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Age and cause-of-death contributions to educational inequalities in life expectancy and lifespan variation in a low-mortality country: A cross-sectional study of 1.67 million deaths in Spain (2016–19)

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ABSTRACT

Background: We aim to assess the age- and cause-specific contributions to differences in life expectancy and lifespan variation between the high- and low-educated groups in Spain.
Methods: We use sex-, age-, education- and cause-specific mortality and population data for individuals aged 30 and over for 2016-19 in Spain. We estimated life expectancies, and standard deviations of the age-at-death distribution (lifespan variation), and we disentangled the contribution of age-causes of death to educational differences in both indicators.
Findings: Life expectancy at age 30 was higher for high-educated groups compared to low-educated groups, 5.5 years for males and 3.0 years for females. Lifespan variation was higher for low-educated groups compared to high-educated groups, 2.9 years for males and 2.2 years for females. The main contributors to the life expectancy gaps in males were lung cancer (0.58 years) and ischaemic heart diseases (0.42 years), and in females were other cardiovascular causes (0.26 years), and ischaemic heart diseases (0.22 years). The main contributors to the lifespan variation gaps were in males lung cancer (−0.25 years) and ischaemic heart diseases (−0.22 years), while in females were other neoplasms and other diseases of the nervous system.
Interpretation: Whereas behavioural causes are more important in explaining educational inequalities in mortality among men, ageing-related causes of death seem more important among women. Attempts at narrowing socioeconomic gaps in mortality may benefit from applying gender-specific preventive policy measures.

1. Background

Socioeconomic position is an important predictor of health and mortality (Galobardes et al., 2006). In all populations, low socioeconomic groups tend to have worse health and mortality outcomes compared to high socioeconomic groups, and these inequalities persist in all countries, including in countries with low mortality levels and overall relatively low socioeconomic inequalities in mortality, as is the case of Spain (Kulhánová et al., 2014; Machón et al., 2020; Mackenbach et al., 2018).

Socioeconomic inequalities in health and mortality can be understood within the social determinants of health (SDH) framework. These determinants refer to the conditions in which people are born, grow, live, work, and age, and how these conditions influence their health outcomes. Such factors thus act across the life course, affecting health and risk of death at any age. This includes decisions regarding education and employment during early adulthood which not only shape an individual's life trajectory, but may also be associated with different disease risks as health-damaging exposures or health-enhancing opportunities (including living and working conditions as well as individual lifestyles) are socially patterned (Commission on Social Determinants of Health, 2008; Davey Smith et al., 1998). While most of these socioeconomic factors are partly correlated, research focusing on mortality inequalities has mostly adopted education as the main socioeconomic variable. Moreover, education is known to be positively associated with the ability to access health-related knowledge, adapt behavior and obtain effective treatment (Galobardes et al., 2006).

Previous studies on cause-specific inequalities in mortality in Spain

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fall into three main categories. First, cross-country studies have used data from the regions of Madrid, Barcelona and/or the Basque Country and information on the main causes of death (Bartoll-Roca et al., 2022; Huisman, 2004; Mackenbach et al., 2018, 2019). Second, other studies have used 2001 census-linked mortality data to examine socioeconomic inequalities in all-cause and cause-specific mortality (Regidor et al., 2016; Reques et al., 2014). The most comprehensive study examined absolute and relative educational inequalities in mortality for about 20 causes of death from 2001 to 08. In the 2000s, educational inequalities in mortality in Spain for females were mainly driven by cardiovascular causes, accounting for nearly 50% of the gap. For males the sum of cardiovascular and respiratory diseases and cancers represented slightly over 50% of the total educational inequality in mortality (Reques et al., 2014). Finally, other studies have made used of the recent availability of mortality data by educational attainment to study socioeconomic inequalities in mortality (Blanes & Trias-Llimós, 2021; Permanyer et al., 2018; Requena, 2017).

Recent research on mortality dynamics has stressed the importance of going beyond average-based indicators, like life expectancy, to incorporate metrics that measure the variability in the ages at which individuals die, i.e., lifespan variation (Aburto et al., 2020; van Raalte et al., 2018). For example, a population in which everyone dies at age 80 is more equal to a population in which half of the people die at age 60 and the other half die at age 100, even if both have a life expectancy of 80 years. It is well-known that, as longevity increases, the variability in the ages at which individuals die tends to decline (Aburto et al., 2020; Smits & Monden, 2009). However, the causes of death that have led to lower variability in lifespans are not necessarily the same causes that have led to higher life expectancy (Aburto et al., 2018; Aburto & van Raalte, 2018; Seligman et al., 2016). Such information is fundamental to better understand whether, and to what extent, it is possible to attain the normatively desirable goals of reducing differences in life expectancy and lifespan variation across education groups *simultaneously*.

At the national level, individual level mortality data by education was only available for Spain from 2012 onwards (Requena, 2017). Recent estimates for 2017-19 in Spain suggest that high-educated groups have an advantage in life expectancy of over 3 years for females and over 5 years for males compared to their low-educated counterparts (Blanes & Trias-Llimós, 2021). In terms of lifespan variation, lower-educated groups have approximately 25% higher lifespan variation than high-educated groups for both males and females (Blanes & Trias-Llimós, 2021). Trends over the last few decades are scarce and suggest that educational inequalities in both life expectancy and lifespan variation persisted or even increased (Permanyer et al., 2018). In this context, examining the role of a granular set of causes of death on educational inequalities in both life expectancy and lifespan variation will allow us to better understand mortality inequalities.

