor sex differences (men: −1.36 years; women: −1.43 years), followed by the highest-educated group (men: −1.06 years; women: −0.86 years). The medium-educated group observed the lowest drop (men: −0.96 years; women −0.66 years). Again, COVID-19 explained most of these declines. Yet, differences in the dynamics of other causes across educational groups are to be noted. While the medium and high-educated recorded life expectancy improvements in most cardiovascular disease categories (+0.21 years for the total COD chapter in the case of middle-educated women), the lower educated did not, and even observed minor losses in hypertensive diseases (−0.03 years among both sexes). Educational differences are also observed for external causes, but only among men (lower educated: −0.10 years; medium educated: −0.01 years; no change among higher educated).

Regarding cause-specific contributions, COVID-19 was actually responsible for more than the total decline in life expectancy at birth (1.67 years for men and 1.34 years for women). This implies that mortality from other COD declined during the pandemic, especially respiratory system diseases (men: contributing to +0.21 years in life expectancy; women: +0.15 years), male lung cancer (+0.08 years), remaining neoplasms (men: +0.14 years; women: +0.07 years), heart and other diseases of the circulatory system (men: +0.04 years; women: +0.08 years) and ill-defined causes (men: +0.09 years; women: +0.02 years). Concurrently, there were also several COD, which contributed to minor declines in life expectancy in 2020 compared to 2018/19 (diabetes −0.02 years men, −0.01 years women; hypertensive diseases −0.02 years both sexes).

Finally, most of the life expectancy gains due to non-COVID-19 were made in the 65-84 age group in the case of men (0.28 years). Regarding women, the 85+ was the main age group responsible for the gains in life expectancy due to lower non-COVID-19 mortality (0.19 years).

Counterfactual scenario by eliminating COVID-19 mortality

Life expectancy at age 30 was estimated to be 1.67 years higher for men and 1.38 years higher for women when COVID-19 mortality was eliminated (table 4). The standard deviation in age at death (lifespan inequality) would be larger as well when eliminating COVID-19. Results by educational level suggest similar values in terms of PGLE. The exception is for low-educated females, leading therefore to lower educational inequalities in lifespan inequality without COVID-19 compared to the observed estimates that include COVID-19 (−22% for women and −8% for men).

Discussion

We analysed the COD dynamics on life expectancy differences between 2018/19 and 2020 in Spain. We made use of both the UCOD and MCOD data that is available on the death certificate, as well as the information on the educational attainment of the deceased that the INE obtained through data linkage. Life expectancy dropped by 0.99 years among men and 0.95 years among women between 2018–19 and 2020. Contributions to this drop were highest among the 65- to 84-year-old age group (men: −0.65 years; women: −0.52 years). Infant, child and young-adult mortality did not increase.

COVID-19, measured in death certificates as either underlying or contributory COD, exceeded the drop in total (all-cause) life expectancy. In contrast, improvements were observed for other COD, particular respiratory system diseases, but also circulatory system diseases (except hypertensive diseases) and cancer (except female lung cancer) showed improvements. With regard to the latter two COD categories, this is likely due to a continuing declining trend, although from just one year of data this is difficult to confirm. For example, we know that cancer patients have been at greater risk to manifest complications and develop severe events from COVID-19, including intensive care unit admission and death, compared with patients without cancer, which would contribute to fewer cancer deaths because of a substitution effect. Conversely, care, diagnostic tests and therapeutic intervention for cancer patients were often delayed during the pandemic as the health care system distracted towards COVID-19. As a result, cancer survival rates may have experienced periodic declines.[31,32]

Similarly, we observed notable declines in mortality from several COD when the underlying cause was analysed. For example, 16% fewer deaths from pneumonia and influenza were recorded in 2020 compared to 2018/19, there was a 11% decline in chronic lower respiratory diseases, 21% decline in remaining lower respiratory system diseases and 7% fewer deaths from ill-defined causes. Mortality declines from these causes were also found using UCOD in England

Table 2 Distribution of causes of death registered in 2020 in Spain compared to 2018/19: underlying cause of death (UCOD) and multiple causes of death (MCOD)

