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Educational inequalities in dementia-related mortality using a multiple cause of death approach and their contribution to life expectancy differences in Spain

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We examine dementia-related mortality in Spain from 2016 to 2021, focusing on its comorbidities and educational inequalities in life expectancy at age 60. Using a multiple cause of death (MCOD) approach, we assess how dementia-related mortality varies by education level and how these differences contribute to disparities in longevity. We used mortality data from the Spanish National Statistics Institute (INE) by level of education from 2016 to 2021 to analyse mortality from dementia-related diseases (ICD-10 codes: F01-F03, G30-G31) both as underlying cause of death (UCOD) and as MCOD (irrespective of their position within the death certificate). We estimated age-standardized mortality rates and used life tables and demographic decomposition techniques to assess the impact of dementia-related diseases on educational differences in life expectancy at age 60. Results showed that in 2016-21 MCOD dementia-related deaths accounted for 17% of all deaths occurring after the age of 60 (men: 11%; women 21%). The higher MCOD dementia-related mortality experienced by the lower educated group contributed 0.13 years (8.4%) to the total life expectancy gap at age 60 between the low and high education groups for men, and 0.26 years (22.7%) for women. Educational gradients in dementia-related mortality in Spain highlight the importance of disentangling risk factors from a socioeconomic perspective. Moreover, the MCOD approach provides a more realistic estimate of the impact of dementia-related diseases on life expectancy, bringing insights into the burden of ageing-related diseases.

Keywords Dementia, Multiple causes of death, Decomposition, Education, Inequalities

Current improvements in life expectancy in ageing societies are dominated by the declining death rates among the elderly. Spain is no exception; it boasts one of the highest life expectancies at age 65 worldwide, which has increased from 12 years among men and 14 years among women in 1952 to 19 and 23 years, respectively, in 2022. Furthermore, it is projected to rise to 22 and 25 years, respectively, by 2052[1,2]. Declines in death rates among the older population coincide with changes in the cause-of-death structure, as mortality rates from certain major degenerative diseases began to decline. Olshansky and Ault[3] described this process of decline —estimated to have begun in the mid-1960s in the United States and other developed nations— as the "fourth stage" of the epidemiological transition or the *age of delayed degenerative diseases*. While degenerative diseases continue to dominate the disease burden today, significant progress has been made in enhancing the survival rates of patients suffering from cardiovascular diseases (CVD) and cancer, the two leading non-communicable diseases. Consequently, other diseases have become more prevalent, especially those related to cognitive decline, including Alzheimer's diseases and other forms of dementia.

In 2019, the Global Burden of Disease Study reported that there were 7.32 million people living with dementia-related diseases in Western and Southern Europe[4]. Specifically for Spain, Alzheimer Europe[5] calculated—based on previous dementia prevalence estimates[6–8]—that in 2018 there were approximately 850,000 people living with

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dementia, making up 1.8% of the total Spanish population, a proportion projected to more than double by 2050 to 4.0%. In 2018, 32% of people with dementia in Spain were men and 68% were women; however, important differences across age groups existed. Notably, the incidence of dementia doubles approximately every 5 years up to the age of 75–79, and it grows at a slower pace thereafter. In a meta-study comprising 16 original studies from Europe, including three from Spain, conducted between 2008 and 2018, it was found that the prevalence of dementia increased from 0.6% in the 60–64 age group to 21.9% in the 85–89 age group and further rose to 40.8% in the 90+ age group[5].

Recent studies indicate that age-specific dementia prevalence and incidence in Western Europe have either stabilised or shown a declining trend in recent decades[9,10]. Likewise for Spain, the only time-trend study conducted showed a significant decline in men and a stable prevalence in women from the 1980 s to the 1990 s in Zaragoza[11]. A subsequent study revealed substantial regional variations in the diagnosis of dementia across the country[12].