We aim to assess the cause-of-death contribution to educational inequalities in life expectancy and lifespan variation in Spain for the most recent pre-covid period, 2016–2019 and for a group of 45 causes of death.

2. Methods

2.1. Data

We use sex-, age-, education- and cause-specific mortality data for individuals aged 30 and over for 2016-19 in Spain from the Spanish National Statistics Institute (INE). Educational attainment was retrieved from multiple data linkages, including municipal population registers ("Padrón") and the 2011 census, all carried out by INE. Population estimates from 2018 by age, sex, and educational attainment, also retrieved from INE, were used as denominators to produce our mortality indicators. Based on both data sources, three educational attainment categories could be distinguished: low (primary education or less, ISCED-2011 0–2) middle (lower and upper secondary education, ISCED-2011 3) and high (postsecondary vocational and university education, ISCED-2011 4+) (see https://www.ine.es/metodologia/t20/t2030306_niveduc.pdf). The distribution of the population by age, sex and educational group is presented in Fig. S1, and clearly shows the rapid educational expansion of the Spanish population. Causes of death were grouped using a classification of 45 causes of death, which were then grouped into 10 categories: Neoplasms (ICD-10 codes: C00-D48), endocrine (E00-E90), mental (F00–F99, G31.0, G31.1, G31.8 and G31.9), nervous (G00-G98 excluding G31.0, G31.1, G31.8 and G31.9), circulatory (I00–I99 excluding I46, I49.0), respiratory (J00-J96), digestive (K00–K93), ill-defined (R00-R94), external causes (chapters S, T, V, W, X and Y) and other causes (ICD-10 codes not previously mentioned (Table S1).

2.2. Methods

We estimated 5-year age group all-cause mortality rates for sex and educational attainment using conventional approaches. We use two mortality indicators to assess educational differences in mortality: life expectancy at age 30, which is estimated using life table methods (Preston et al., 2001); and lifespan variation at age 30, which is estimated using the standard deviation. Using life table notation, it is defined as:

$$sd_{30} = \sqrt{\sum_{x=30}^{95} d_x (x + a_x - e_{30} - 30)^2} \quad (1)$$

where x represents age, d_x the proportion of deaths at age x, and a_x the average person-years lived in the age interval by those dying in the interval.

We estimated educational gaps in the two selected mortality measures in two different ways: i) Comparing the outcomes of those with high versus low education; which implies that positive life expectancy gaps represent higher life expectancy among the highest educated group, while negative lifespan variation gaps imply lower lifespan variation among higher educated groups; ii) Comparing the outcomes of each educational group against the overall population for each sex. Age- and cause-specific contributions to these differences were estimated using the continuous decomposition method derived by Horiuchi (Horiuchi et al., 2008) implemented in the DemoDecomp package in R (Riffe, 2018).

3. Results

Age-specific mortality rates by educational attainment showed a clear educational gradient in mortality: high-educated groups had the lowest mortality and low-educated groups had the highest mortality, particularly among working age groups (Fig. 1). The differences between high- and medium-educated groups persisted up to around ages 65–69 in men and up to around ages 60–64 in women. The mortality disadvantage observed among the low-educated group persisted up until about the age of 80. For older age groups, educational differences in mortality rates were very small.

3.1. Life expectancy and lifespan variation by education groups

In 2016-19, life expectancy at age 30 in Spain was 50.9 years for males and 56.2 years for females (Table 1). For both males and females, the high-educated groups had higher life expectancy compared to their low-educated counterparts. For males, life expectancy at age 30 was 53.2 years for the high-educated and 47.7 years for the low-educated (5.5 years difference), whereas the corresponding numbers for females were 57.6 years and 54.6 years, respectively (3.0 years difference). Lifespan variation at age 30 was 12.3 years for males and 10.9 years for females. Differences in this indicator across educational groups were