	Cause of death	Mean n° of causes per death certificate by UCOD 2020		Number of deaths						% COVID-19 deaths on certificate 2020
				UCOD 2020		MCOD 2020		Ratio MCOD/UCOD		
		N	Δ 2020 vs. 2018/19 (%)	*N*	Δ 2020 vs. 2018/19 (%)	*N*	Δ 2020 vs. 2018/19 (%)	2020	2018/19	
	All deaths	**3.8**	**3.7**	**493 776**	**16.7**	–	–	–	–	**16.5**
1	COVID-19	3.8	–	74 839	NA[b]	83 114	–	1.1	NA[b]	97.9[a]
2	Flu, pneumonia	3.4	3.4	9 662	−16.4	48 889	63.0	5.1	2.6	3.1
3	Chronic lower respiratory diseases	4.2	4.1	12 351	−10.5	27 088	7.3	2.2	1.8	3.1
4	Remaining respiratory system diseases	3.4	3.4	18 837	−20.6	82 235	4.5	4.4	3.3	3.0
5	Sepsis	3.6	3.4	2 745	−7.3	14 587	6.3	5.3	4.6	1.5
6	Remaining infectious and parasitic diseases	4.5	4.4	3 211	−2.6	14 917	38.2	4.6	3.3	2.8
7	Malignant neoplasm of lymphoid, haematopoietic and related tissue	3.7	3.7	8 374	−0.7	10 453	7.5	1.2	1.2	3.2
8	Lung cancer	3.7	3.6	23 099	−1.0	25 590	1.7	1.1	1.1	2.2
9	Neoplasms of reproductive organs	3.9	3.8	16 803	1.8	21 397	6.0	1.3	1.2	2.0
10	Remaining neoplasms	3.8	3.7	64 465	−0.2	126 676	2.3	2.0	1.9	1.8
11	Diseases of the blood (-forming organs), immunological disorders	4.4	4.3	2 062	4.2	16 028	10.4	7.8	7.3	2.8
12	Diabetes mellitus	4.6	4.6	11 297	15.5	44 156	25.8	3.9	3.6	2.1
13	Obesity	4.6	4.6	503	1.7	3 952	51.9	7.9	5.3	2.2
14	Other endocrine, nutritional and metabolic diseases	4.3	4.3	3 490	11.5	33 772	21.7	9.7	8.9	2.2
15	Dementia, Alzheimer	4.1	4.1	37 793	−0.3	74 349	18.9	2.0	1.6	2.2
16	Other mental/behavioural disorders and diseases of nervous system	4.1	4.0	11 386	4.2	44 316	4.0	3.9	3.9	2.6
17	Hypertensive diseases	4.3	4.3	14 271	17.2	73 194	32.6	5.1	4.5	1.4
18	Ischaemic heart diseases	3.6	3.6	29 654	−1.8	44 210	5.0	1.5	1.4	1.7
19	Other heart diseases	3.9	3.8	14 357	0.6	36 885	8.9	2.6	2.4	1.8
20	Cerebrovascular diseases	3.7	3.6	25 817	−1.0	43 659	5.1	1.7	1.6	1.8
21	Other diseases of the circulatory system	3.4	3.4	35 640	−0.4	114 677	9.2	3.2	2.9	1.3
22	Chronic liver diseases	4.3	4.1	3 976	−0.9	6 749	3.1	1.7	1.6	2.3
23	Other diseases of the digestive system	4.0	3.9	17 589	−1.5	46 973	1.1	2.7	2.6	1.9
24	Diseases of the skin and subcutaneous tissue	3.9	3.8	1 902	5.6	9 415	12.3	5.0	4.7	1.7
25	Diseases of the musculoskeletal system/connective tissue	4.4	4.3	5 225	0.8	14 768	13.3	2.8	2.5	2.5
26	Diseases of the genitourinary system	3.7	3.6	15 810	12.7	84 741	16.4	5.4	5.2	2.4
27	Other diseases	4.0	3.6	1 433	−4.8	3 680	23.2	2.6	2.0	2.2
28	Ill-defined causes	1.7	1.6	11 107	−7.0	496 992	19.5	44.7	34.8	0.1
29	Transport accidents	1.7	1.6	1 686	−18.9	1 719	−17.7	1.0	1.0	0.3
30	Accidental falls	4.2	3.6	3 605	12.0	4 211	17.2	1.2	1.1	2.1
31	Other accidental threats to breathing	4.0	3.6	2 511	−7.0	17 115	1.7	6.8	6.2	1.1
32	Suicide and self-inflicted injury	1.8	1.4	3 941	9.3	3 955	9.6	1.0	1.0	0.3
33	Other external causes	3.3	3.1	4 335	−0.4	30 568	13.7	7.1	6.2	1.3