Two recent systematic reviews and meta-analyses of prospective, longitudinal studies measuring the association between socioeconomic position (SEP) and the risks of dementia[13,14] concluded that there is a significant negative association between social class and risk of dementia, with education and occupation being the most relevant indicators regarding this risk. Regarding possible pathways between educational attainment and the risk of dementia, research attributes the protective effect of higher educational attainment to a greater cognitive reserve, which is a known protective factor against cognitive decline in the presence of neurodegeneration. Some of these benefits include increased literacy, a slower decline in memory, executive function, and language skills. These factors not only contribute to delay the onset of dementia but also enable individuals to cope more effectively with brain changes encountered in normal ageing and better handle Alzheimer's disease-related changes in their brains without showing noticeable differences in their behaviour or cognitive abilities compared to those with less education[15]. Likewise, in one of the few extant meta-analyses on SEP as a risk factor for dementia, it was found that lower educational attainment in women but not in men was associated with an increased risk of dementia in the United Kingdom, independently of common risk behaviours and comorbidities[16].

In contrast with the mixed evidence regarding trends in the prevalence of dementia as a disease, dementia-related mortality trends have been increasing in most European Union countries[17,18], including Spain in the last decades[19]. Nowadays they represent a major cause of death among individuals aged 70+, third behind ischaemic heart disease and stroke in high sociodemographic index countries[20].

However, there is a growing debate on the importance and accuracy of dementia-related mortality estimates[21–23]. Due to its relatively high prevalence at older ages and the competing risks across potential causes of death, dementia-related diseases often manifest as a comorbidity[24], and may therefore not always be considered as the underlying cause-of-death (UCOD)—defined as the condition that initiated the train of events leading to death[25]. As a result, relying solely on UCOD, which is the most commonly used metric in mortality studies, may not be the most appropriate method for estimating the total burden of dementia-related mortality because it ignores the presence of dementia as a comorbidity with other health conditions and could consequently lead to significant underestimation[23,26,27]. For instance, in Australia, there were 10,000 dementia-related deaths registered as UCOD in 2011, but this increased to 25,000 when dementia-related deaths were also considered as a contributory cause[28]. Similarly, in France and Italy, the burden of dementia-related mortality was twice as high when using an MCOD approach compared to UCOD alone[29]. This issue is particularly critical at old ages, as the UCOD becomes less indicative of a single, clearly-defined aetiological (causal) path and more result of a generalized deterioration in the capacity to sustain life[30]. This is due to the greater health heterogeneity at old ages[31,32]. In this context, the utilisation of multiple cause of death (MCOD) data—which includes all conditions mentioned on the death certificate, regardless of whether they were considered the primary driver of death or contributed to it—offers a valuable opportunity to improve our understanding of mortality associated to conditions that are not always considered underlying causes of death, including dementias[21,29,33–36].

To the best of our knowledge, no study has yet examined educational differences in dementia-related mortality in Spain. Similarly, research on SEP disparities in dementia-related mortality that consider both the UCOD and any mention of a dementia-related disease on the death certificate remains scarce.

This study therefore aims to address this gap by investigating educational inequalities in dementia-related mortality from a MCOD perspective in Spain between 2016 and 2021. Firstly, we assess dementia-related mortality and its contribution to the educational gap in life expectancy at age 60. Secondly, we analyse patterns in both UCOD and MCOD dementia-related mortality, as well as other important UCODs that are highly prevalent or associated with dementia. These include cancer, diabetes, heart disease, stroke, respiratory system diseases, and accidental falls.

Method

Setting

We studied dementia-related mortality in Spain and educational inequalities therein for the population aged 60 years and over for the periods 2016-17, 2018-19 and 2020-21. In assessing dementia-related mortality we adopted two approaches, one based on underlying causes of death (UCOD) and the other on multiple causes of death (MCOD). We focus on the population aged 60 + as the prevalence of dementia is low in younger ages[37].

Data

From the Spanish National Statistics Institute (INE), we obtained age-specific mortality rates from the life tables by sex and educational attainment along with individual-level cause-specific mortality data for individuals aged 60 years and over in Spain from 2016 to 2021. They are population-based, covering all deaths occurring in Spain.