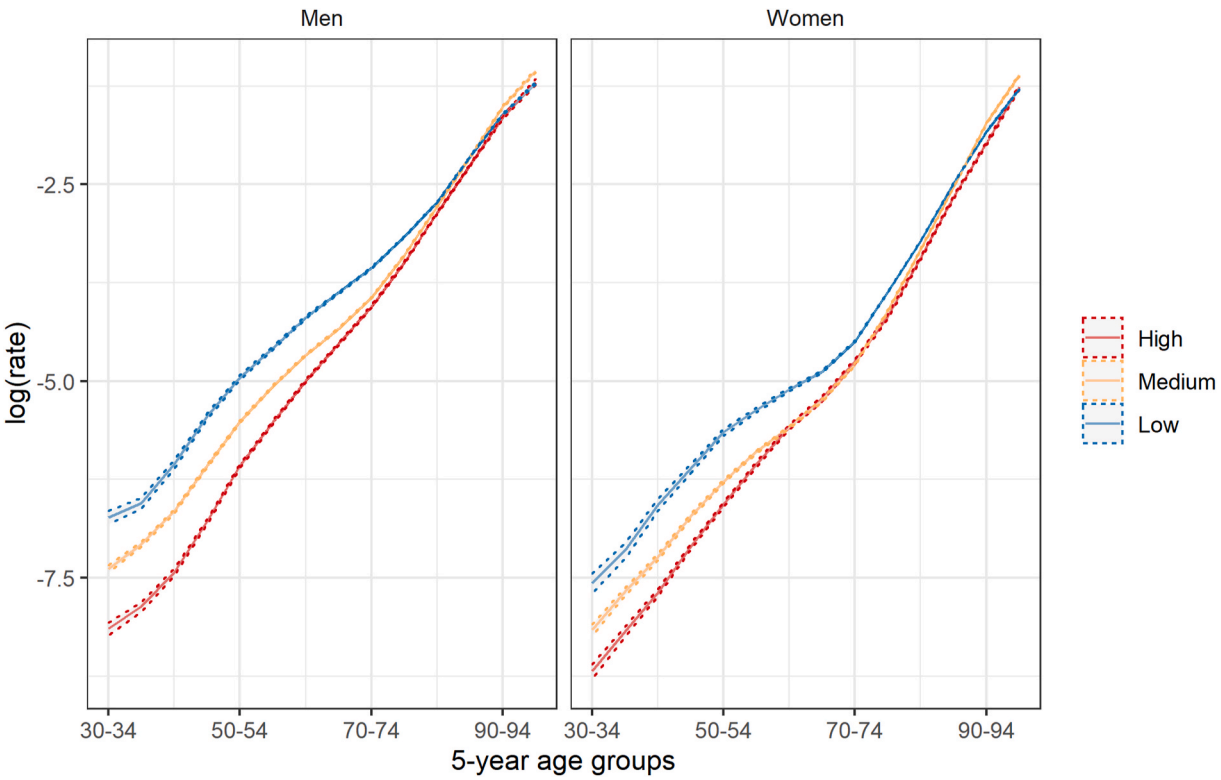

Fig. 1. Age-specific all-cause mortality rates (95% CI) by sex and educational group, Spain 2016-19.

Table 1
Life expectancy and lifespan variation at age 30 in Spain by sex and educational attainment, 2016-19.

	Life expectancy	diff	Lifespan variation	diff
Men				
All	**50.95**		**12.34**	**−2.93**
High	53.24	−2.29	11.25	1.10
Medium	51.11	−0.16	12.49	−0.14
Low	47.72	3.24	14.18	−1.83
High-Low gap		*5.52*		*−2.93*
Women				
All	**56.24**		**10.95**	
High	57.62	−1.38	10.55	0.39
Medium	56.53	−0.29	10.75	0.20
Low	54.60	1.64	12.73	−1.78
High-Low gap		*3.02*		*−2.17*

also in favour of the high-educated group, as they were found to have lower lifespan variation compared to their lower-educated counterparts. For males, lifespan variation was 11.2 years for high-educated and 14.2 years for low-educated, while for females it was 10.6 years and 12.7 years, respectively.

3.2. Age contributions to educational gaps in life expectancy and lifespan variation

The contribution of age groups to the educational gaps in life expectancy peaked for males at ages 60–64 with almost 0.8 years, and at ages 50–54 with around 0.35 years of contribution for females (Fig. 2). A visual inspection of the graphs suggests higher relative concentration across ages for males compared to females. For example, over half (53%) of the contribution to the educational life expectancy gap for males was found in the age group 50–69; while for females, a broader age range was needed to account for at least 50% of the educational life expectancy gap, as the age groups 45–74 represented 54.5% of this gap. The contribution of age groups to educational gaps in lifespan variation was largest at ages 50–54 and particularly important across working age groups.

3.3. Cause-of-death contributions to educational gaps in life expectancy and lifespan variation

For both males and females, the causes that contributed the most to educational gaps in life expectancy were cardiovascular causes (1.5 years for males, 0.9 years for females) and cancers (1.5 years for males, 0.3 years for females). These two major groups of causes accounted for nearly 50% of the gap for males (48.3%) and females (40.7%). For males, respiratory diseases were the third cause of death that contributed the most (0.75 years), and they were particularly important at old ages. External causes were also important (0.49 years), particularly at young ages. For females, cause-specific patterns were less clear and a larger group of causes contributed in a similar magnitude, for instance, respiratory diseases (0.32 years), nervous system diseases (0.25 years), digestive diseases (0.25 years) and endocrine diseases (0.21 years). Yet, the contribution of these groups of causes differed across age groups. For example, the contribution of diseases of the nervous system to educational differences in life expectancy was particularly relevant at working ages, while the contribution of endocrine diseases was mainly attributable to mortality from older age groups.

The causes that contributed the most to the lifespan variation between high- and low-educated groups were cancers and cardiovascular causes in both men (−0.75 years and −0.53 years, respectively) and women (−0.52 years and −0.33 years, respectively). External causes accounted for a relatively large part of the gap in men (−0.47 years), but not in women (−0.16 years), and were particularly important at young ages. The contributions of digestive, nervous and respiratory diseases were at similar levels between men and women, ranging from −0.16 years in digestive diseases in women to −0.26 years in nervous diseases in women. In contrast with the age contributions to life expectancy gaps, the age distribution accounting the most to the educational gaps in