Notes: See Supplementary table S1 for the ICD codes of each cause of death category.

a: Does not equal to 100% because about 1600 COVID-19 cases did not have COVID-19 in the death certificate. Following the WHO recommendations, in March 2020, the optical character recognition (OCR) dictionary (used to scan the death certificate) was updated to include terms related to COVID-19 and was deployed by all the regional delegations of the INE. In the first version of the OCR dictionary, the terms included were mainly theoretical or based on the actual terms used by doctors in the first certificates that the INE had access to and where COVID-19 was reported (but whereby COVID-19 was not necessarily mentioned on the death certificate). Subsequently, a second version of the OCR dictionary was deployed in which more real terms used by doctors to name this disease were included. The discrepancy therefore pertains to cases that were posteriori coded by IRIS as COVID-19, as well as more complex cases that had been transferred to the WHO for recoding (see Supplementary reference S2).

b: There were no COVID-19 deaths in Spain prior to 2020.

and Wales.[33] Given that COVID-19 is caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) a substitution effect is likely behind the declines in these UCOD as we observed notable increases in the deaths with respiratory diseases as contributory cause. For example, flu and pneumonia appeared 63% more times on the death certificate in 2020 (table 2). This was particularly evident when COVID-19 was identified as the UCOD, with flu and pneumonia being identified as contributing causes on 30% of these death certificates. This suggests that flu and pneumonia were, at least partially, consequences of COVID-19 (Supplementary table S2). Considerable declines in deaths were also observed for transport accidents (−19%), which is line with to the reduction in mobility early on during the pandemic and ensuing lockdowns.[34]

On the other hand, minor increases in mortality were observed for hypertensive diseases (+17%), accidental falls (+12%) and suicide (+9%). Taking external causes as a whole, we found it had a strong educational component in terms of years of life expectancy lost, as a decline was only observed among low-educated men. There was not an external COD that stood out, but most of the contribution to the change in life expectancy occurred at working age, which could imply that lower-skilled men were more likely to be physically present at work.

Table 3 Change in life expectancy between 2018/19 and 2020 according to several main cause of death groupings: COVID-19 as underlying cause of death (UCOD) or contributing cause of death and other causes of death as UCOD[a]

	Total	Age						Edu (age 30+)		
		0	1–29	30–44	45–64	65–84	85+	Low	Medium	High
Men										
Total mortality	−0.99	0.00	0.02	−0.03	−0.12	−0.65	−0.22	−1.36	−0.96	−1.06
COVID−19	−1.67	0.00	0.00	−0.03	−0.35	−0.92	−0.37	−1.78	−1.60	−1.74
Other causes	0.67	0.00	0.02	0.00	0.23	0.28	0.14	0.42	0.64	0.68
Lung cancer	0.08	0.00	0.00	0.00	0.04	0.03	0.00	0.07	0.08	0.11
Remaining Neoplasms	0.16	0.00	0.00	0.01	0.07	0.07	0.01	0.17	0.15	0.16
Diabetes mellitus	−0.01	0.00	0.00	0.00	0.00	−0.01	0.00	−0.02	−0.02	−0.02
Dementia, Alzheimer	0.03	0.00	0.00	0.00	0.00	0.01	0.02	0.04	0.04	0.03
Hypertensive diseases	−0.02	0.00	0.00	0.00	−0.01	−0.01	0.00	−0.03	−0.01	−0.01
Heart and other diseases of the circulatory system	0.04	0.00	0.00	−0.01	−0.02	0.05	0.02	0.00	0.05	0.11
Cerebrovascular diseases	0.02	0.00	−0.01	0.00	0.01	0.01	0.01	0.01	0.03	0.04
Respiratory system diseases	0.21	0.00	0.01	0.00	0.04	0.09	0.06	0.17	0.20	0.16
Chronic liver diseases	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.00	0.00
Other diseases of the digestive syst.	0.03	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.03
Other diseases	0.04	0.00	0.01	0.00	0.02	0.01	0.01	0.00	0.05	0.03
Ill-defined causes	0.09	0.00	0.01	0.02	0.05	0.01	0.00	0.08	0.06	0.03
External causes	−0.01	0.00	−0.01	−0.01	0.00	0.01	0.00	−0.10	−0.01	0.00
Women										
Total mortality	−0.95	0.00	0.02	−0.01	−0.09	−0.52	−0.34	−1.43	−0.66	−0.86
COVID-19	−1.34	0.00	0.01	−0.01	−0.17	−0.63	−0.53	−1.60	−1.29	−1.41
Other causes	0.39	0.00	0.02	0.00	0.08	0.11	0.19	0.17	0.64	0.55
Lung cancer	0.01	0.00	0.00	0.00	0.02	−0.01	0.00	−0.01	0.01	0.04
Remaining neoplasms	0.07	0.00	−0.01	0.00	0.04	0.03	0.01	0.01	0.07	0.12
Diabetes mellitus	−0.01	0.00	0.00	0.00	0.00	−0.01	−0.01	−0.03	0.00	−0.01
Dementia, Alzheimer	0.02	0.00	0.00	0.00	0.00	−0.01	0.03	0.01	0.07	0.05
Hypertensive diseases	−0.02	0.00	0.00	0.00	0.00	−0.01	−0.01	−0.03	0.01	0.00
Heart and other diseases of the circulatory system	0.08	0.00	0.00	0.00	0.00	0.04	0.04	0.04	0.14	0.10
Cerebrovascular diseases	0.03	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.05	0.04
Respiratory system diseases	0.15	0.00	0.00	0.00	0.01	0.05	0.09	0.16	0.19	0.14
Chronic liver diseases	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Other diseases of the digestive syst.	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.02	0.00
Other diseases	−0.01	0.00	0.01	0.00	0.00	−0.01	0.00	−0.04	0.03	0.02
Ill-defined causes	0.02	0.00	0.00	0.00	0.01	0.01	0.00	0.03	0.03	0.04
External causes	0.03	0.00	0.02	0.00	0.00	0.01	0.00	0.02	0.02	0.01