The mortality data includes all COD listed on the death certificate, along with the age, sex, and educational attainment of the deceased. In Spain, the COD is derived from official death certificates, which are completed by physicians (either the treating doctor or a forensic specialist in cases requiring autopsy). Regional mortality register centres are responsible for collecting and coding the data, with some exceptions for deaths involving judicial intervention or other regional-specific matters, more details can be found elsewhere[38]. The COD classifications used in this study follow the 10th revision of the international statistical classification of diseases and health problems (ICD-10). Each death certificate contains a structured section where the physician records the UCOD along with the contributing causes (additional conditions that played a role in the individual's death but were not the primary cause). The resulting MCOD are coded using the International Automatic Coding system IRIS, which applies both automated and manual coding procedures to classify deaths according to ICD-10 rules, ensuring consistency and comparability across mortality statistics. INE centralises the data collection and is responsible for its dissemination. Further information on the COD data production process, death certificates and coding methods can be found elsewhere[39–41].

For the purpose of our study, we identified and combined the following dementia-related disease categories into one group: Alzheimer disease (ICD-10 G30, other generative diseases of nervous system not elsewhere classified (ICD-10 G31), and other dementias (ICD-10 F01-F03). The other causes of death analysed pertain to the most prevalent UCOD categories for the studied age group and period, along with COVID-19. These were grouped into 10 COD categories and 7 subcategories (Table 1).

Regarding the educational attainment of the deceased and population at risk, INE estimated this through data linkage from multiple datasets, comprising municipal population registers (*padrón*), data on official degrees conferred by the Ministry of Education or records of enrolment and university and non-university diplomas[42]. Due to the rapid educational expansion, few individuals aged 60 had attained only primary education, while the majority of those aged 85 and older had low educational levels. To account for this age-related educational gradient, we dichotomised the available categories into low (International Standard Classification of Education (ISCED)−2011 levels 0–2; up to lower-secondary education) and high (ISCED-2011 levels 3+; at least upper-secondary education) (see Supplementary Figure S1). The 1.68% of the deaths for which no educational level was assigned were proportionally distributed between the two educational groups according to age group, sex and year[43].

Ethics declarations

The results presented in this paper are based on the analysis of fully anonymised secondary cause-specific mortality data from INE that are publicly available and have no individual identifiers. Ethical approval was therefore not required.

Analytical approach

The age-specific mortality rate for each cause of death $m(a)^c$, disaggregated by sex and educational attainment, is estimated by multiplying the mortality rate for all causes from the life table by the proportion of deaths for each specific cause within each corresponding age group, i.e.:

$$m\,(a)^c = m\,(a) * \frac{D(a)^c}{D\,(a)}$$

where $m(a)$ is the mortality rate at age a estimated by INE; $D(a)^c$ is the number of observed deaths from cause c at age a; and $D(a)$ is the total number of observed deaths at age a[44]. To compare sex, educational categories and over time, we age-standardise the rates using the total person years of the population aged 60 + between 2016 and 2021 as the standard population. Dementia-related deaths and rates are estimated for dementia-related causes of death when listed as the UCOD (referred to as Dementia-UCOD) and when mentioned anywhere (i.e. as UCOD or contributing cause) on the death certificate (hereafter referred to as Dementia-MCOD).

Subsequently, we estimate life expectancies at age 60 using standard life table approaches[45]. To quantify the contribution of dementia-related deaths to educational differences in life expectancy, we decompose the differences in life expectancy between the high- and low-educational groups by five-year age groups and the COD categories: Dementia-UCOD, Dementia as a contributing cause (Dementia-contributing), and all remaining non-dementia-related causes. Summing the contributions of Dementia-UCOD and Dementia-contributing equals the contribution of dementia as an MCOD (Dementia-MCOD). We apply Horiuchi et al.'s[46] decomposition method using the DemoDecomp R package[47]. This method assumes that differences in life expectancy by educational level can be approximated by a linear combination of n partial derivatives of the function with respect to each cause of death x in each age group, denoted by the vector $\boldsymbol{A}=[x_1, x_2, ., x_n]^T$. Another assumption is that A depends on t (here representing educational attainment), for which we have observations for two groups: low and high education. Assuming A is differentiable between these two groups, the total educational gap in life expectancy can be calculated as:

$$f_2 - f_1 = \sum_{i=1}^{n} \int_{x_i(t_1)}^{x_i(t_2)} \frac{\partial f}{\partial x_i} dx_i = \sum_{i=1}^{n} c_i$$

where c_i is the contribution of each variable x_i (i.e. cause-specific mortality at a given age) to the total difference in life expectancy between educational groups. Numerical integration is then used to calculate the total contribution of each cause-age combination to the observed gap. We also provide 95% confidence intervals for the results.