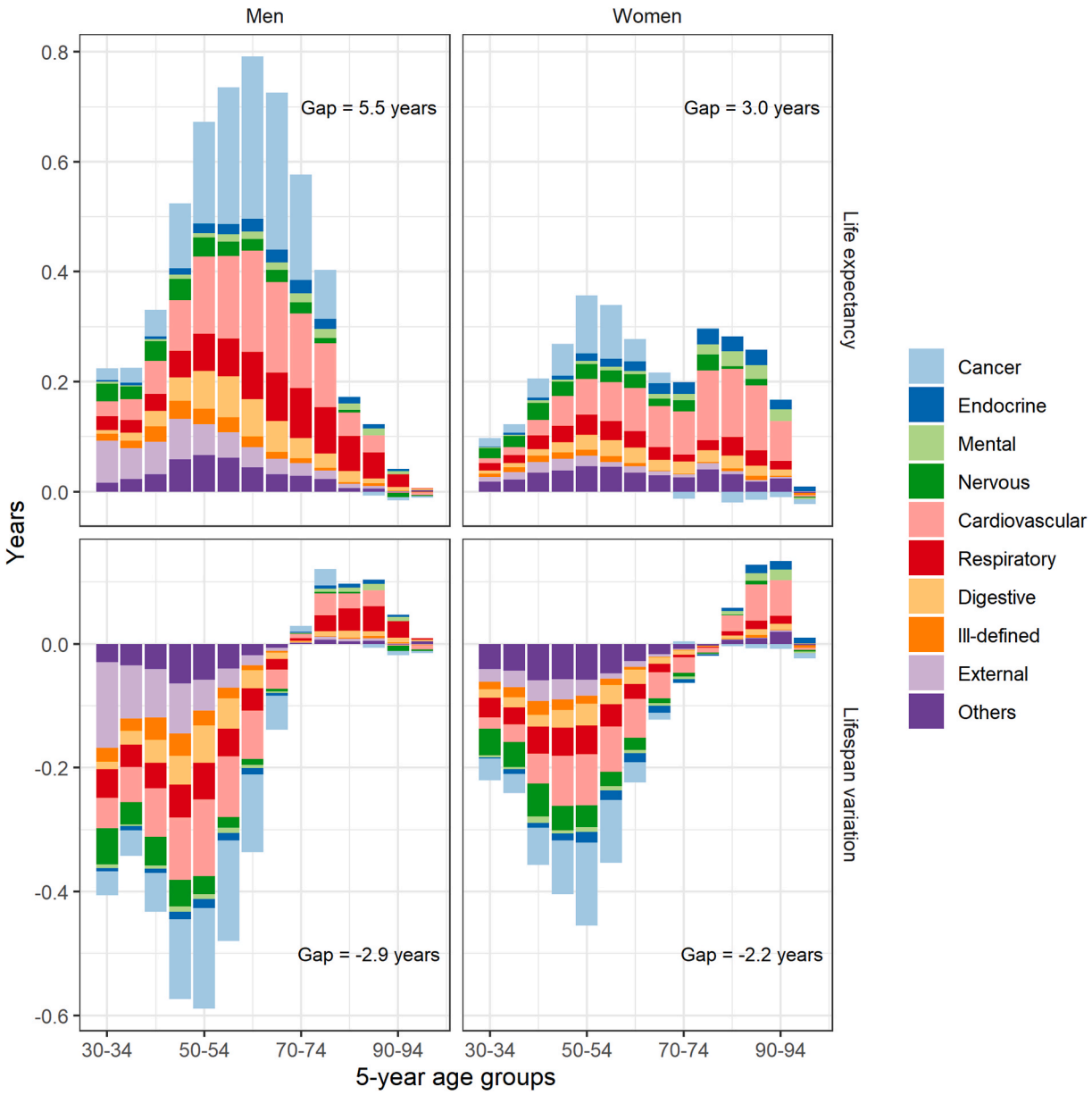

Fig. 2. Age- and cause-specific decomposition of life expectancy and lifespan variation gaps between high and low educational groups by sex, Spain 2016–19 (list of 10 major causes).

lifespan variation was shifted towards the left, and therefore to younger age groups.

3.4. *The role of detailed causes of death on educational inequalities in life expectancy*

The contribution of specific causes of death to the educational gaps in mortality presented notable differences across sex. For males, lung cancer was the largest contributor to educational differences in life expectancy with 0.58 years (10.6%), followed by ischaemic heart diseases (0.42 years, 7.6%) and by other chronic lower respiratory diseases (0.33 years, 6.0%) (Table 2). For females, lung cancer was found to play the opposite role, and therefore contributed toward reducing the life expectancy gap between the highest and lowest educational groups (−0.10 years, −3.2%), whereas the main drivers of the gap were all cardiovascular causes: other cardiovascular causes (0.26 years, 8.7%), ischaemic diseases (0.22 years, 7.2%), and cerebrovascular diseases (0.20 years, 6.7%); as well as all cancers (0.22 years, 7.3%). In most cases, these contributions were particularly important at ages 50–84.