Note: Age- and/or cause-specific contributions may not always add up to the total/education-specific change due to rounding.
a: Excludes deaths that had COVID-19 mentioned on the death certificate as a contributing cause.

Table 4 Contribution of COVID-19 (as underlying and contributing cause of death) to all-cause life expectancy and lifespan inequality at age 30 by sex; Spain, 2020

	Educational groups				Inequality gap	Changes in inequality by eliminating COVID-19 (%)
	All	Low	Medium	High		
Men						
e30	49.99	48.46	49.91	52.20	3.74	
e30 eliminating COVID-19	51.67	50.33	51.67	54.10	3.76	
PGLE COVID-19	1.68	1.87	1.76	1.89	0.02	0.5
SD30	12.06	13.18	12.27	10.94	−2.24	
SD30 eliminating COVID-19	12.44	13.39	12.71	11.33	−2.05	
Difference	0.38	0.21	0.44	0.40	0.19	−8.4
Women						
e30	55.31	54.00	55.76	56.70	2.71	
e30 eliminating COVID-19	56.69	55.65	57.24	58.26	2.61	
PGLE COVID-19	1.38	1.65	1.48	1.55	−0.10	−3.6
SD30	10.83	12.30	10.99	10.31	−1.99	
SD30 eliminating COVID-19	10.99	12.19	11.19	10.65	−1.54	
Difference	0.16	−0.11	0.21	0.33	0.44	−22.3

Note: PGLE, potential gains in life expectancy.

Strengths and limitations of using MCOD

Our methodological approach using multiple COD allowed us to capture all COVID-19 mentions in death certificates. This was particularly necessary in the context of changing definitions, inconsistent and incomplete reporting and limited testing availability which only detected the most severe cases of COVID-19 deaths during the initial stages of the pandemic.[35] Moreover, inconsistent coding, especially early on, may have led to certain COVID-19 deaths being coded as the contributing rather than UCOD.[15] An MCOD approach also provides additional information regarding other COD involved

in the death process. For instance, given the seasonality of COVID-19, we conducted a sensitivity analysis by repeating the comparative analysis presented in table 2 for the four distinguishable COVID-19 periods in 2020 (table 1). Results showed that respiratory system disease mortality was actually lower during all four periods when it was the UCOD, while concurrently any mention of these causes increased substantially during the COVID-19 waves. This was up to 172.9% in the case of flu and pneumonia during March–May. (Supplementary table S3). Interestingly, in the case of flu and pneumonia, as a contributing cause of COVID-19 the proportion remained remarkably the same throughout the year, including during the summer months when there were few COVID-19 deaths (Supplementary table S2).