	Men						Women						Total	
	Low education		High education		Total		Low education		High education		Total			
	n	% DRD	*n*	% DRD	*n*	% DRD	*n*	% DRD	*n*	% DRD	*n*	% DRD	*n*	% DRD
All causes of death mentioning DRD	**105,636**	**11.52**	**22,396**	**8.78**	**128,032**	**10.93**	**226,139**	**21.07**	**21,790**	**15.97**	**247,929**	**20.50**	**375,961**	**17.24**
Dementia-related diseases (F01-F03, G30-G31)	58,060	99.66#	12,252	99.73#	70,312	99.68#	136,215	99.72#	13,185	99.78#	149,400	99.72#	**219,712**	**99.71#**
Parkinson's disease (G20-G21)	3,455	31.20	972	28.72	4,427	30.62	4,331	36.86	543	32.95	4,874	36.38	**9,301**	**33.64**
Neoplasms (C00-D49)	7,242	2.76	1,666	1.83	8,908	2.52	9,007	4.87	1,065	2.58	10,072	4.45	**18,980**	**3.54**
Circulatory system diseases (I00-I99)	15,666	6.56	3,139	5.02	18,805	6.24	38,073	11.20	3,372	9.64	41,445	11.05	**60,250**	**9.55**
Cerebrovascular diseases (I60-I69)	*4,391*	*8.62*	*857*	*7.11*	*5,248*	*8.33*	*10,308*	*13.24*	*900*	*10.84*	*11,208*	*13.01*	**16,456**	**11.52**
Ischaemic heart diseases (I20-I25)	*4,098*	*5.60*	*932*	*4.17*	*5,030*	*5.27*	*6,884*	*10.86*	*621*	*8.68*	*7,505*	*10.64*	**12,535**	**8.49**
Other circulatory system diseases (remainder of I00-I99)	*7,176*	*6.26*	*1,351*	*4.79*	*8,527*	*5.97*	*20,881*	*10.51*	*1,851*	*9.48*	*22,732*	*10.41*	**31,259**	**9.20**
Diabetes mellitus (E10-E14)	2,650	12.53	459	10.10	3,109	12.10	5,925	19.04	338	16.81	6,263	18.91	**9,372**	**16.65**
Chronic liver disease & cirrhosis (K70, K73-K74)	330	2.83	61	1.60	391	2.52	327	5.28	38	3.53	365	5.02	**756**	**3.73**
Respiratory system diseases (J00-J99)	6,671	5.47	1,097	4.41	7,768	5.29	7,773	7.22	708	5.82	8,481	7.08	**16,249**	**6.22**
Chronic lower respiratory diseases (J40-J47)	*3,603*	*7.31*	*527*	*5.99*	*4,130*	*7.11*	*2,436*	*12.68*	*251*	*8.21*	*2,687*	*12.07*	**6,817**	**9.07**
Other respiratory system diseases (remainder of J00-J99)	*3,069*	*4.22*	*569*	*3.54*	*3,638*	*4.09*	*5,337*	*6.03*	*457*	*5.02*	*5,794*	*5.94*	**9,432**	**5.23**
COVID-19 (U07.1, U07.2)	3,860	8.89	1,066	7.30	4,926	8.49	7,508	16.66	964	14.90	8,472	16.44	**13,398**	**13.52**
Other natural causes of death (remainder of A00-R99)	69,23	5.56	1,504	4.79	8,427	5.41	15,530	8.34	1,461	7.16	16,991	8.22	**25,418**	**7.29**
External causes of death (S00-Y98)	780	3.28	179	2.76	959	3.17	1,450	6.16	116	3.63	1,566	5.86	**2,525**	**4.84**
Accidental falls (W00-W19)	*321*	*4.80*	*69*	*3.78*	*390*	*4.58*	*634*	*7.99*	*52*	*5.81*	*686*	*7.77*	**1,076**	**6.61**
Other external causes of death (remainder of S00-Y98)	*459*	*2.69*	*110*	*2.36*	*569*	*2.62*	*817*	*5.23*	*63*	*2.77*	*880*	*4.92*	**1,449**	**4.02**