3.5. *The role of detailed causes of death on educational inequalities in lifespan variation*

The cause-specific contribution to educational differences in lifespan variation between high and low educated groups was led by lung cancer (−0.25 years) and ischaemic diseases (−0.22 years) in males, and for other neoplasms (−0.22 years) and other nervous system diseases (−0.21 years) in females (Table 3). Other cause-specific contributions that contributed more than −0.15 years to the lifespan variation were other neoplasms, other nervous system diseases, other heart diseases in males and other diseases in females. Regarding the age-specific contributions within these cause-specific contributions an interesting pattern emerges, namely that contrary to the absolute educational differences in life expectancy, it is not the older age groups that contribute the most but the 30–49 and 50–64 year age groups (−2.17 years out of −2.93 years in males and −2.25 years out of −2.17 years in females). For

Table 2
Age- and cause-specific contributions to the high-low educational gaps in life expectancy at age 30, Spain, 2016-19. List of 45 causes of death. d

	Males					Females				
	30–49	50–64	65–84	85+	30+	30–49	50–64	65–84	85+	30+
AIDS	0.03	0.03	0.00	0.00	**0.06**	0.02	0.01	0.00	0.00	**0.02**
Other infectious diseases	0.03	0.05	0.03	0.00	**0.11**	0.02	0.02	0.03	0.01	**0.09**
Benign neoplasms	0.01	0.01	0.01	0.00	**0.03**	0.01	0.01	0.01	0.00	**0.02**
Breast cancer	0.00	0.00	0.00	0.00	**0.00**	0.01	0.02	−0.04	−0.01	**−0.02**
Intestine cancer	0.02	0.06	0.08	0.00	**0.16**	0.01	0.03	0.01	0.00	**0.05**
Liver cancer	0.03	0.07	0.03	0.00	**0.13**	0.01	0.02	0.03	0.00	**0.06**
Lung cancer	0.05	0.31	0.23	0.00	**0.58**	0.02	0.00	−0.11	−0.01	**−0.10**
Other neoplasms	0.06	0.15	0.10	−0.02	**0.29**	0.06	0.12	0.06	−0.02	**0.22**
Prostate cancer	0.00	0.01	0.03	0.00	**0.04**	0.00	0.00	0.00	0.00	**0.00**
Stomach cancer	0.01	0.03	0.05	0.00	**0.10**	0.01	0.02	0.03	0.01	**0.07**
Upper Aero cancers	0.02	0.09	0.05	0.00	**0.16**	0.00	0.01	0.00	0.00	**0.02**
Blood diseases	0.00	0.01	0.01	0.00	**0.02**	0.01	0.01	0.00	0.00	**0.02**
Diabetes	0.01	0.04	0.06	0.01	**0.13**	0.01	0.03	0.08	0.05	**0.16**
Other endocrine diseases	0.01	0.02	0.01	0.00	**0.05**	0.01	0.02	0.02	0.01	**0.06**
Alcohol psychosis	0.00	0.01	0.01	0.00	**0.02**	0.00	0.00	0.00	0.00	**0.00**
Dementia	0.00	0.01	0.05	0.02	**0.08**	0.00	0.01	0.06	0.04	**0.12**
Drug dependence	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	**0.00**
Other mental diseases	0.01	0.01	0.01	0.00	**0.03**	0.01	0.01	0.01	0.00	**0.02**
Alzheimer	0.00	0.01	0.03	0.00	**0.04**	0.00	0.01	0.04	0.02	**0.07**
Epilepsy	0.03	0.02	0.00	0.00	**0.05**	0.02	0.01	0.01	0.00	**0.04**
Other diseases nervous system	0.10	0.06	0.03	−0.01	**0.17**	0.07	0.05	0.02	−0.01	**0.14**
Cerebrovascular diseases	0.04	0.09	0.11	0.02	**0.25**	0.02	0.05	0.08	0.05	**0.20**
Hypertension	0.01	0.02	0.03	0.01	**0.06**	0.01	0.01	0.05	0.04	**0.10**
Ischaemic heart diseases	0.06	0.21	0.15	−0.01	**0.42**	0.03	0.06	0.10	0.02	**0.22**
Other circulatory diseases	0.03	0.05	0.06	0.00	**0.14**	0.02	0.04	0.06	0.01	**0.13**
Other heart diseases	0.08	0.11	0.11	0.01	**0.30**	0.03	0.05	0.12	0.07	**0.26**
Acute lower respiratory diseases	0.03	0.06	0.05	0.01	**0.15**	0.03	0.03	0.03	0.02	**0.10**
Asthma	0.00	0.00	0.00	0.00	**0.01**	0.00	0.01	0.01	0.01	**0.03**
Chronic lower respiratory diseases	0.01	0.08	0.19	0.05	**0.33**	0.01	0.02	−0.02	0.00	**0.01**
Other diseases of the respiratory system	0.08	0.09	0.08	0.02	**0.27**	0.04	0.04	0.06	0.02	**0.17**
Chronic liver disease	0.04	0.12	0.05	0.00	**0.21**	0.01	0.03	0.02	0.00	**0.06**
Other digestive diseases	0.05	0.09	0.09	0.02	**0.25**	0.03	0.05	0.07	0.03	**0.18**
Skin diseases	0.00	0.00	0.01	0.00	**0.01**	0.00	0.00	0.01	0.00	**0.02**
Musculoskeletal diseases	0.00	0.01	0.01	0.00	**0.02**	0.01	0.01	0.02	0.00	**0.03**
Genitourinary diseases	0.01	0.03	0.04	0.01	**0.09**	0.01	0.03	0.06	0.03	**0.12**
Other diseases	0.04	0.04	0.00	0.00	**0.09**	0.05	0.05	0.01	0.00	**0.10**
Mechanisms of the death	0.02	0.02	0.01	0.00	**0.05**	0.01	0.01	0.00	0.00	**0.02**
Other ill-defined causes	0.06	0.06	0.02	0.00	**0.15**	0.03	0.02	0.01	0.00	**0.06**
Accidental drowning and exposure to substances	0.07	0.02	0.01	0.00	**0.10**	0.01	0.01	0.00	0.00	**0.02**
Accidental falls	0.02	0.02	0.01	0.00	**0.04**	0.01	0.00	0.01	0.00	**0.02**
Other accidents	0.02	0.02	0.01	0.00	**0.05**	0.01	0.01	0.01	0.00	**0.03**
Assault	0.02	0.00	0.00	0.00	**0.02**	0.01	0.00	0.00	0.00	**0.01**
Other external causes	0.03	0.02	0.01	0.00	**0.06**	0.01	0.01	0.01	0.00	**0.03**
Suicide	0.06	0.04	0.03	0.00	**0.13**	0.01	0.00	0.00	0.00	**0.01**
Transport accidents	0.05	0.02	0.01	0.00	**0.08**	0.01	0.01	0.00	0.00	**0.01**
All causes	1.30	2.20	1.88	0.14	**5.52**	0.69	0.97	0.96	0.39	**3.02**