While MCOD data allows to capture more COVID-19-related death than when only relying on UCOD this approach also has its limitations. COVID-19-related death may be overstated if health authorities were classifying COVID-19 deaths as those who tested positive for the virus but had died of another pathology.[17] However, in 90% of all death where COVID-19 was mentioned on the death certificate, it was considered the UCOD, i.e. the disease or injury that began the chain of events that ultimately led to the person's death. This is similar to what has been reported in other countries.[14,15] Nevertheless, an argument could still be made for a possible overestimation of COVID-19 deaths as the contribution of COVID-19 was actually higher than the overall one-year drop in life expectancy. This is partly attributed to the fact that deaths coded as underlying or contributing cause were included here. But also our sensitivity analysis showed that when COVID-19 was only included as UCOD, there would still have been a higher reduction in life expectancy than overall (1.5 and 1.2 years for men and women, respectively) (Supplementary table S4). As this raises the question of whether many COVID-19 deaths were in fact deaths from other causes, further research should delve deeper into the specific contributing causes associated with COVID-19.

The observed discrepancy could also be related to another limitation of the MCOD approach, which concerns the assumption of independent competing risks between COD. Our approach has implicitly assumed that eliminating COVID-19 does not alter mortality rates from other COD, which may not necessarily be the case. Although removing only one COD (COVID-19) from the calculations limits this possible bias, if the underlying processes that lead to COVID-19 are not independent from certain respiratory system diseases,[19] the true effect of COVID-19 on the loss of life expectancy could be slightly lower. Future research should therefore compare estimates of life years lost due to COVID-19 using different methods, including those that deal with competing risks.[36]

Conclusion and policy recommendations

Using both UCOD and MCOD data allows researchers to provide a more holistic view of COD dynamics in a context of the COVID-19 pandemic. This is especially the case regarding old-age mortality due to the complexity of morbid processes that lead or might contribute to death.[13] Although the pandemic only led to a minor increase in the mean number of causes per death certificate (table 2), it is well known that people who recover from COVID-19 may develop persistent or new symptoms, also referred to as "long COVID".[37] Although long COVID does not itself result in death, the risk of death is increased during the following months.[38] It is therefore essential that we continue monitoring cause-specific mortality trends closely from an MCOD perspective, even after the COVID-19 pandemic has subsided. As the UCOD is not necessarily registered and coded as COVID-19,[39] we recommend analysing monthly mortality data in order to discern whether the COVID-19 pandemic has led to trend breaks in mortality from different causes, in particular cancer, as cancer patients need continuous care, and undergo diagnostic tests or therapeutic interventions.

Finally, given the increase in educational inequalities in lifespan variation at age 30 due to COVID-19, especially among women, health and crisis management policies should consider the potential unequal impact of a pandemic on social outcomes (e.g. education, employment) and on the health of the population.[20] For instance, we already know from previous research that hospitalized patients, nursery home residents and health workers were particularly vulnerable.[40] For future pandemics health impact evaluation tools should therefore be developed as they permit for the management of the pandemic equity to be introduced in the design of interventions, positive and negative impacts of said measures on different population groups to be predicted and recommendations that advocate equity in health to be issued.[20]

Supplementary data

Supplementary data are available at *EURPUB* online.

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Conflicts of interest: None declared.

Data availability

Multiple causes of death data and population exposures by educational attainment were obtained from the Instituto Nacional de Estadística (INE). These data are not publicly available but interested researchers have the possibility to obtain data access by contacting INE (www.ine.es).

Key points

- In Spain, 15.2% of all deaths in 2020 had COVID-19 diagnosed or suspected as underlying cause of death on the death certificates, rising to 16.8% when including the COVID-19 cases coded as contributing cause.
- Besides COVID-19, cause-of-death patterns between 2018/19 and 2020 were heterogeneous with very minor increases from some causes (e.g. diabetes, hypertensive diseases) and more substantial declines from other causes (e.g. cancer, respiratory diseases, heart and other diseases of the circulatory system (women only) and ill-defined causes).
- Compared to 2018/19, life expectancy at birth and age 30 declined by 1.0 year in both men and women. At age 30, these declines were higher among lower educated (1.4 years in both sexes) compared to higher educated (−1.1 years in men and −0.9 years in women), whereby COVID-19 was responsible for more than the total decline in life expectancy.
- A hypothetical elimination of COVID-19-related mortality in 2020 would have increased lifespan inequality (age at death variation), except for low-educated females. Without COVID-19, educational inequalities in lifespan variation would therefore have been lower (−22% for women and −8% for men).
- Disentangling the role of COVID-19 and other causes of death using multiple cause-of-death approaches aids our understanding of cause-specific mortality during the pandemic.