Table 1. UCOD (ICD-10 codes) used in the main analysis, number of deaths (n) mentioning dementia-related diseases (DRD) anywhere else on the death certificate and as a proportion of all deaths (% DRD) for all-cause mortality and UCOD by education. Ages 60+. Spain. 2016–2021. Source: Spanish National Statistics Institute (see also main text). Note: # In theory, this should be 100% (i.e. all deaths with a dementia-related disease (DRD) as UCOD has a DRD listed anywhere in the death certificate). However, minor discrepancies are possible because the multiple causes of death are coded by the International Automatic Coding system IRIS. Hence, there may be instances that the algorithm doesn't identify a DRD as the UCOD or contributing cause (since it will depend on the rest of the diseases that have also been mentioned)[39]. Bold values refer to totals and in italics to the UCOD sub-categories that were analysed.

Conceptually, this method estimates how much each age group and cause of death contributes to the overall life expectancy gap between the low and high education groups by simulating small changes in mortality rates across the two education groups. This allows us to isolate, for example, the share of the gap attributable specifically to dementia-related mortality—both as an underlying and contributing cause—versus other causes of death. The output provides an interpretable framework for assessing the relative weight of each component in driving observed educational inequalities in life expectancy.

We also examined whether the contribution of dementia-related mortality to educational differences in life expectancy changed over time by repeating all analyses separately for three two-year periods (2016–2017, 2018–2019, and 2020–2021). This allowed us to assess whether the patterns observed across the full study period were consistent, including during the COVID-19 pandemic, when cause-of-death patterns shifted[33].

Results

Overall mortality trends and comorbidities of dementia-related deaths

In 2016-21 a dementia-related disease was mentioned in 375,961 death certificates (MCOD approach) of individuals aged 60 and above in Spain, equivalent to 17% of all deaths for this age group (Table 1). In both absolute and relative terms, more women than men died from or with a dementia-related disease (men: 11% of all deaths; women 21%). Moreover, larger educational disparities were also identified among women, with 21% of all death certificates of low-educated women mentioning a dementia-related disease, compared to 16% among their high-educated counterparts. In contrast, for men, these percentages were 12% and 9%, respectively.

Regarding the proportions of UCOD mentioning a dementia-related disease, similar sex- and educational differences were observed, i.e. higher proportions of all deaths were noted among women and the low-educated.

Among specific UCODs with dementia-related diseases mentioned as a contributory cause, Parkinson's disease showed the highest proportion: 31% of deaths of low-educated men, 29% of high-educated men, 37% of low-educated women, and 33% of high-educated women who died from Parkinson's disease had a dementia-related disease as contributing cause. Similar sex- and educational differences were also found among important UCODs where dementia-related diseases play a less important role. For example, 2.8% of deaths due to neoplasms among low-educated men had a dementia-related disease mentioned on the death certificate, compared to only 1.8% among high-educated men, while the proportions for women were considerably higher: respectively 4.9% and 2.6%.

Age-Standardized mortality rates (ASMR) and educational differences in dementia-related mortality

The ASMR for Dementia-MCOD in 2016–2021 was 6.1 and 6.7 per 1,000 for men and women, respectively (Table 2). At the same time, dementia-related mortality was significantly higher among the low-educated (low-educated men ASMR 6.2 per 1,000; low-educated women 6.6; compared to high-educated men 5.4; and high-educated women 5.5 per 1,000).