instance, in men aged 30–49 other nervous disease system diseases contributed −0.14 years to the lifespan variation, respiratory system diseases −0.11 years and other heart diseases, accidents and suicide −0.10 years (each). At ages 50–64 the contributions were highest for lung cancer (−0.19 years) and ischaemic heart disease (−0.13 years). Females presented a similar pattern although values were generally slightly lower: at ages 30–49 other diseases of the nervous system (−0.14 years) and other forms of cancer (−0.10 years) were the most important contributors; while at the 50–64 age group were mostly responsible for the lifespan variation due to other forms of cancer (−0.13 years).

4. Discussion

This study showed that higher educated groups had a higher life expectancy at age 30 as compared to lower educated groups in both males (5.5 years) and females (3.0 years), and lower lifespan variation. These education inequalities were driven by a wide variety of factors and causes of death, which were led by cardiovascular diseases, diseases of the respiratory system, and cancer. Our detailed analysis of 45 causes of death by age groups pointed towards the important contribution of ischaemic and other heart diseases, lung cancer and other respiratory (males).

This study used individual-level mortality data for Spain of 1.67 million deaths in the pre-Covid-19 period (2016–2019). Pulling the data over 4 years allowed us to focus beyond main groups of causes such as ICD chapters (e.g. cardiovascular diseases, diseases of the respiratory system) as we could analyse a much wider range of specific causes of death (e.g. dementia, intestine cancer) as well as educational differences. However, some limitations deserve to be discussed. First, we relied on educational attainment data estimated from INE. Most of the data were obtained by linking it with either the 2001 Census or "Padrón" (>80%), but also from the official degrees issued by the Ministry of education or data on enrolment at Spanish universities or non-university education (see https://www.ine.es/metodologia/t20/t2030306_niveduc.pdf for more details). When studying health inequalities two critical choices need to be made: the distribution and grouping of individuals across educational groups; and the pair-wise comparison of groups. Education has been widely used as a socioeconomic indicator in several other mortality studies (Mackenbach et al., 2018; Permanyer et al., 2018). In order to ensure a sufficiently large sample size in all groups we distinguished three educational groups (Spijker &

Table 3
Age- and cause-specific contributions to the high-low educational gaps in lifespan variation at age 30, Spain, 2016-19. List of 45 causes of death.