References

1 National Center of Epidemiology. Incidencias acumuladas e indicadores de transmisibilidad [Cumulative incidences and transmissibility indicators]. Health Institute Carlos III, 2022. Available at: https://cnecovid.isciii.es/covid19/resources/casos_hosp_uci_def_sexo_edad_provres.csv (12 May 2022, date last accessed).

2 Weinberger DM, Chen J, Cohen T, et al. Estimation of excess deaths associated with the COVID-19 pandemic in the United States, March to May 2020. *JAMA Intern Medi* 2020;180:1336–44.

3 Basellini U, Alburez-Gutierrez D, Del Fava E, et al. Linking excess mortality to mobility data during the first wave of COVID-19 in England and Wales. *SSM Popul Health* 2021;14:100799. https://doi.org/10.1016/j.ssmph.2021.100799.

4 Modig K, Ahlbom A, Ebeling M. Excess mortality from COVID-19: weekly excess death rates by age and sex for Sweden and its most affected region. *Eur J Public Health* 2021;31:17–22.

5 Aburto JM, Schöley J, Kashnitsky I, et al. Quantifying impacts of the COVID-19 pandemic through life-expectancy losses: a population-level study of 29 countries. *Int J Epidemiol* 2021;51:63–74.

6 Trias-Llimós S, Riffe T, Bilal U. Monitoring life expectancy levels during the COVID-19 pandemic: example of the unequal impact of the first wave on Spanish regions. *PLoS One* 2020;15:e0241952.

7 INE. Indicadores de Mortalidad. Resultados nacionales. *Esperanza de Vida al Nacimiento según sexo [Mortality Indicators. National Results. Life Expectancy at Birth by Sex]*. Madrid: INE (National Statistics Institute), 2022. Available at: https://www.ine.es/jaxiT3/Datos.htm?t=1414.updated (12 May 2022, date last accessed).

8 Islam N, Jdanov DA, Shkolnikov VM, et al. Effects of covid-19 pandemic on life expectancy and premature mortality in 2020: time series analysis in 37 countries. *BMJ* 2021;375:e066768.

9 Bonow RO, Fonarow GC, O'Gara PT, et al. Association of coronavirus disease 2019 (COVID-19) with myocardial injury and mortality. *JAMA Cardiol* 2020;5:751–3.

10 Onder G, Rezza G, Brusaferro S. Case-fatality rate and characteristics of patients dying in relation to COVID-19 in Italy. *JAMA* 2020;323:1775–6.

11 Trias-Llimós S, Permanyer I. A need for better understanding old-age mortality dynamics. Correspondence letter in response to: Bergeron-Boucher M-P, Aburto JM, Raalte A van. Diversification in causes of death in low-mortality countries: emerging patterns and implications. *BMJ Glob Health* 2020;5:e002414.

12 Désesquelles A, Demuru E, Egidi V, et al. Cause-specific mortality analysis: is the underlying cause of death sufficient? *Revue Quetelet* 2014;2:119–35.

13 Gorina Y, Lentzner HR. Multiple causes of death in old age. *Aging Trends* 2008;9:1–9.

14 Fineberg HV. The toll of COVID-19. *JAMA* 2020;324:1502–3.

15 Nogales Vasconcelos AM, Ishitani L, Abreu DMX, et al. Covid adult mortality in Brazil: an analysis of multiple causes of death. *Front Public Health* 2022;9:788932.

16 Grippo F, Navarra S, Orsi C, et al. The role of COVID-19 in the death of SARS-CoV-2–positive patients: a study based on death certificates. *J Clin Med* 2020;9:3459.

17 Kumar A, Kalra Y, Guan WW, et al. COVID-19 impact on excess deaths of various causes in the United States. *Ann GIS* 2022;28:457–478.