	Males					Females				
	30–49	50–64	65–84	85+	30+	30–49	50–64	65–84	85+	30+
AIDS	−0.03	−0.02	0.00	0.00	**−0.06**	−0.03	−0.01	0.00	0.00	**−0.04**
Other infectious diseases	−0.04	−0.03	0.00	0.00	**−0.07**	−0.03	−0.03	−0.01	0.01	**−0.06**
Benign neoplasms	−0.01	−0.01	0.00	0.00	**−0.02**	−0.01	−0.01	0.00	0.00	**−0.02**
Breast cancer	0.00	0.00	0.00	0.00	**0.00**	−0.02	−0.03	0.00	−0.01	**−0.05**
Intestine cancer	−0.03	−0.04	0.00	0.00	**−0.06**	−0.02	−0.03	0.00	0.00	**−0.06**
Liver cancer	−0.04	−0.05	0.00	0.00	**−0.09**	−0.01	−0.02	−0.01	0.00	**−0.04**
Lung cancer	−0.06	−0.19	−0.01	0.00	**−0.25**	−0.03	−0.01	0.03	−0.01	**−0.01**
Other neoplasms	−0.09	−0.09	−0.01	−0.02	**−0.21**	−0.10	−0.13	−0.02	−0.01	**−0.27**
Prostate cancer	0.00	−0.01	0.00	0.00	**−0.01**	0.00	0.00	0.00	0.00	**0.00**
Stomach cancer	−0.02	−0.02	0.00	0.00	**−0.03**	−0.02	−0.02	−0.01	0.00	**−0.05**
Upper Aero cancers	−0.03	−0.05	0.00	0.00	**−0.09**	−0.01	−0.01	0.00	0.00	**−0.02**
Blood diseases	−0.01	0.00	0.00	0.00	**−0.01**	−0.01	−0.01	0.00	0.00	**−0.02**
Diabetes	−0.02	−0.03	0.01	0.01	**−0.02**	−0.01	−0.03	−0.01	0.03	**−0.01**
Other endocrine diseases	−0.02	−0.01	0.00	0.00	**−0.03**	−0.02	−0.02	0.00	0.00	**−0.04**
Alcohol psychosis	0.00	−0.01	0.00	0.00	**−0.01**	0.00	0.00	0.00	0.00	**0.00**
Dementia	0.00	−0.01	0.01	0.02	**0.02**	0.00	−0.01	0.00	0.03	**0.01**
Drug dependence	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	**0.00**
Other mental diseases	−0.02	−0.01	0.00	0.00	**−0.03**	−0.02	−0.01	0.00	0.00	**−0.03**
Alzheimer	0.00	0.00	0.01	0.00	**0.00**	0.00	−0.01	−0.01	0.01	**0.00**
Epilepsy	−0.04	−0.01	0.00	0.00	**−0.05**	−0.04	−0.01	0.00	0.00	**−0.05**
Other diseases nervous system	−0.14	−0.04	0.00	−0.01	**−0.20**	−0.14	−0.06	−0.01	−0.01	**−0.21**
Cerebrovascular diseases	−0.05	−0.05	0.01	0.01	**−0.08**	−0.04	−0.05	−0.01	0.04	**−0.06**
Hypertension	−0.01	−0.01	0.01	0.01	**−0.01**	−0.01	−0.01	0.00	0.02	**0.00**
Ischaemic heart diseases	−0.08	−0.13	0.00	−0.01	**−0.22**	−0.04	−0.06	−0.02	0.01	**−0.11**
Other circulatory diseases	−0.04	−0.03	0.00	0.00	**−0.06**	−0.04	−0.04	−0.01	0.00	**−0.09**
Other heart diseases	−0.10	−0.07	0.01	0.01	**−0.16**	−0.04	−0.06	−0.01	0.04	**−0.07**
Acute lower respiratory diseases	−0.04	−0.04	0.01	0.01	**−0.07**	−0.06	−0.03	0.00	0.01	**−0.08**
Asthma	0.00	0.00	0.00	0.00	**0.00**	−0.01	−0.01	0.00	0.00	**−0.01**
Chronic lower respiratory diseases	−0.02	−0.05	0.03	0.05	**0.02**	−0.01	−0.03	0.00	0.00	**−0.04**
Other diseases of the respiratory system	−0.11	−0.06	0.01	0.01	**−0.14**	−0.08	−0.04	−0.01	0.01	**−0.11**
Chronic liver disease	−0.05	−0.08	0.00	0.00	**−0.13**	−0.02	−0.04	−0.01	0.00	**−0.06**
Other digestive diseases	−0.07	−0.06	0.01	0.02	**−0.10**	−0.05	−0.05	−0.01	0.02	**−0.10**
Skin diseases	0.00	0.00	0.00	0.00	**−0.01**	0.00	0.00	0.00	0.00	**−0.01**
Musculoskeletal diseases	0.00	−0.01	0.00	0.00	**−0.01**	−0.01	−0.01	0.00	0.00	**−0.02**
Genitourinary diseases	−0.02	−0.02	0.00	0.01	**−0.03**	−0.02	−0.03	−0.01	0.02	**−0.04**
Other diseases	−0.06	−0.03	0.00	0.00	**−0.09**	−0.09	−0.05	0.00	0.00	**−0.15**
Mechanisms of the death	−0.03	−0.01	0.00	0.00	**−0.04**	−0.02	−0.01	0.00	0.00	**−0.02**
Other ill-defined causes	−0.09	−0.04	0.00	0.00	**−0.12**	−0.05	−0.02	0.00	0.00	**−0.07**
Accidental drowning and exposure to substances	−0.10	−0.02	0.00	0.00	**−0.11**	−0.02	−0.01	0.00	0.00	**−0.03**
Accidental falls	−0.02	−0.01	0.00	0.00	**−0.03**	−0.01	0.00	0.00	0.00	**−0.01**
Other accidents	−0.03	−0.01	0.00	0.00	**−0.04**	−0.03	−0.01	0.00	0.00	**−0.04**
Assault	−0.03	0.00	0.00	0.00	**−0.03**	−0.01	0.00	0.00	0.00	**−0.02**
Other external causes	−0.04	−0.01	0.00	0.00	**−0.05**	−0.02	−0.01	0.00	0.00	**−0.03**
Suicide	−0.10	−0.02	0.00	0.00	**−0.11**	−0.02	0.00	0.00	0.00	**−0.02**
Transport accidents	−0.07	−0.01	0.00	0.00	**−0.09**	−0.01	−0.01	0.00	0.00	**−0.02**
All causes	−1.76	−1.41	0.11	0.12	**−2.93**	−1.22	−1.03	−0.15	0.23	**−2.17**

Trias-Llimós, 2023). Second, we chose to compare the highest and the lowest educational groups. A sensitivity analysis comparing each educational group with the total population suggests consistent results (Figs. S2 and S3), therefore our choices of educational attainment categories did not have a major impact on our conclusions. Further research should explore how other socioeconomic dimensions, for instance income or labour market trajectories, are associated with cause-specific mortality. Third, we used life expectancy and lifespan variation as an indicator of age-at-death variability. We should acknowledge that these metrics use cross-sectional data to build fictitious cohorts, and therefore that our results do not reflect inequalities from any specific cohort (Luy et al., 2020). Fourth, due to data limitations we adopted a cross-sectional perspective. We acknowledge that, particularly in the case of Spain with a rapid educational expansion and a lag in time between genders and social classes in the adoption of unhealthy lifestyles, a longitudinal study could provide further insights to our results. Unfortunately, longitudinal long-term mortality data is not yet available in Spain. Fifth, we used a detailed list of 45 causes of death, including the major diseases. More granular detail and estimates for a list of 72 causes of death can be found in Table S2. Finally, as in any study focusing on causes of death, the grouping of the causes has a direct impact on the results, even in our case where a rather large number of causes of death were assessed.