18 Redelings MD, Sorvillo F, Simon P. A comparison of underlying cause and multiple causes of death: US vital statistics, 2000–2001. *Epidemiology* 2006;17:100–3.

19 Fedeli U, Schievano E, Avossa F, et al. Different approaches to the analysis of causes of death during the COVID-19 epidemic. *Eur Rev Med Pharmacol Sci* 2021;25:3610–3.

20 Bacigalupe A, Martín U, Franco M, et al. Socioeconomic inequalities and COVID-19 in Spain. SESPAS report 2022. *Gac Sanit* 2022;36:S13–S21.

21 Bambra C, Riordan R, Ford J, et al. The COVID-19 pandemic and health inequalities. *J Epidemiol Community Health* 2020;74:964–8.

22 Niedzwiedz CL, O'Donnell CA, Jani BD, et al. Ethnic and socioeconomic differences in SARS-CoV-2 infection: prospective cohort study using UK Biobank. *BMC Med* 2020;18:1–14.

23 Mackenbach JP, Kulhanova I, Bopp M, et al. Variations in the relation between education and cause-specific mortality in 19 European populations: a test of the "fundamental causes" theory of social inequalities in health. *Soc Sci Med* 2015;127:51–62.

24 Krieger N, Williams DR, Moss NE. Measuring social class in US public health research: concepts, methodologies, and guidelines. *Annu Rev Public Health* 1997;18:341–78.

25 Permanyer I, Spijker J, Blanes A, et al. Longevity and Lifespan Variation by Educational Attainment in Spain: 1960–2015. *Demography* 2018;55:2045–70.

26 Preston SH, Heuveline P, Guillot M. *Demography: Measuring and Modeling Population Processes*. Oxford: Wiley-Blackwell, 2000.

27 Horiuchi S, Wilmoth JR, Pletcher SD. A decomposition method based on a model of continuous change. *Demography* 2008;45:785–801.

28 Riffe T. *DemoDecomp: Decompose Demographic Functions [R Package Version 1.0.1]*, 2018.

29 Tsai SP, Lee ES, Hardy RJ. The effect of a reduction in leading causes of death: potential gains in life expectancy. *Am J Public Health* 1978;68:966–71.

30 Trias-Llimós S, Spijker J. Educational differences in alcohol-related mortality and their impact on life expectancy and lifespan variation in Spain (2016–2018): a cross-sectional analysis using multiple causes of death. *BMJ Open* 2022;0:e053205.

31 Cortiula F, Pettke A, Bartoletti M, et al. Managing COVID-19 in the oncology clinic and avoiding the distraction effect. *Ann Oncol* 2020;31:553–5.

32 Moujaess E, Kourie HR, Ghosn M. Cancer patients and research during COVID-19 pandemic: a systematic review of current evidence. *Crit Rev Oncol Hematol* 2020;150:102972.

33 Laliotis I, Stavropoulou C, Ceely G, et al. *Excess Deaths in England and Wales during the First Year of COVID-19*. Essen: Global Labor Organization (GLO), 2022. Available at: http://hdl.handle.net/10419/260493 (12 May 2022, date last accessed).

34 Saladié Ò, Bustamante E, Gutiérrez A. COVID-19 lockdown and reduction of traffic accidents in Tarragona province, Spain. *Transp Res Interdiscip Perspect* 2020;8:100218.

35 Karanikolos M, McKee M. How comparable is COVID-19 mortality across countries? *Eurohealth* 2020;26:45–50.

36 Andersen PK, Canudas-Romo V, Keiding N. Cause-specific measures of life years lost. *Demogr Res* 2013;29:1127–52.

37 Raveendran AV, Jayadevan R, Sashidharan S. Long COVID: an overview. *Diabetes Metab Syndr Clin Res Rev* 2021;15:869–75.

38 Shoucri SM, Purpura L, DeLaurentis C, et al. Characterising the long-term clinical outcomes of 1190 hospitalised patients with COVID-19 in New York City: a retrospective case series. *BMJ Open* 2021;11:e049488.

39 Singh B. International comparisons of COVID-19 deaths in the presence of comorbidities require uniform mortality coding guidelines. *Int J Epidemiol* 2021;50:373–7.

40 López-Gay A, Spijker J, Cole HVS, et al. Sociodemographic determinants of intra-urban variations in COVID-19 incidence: the case of Barcelona. *J Epidemiol Community Health* 2021;76:1–7.