Assessing both life expectancy and lifespan variation inequalities was particularly insightful for the (groups of) causes in which the differences between high and low educational groups are concentrated either at young or old ages (Seligman et al., 2016). For example, among males, respiratory system diseases explained 13.8% of the life expectancy gap but only 6.5% of the lifespan variation gap; while external causes -more prevalent at younger ages-explained 8.7% and 15.7%, respectively. Similarly, cardiovascular diseases among females -particularly important at old ages-had a notable impact on life expectancy gaps (30.1%), but a much lower impact on lifespan variation gaps (12.0%). In other words, deaths that kill at young ages (e.g. external causes) have a higher impact on population-level mortality indicators (Lazarus et al., 2022). Whereas this is a straightforward conclusion, the relative difference between these contributions and contributions from causes that tend to be fatal at older ages (e.g. cardiovascular diseases) seems not negligible. Therefore, this suggests that efforts to reduce mortality inequalities should carefully consider both mean and length of life indicators as they could yield different results, and provide essential knowledge when aiming at reducing mortality inequalities.

The results of this study suggest that educational inequalities persisted up to the pre-Covid-19 times, particularly in premature mortality (before age 75). Our cause-specific results on the important contribution of lung cancer and other respiratory diseases to overall inequalities in mortality for males are in line with previous results from the early 2000s (Reques et al., 2014). Yet, we identified a set of causes of death that were overlooked in previous Spanish studies and that had an important impact on mortality inequalities. For instance, Alzheimer's and other dementias contributed to almost three months (6.3%) of the life expectancy gap for females. In Spain, the prevalence of dementia at age 65+ ranged between 4 and 9%, although it was higher for females and increased rapidly with age (Villarejo Galende et al., 2021). Whereas robust studies on dementia prevalence by education in Spain are lacking, a systematic review of international studies suggests lower dementia prevalence among higher-educated groups (Bodryzlova et al., 2022). Our findings for Spain are also supported by other international studies that suggest poorer Alzheimer's prognosis among low social classes (Ono et al., 2022), and an important role in socioeconomic inequalities in old age (Korhonen et al., 2020).

A particularly interesting finding was the observed differences in the contribution of causes of death to educational inequalities in mortality between males and females. In men, most inequalities were concentrated at younger ages and were due to lung cancer, cardiovascular, respiratory and digestive diseases. A relatively large fraction of education gaps in mortality seems to be explained by behavioural-related causes of death such as lung, lip, pharynx and oesophagus cancers or respiratory diseases, which is well-aligned with previous research suggesting that smoking account for 1.5-year educational gap in life expectancy among men (Piñeiro et al., 2022). Chronic liver diseases, which are partly caused by alcohol consumption, were also important in men, but not in women, and a similar story is observed for suicides and other external causes. From a social determinants of health perspective, these lifestyle-related causes can also be influenced by living and working conditions or the neighborhood environment (Commission on Social Determinants of Health, 2008). In contrast, for females, the age contributions were shifted towards older ages, and the causes that contributed the most to mortality inequalities were driven by cardiovascular disease, diabetes and dementia-related diseases. This is in line with recent research that found higher educational inequalities in females compared to males in cardiovascular mortality (Haeberer et al., 2020), as well as in obesity and hypertension prevalence (Gullón et al., 2021). The fact that the detrimental effects of unhealthy lifestyles impacted a greater number of men with low educational attainment compared to both other men and women may be related to the social determinants of health framework as education places a crucial role in health literacy, i.e. and individual's ability to obtain, understand, and apply health information (Kuh & Shlomo, 2004). Individuals with higher education levels are better able to make informed decisions about their health and engage in preventive measures. In a similar way, due to gender norms, traditional masculine ideals often discourage help-seeking behaviours and vulnerability (Evans et al., 2011). As individuals grow older, however, educational differences in age-related disease mortality decreased among men, possibly because the male population became more selected than the female population.

5. Conclusions

This study showed that important differences existed in the cause-specific contribution to educational differences in both life expectancy and lifespan variation. Reducing inequalities in respiratory disease will mostly contribute to reducing life expectancy gaps, but will have a more limited impact on lifespan variation gaps. Additionally, an increasing part of the educational gap in both life expectancy and lifespan variation is attributable to ageing factors, especially in females. This suggests that, as mortality switches towards older ages, there is a growing importance of dementias and other neurodegenerative diseases on all-cause mortality in ageing societies. These patterns observed in Spain are insightful and could motivate studies on mortality inequalities in other low-mortality countries. Yet, monitoring detailed cause-of-death mortality inequalities is a priority in light of the potential increases of them derived from the consequences of the COVID-19 pandemic (Bambra et al., 2020). In conclusion, improving our understanding of inequalities in mortality in low-mortality settings would allow policymakers to draw better preventive policies to improve health and survival across all educational groups while reducing the differences therein.

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Data availability

The authors do not have permission to share data.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmph.2023.101461.

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