Regarding the ASMR of the different UCODs with a dementia-related disease mentioned anywhere on the death certificate, we observed the highest rates for dementia as UCOD, with slightly higher ASMR for women compared to men (4.1 and 3.4 per 1,000, respectively). In relative terms, dementia as an UCOD accounted for a lower proportion of all mentions of dementia-related mortality (MCOD-Dementia) for men (55.5%) than for women (60.4%). The second leading UCOD, when a dementia-related disease is a contributing cause, were circulatory system diseases (0.9 per 1,000 and 15.1% of all Dementia-MCOD in the case of men and, respectively, 1.1 per 1,000 and 16.8% in the case of women), followed by neoplasms (men: 0.4 per 1,000 and 6.6% of all Dementia-MCOD; women 0.3 and 4.0%), respiratory system diseases (men: 0.4 per 1,000 and 6.1% of all Dementia-MCOD; 0.2 and 3.4% for women), COVID-19 (men: 0.2 per 1,000 and 3.8% of all Dementia-MCOD; women 0.2 and 3.4%, but equalled 0.7 per 1000 and 10.7% of all Dementia-MCOD for men and 0.7 and 9.6% for women, respectively, if only the 2020-21 period is considered, see Supplementary Table S6), Parkinson's disease (men: 0.2 per 1000 and 3.1% of all Dementia-MCOD; women 0.1 and 1.9%) and diabetes (men: 0.1 per 1000 and 2.3% of all Dementia-MCOD; women 0.2 and 2.5%). It is important to note that the UCOD-specific shares of Dementia-MCOD was similar across most educational groups. Finally, the overall higher ASMR for dementia-related mortality among the low educated is not driven by higher mortality rates at certain ages but rather by a persistent educational disparity observed across at all age groups. This applies to both dementia as UCOD and MCOD and both men and women (see Fig. 1).

The contribution of dementia-related mortality to the educational gap in life expectancy at age 60

The all-cause mortality differentials between high- and low-educated groups translate into an educational gap in life expectancy. Considering life expectancy at age 60 in 2016-21, high educated men were expected to live 1.61 years more than low-educated men, while high-educated women were expected to live 1.16 years longer than their low-educated counterparts (Fig. 2). Regarding the role of dementia-related mortality in the observed educational gap in life expectancy at age 60, Dementia-MCOD accounted for 0.13 years (8.4%) of the differences between the low- and high-education groups among men (0.07 years or 4.5% as UCOD and 0.06 years or 3.9% as contributing cause) (see Fig. 2 and Supplementary Table S8 that also includes 95% CI). Among women, the contribution of dementia-related diseases to the educational gap was markedly higher in both relative and absolute terms: 0.26 years (22.7%; 0.15 years or 13.2% as UCOD and 0.11 years or 9.5% as a contributing cause). These findings illustrate that relying on UCOD alone would underestimate the role of dementia in explaining educational inequalities in life expectancy, particularly among women.

As dementia is much more prevalent at older ages, we also stratified the results by age groups. We observe that the contribution of dementia-related mortality to the educational differences in life expectancy increased

	Men						Women					
	Low education		High education		Total		Low education		High education		Total	
	Rate	% DRD	Rate	% DRD	Rate	% DRD	Rate	% DRD	Rate	% DRD	Rate	% DRD
All deaths	**49.97**		**43.87**		**49.01**		**31.94**		**27.66**		**32.49**	
MCOD Dementia	6.16	100.00	5.39	100.00	6.11	100.00	6.61	100.00	5.54	100.00	6.74	100.00
UCOD, with MCOD Dementia-related dis.												
Dementia-related diseases	3.42	55.47	3.01	55.87	3.39	55.53	3.99	60.33	3.37	60.75	4.07	60.36
Parkinson's disease	0.18	3.00	0.20	3.68	0.19	3.11	0.12	1.89	0.13	2.31	0.13	1.92
Neoplasms	0.40	6.53	0.36	6.65	0.40	6.55	0.26	3.94	0.24	4.41	0.27	3.99
Circulatory system diseases	0.93	15.12	0.80	14.80	0.92	15.09	1.11	16.84	0.89	16.12	1.13	16.79
Cerebrovascular diseases	*0.25*	*4.08*	*0.20*	*3.74*	*0.25*	*4.02*	*0.30*	*4.53*	*0.23*	*4.08*	*0.30*	*4.50*
Ischaemic heart diseases	*0.24*	*3.88*	*0.23*	*4.21*	*0.24*	*3.95*	*0.20*	*3.04*	*0.16*	*2.94*	*0.20*	*3.03*
Remaining circulatory system diseases	*0.44*	*7.16*	*0.37*	*6.86*	*0.44*	*7.13*	*0.61*	*9.27*	*0.50*	*9.10*	*0.62*	*9.26*
Diabetes mellitus	0.15	2.41	0.10	1.94	0.14	2.33	0.17	2.59	0.09	1.54	0.17	2.50
Chronic liver disease and cirrhosis	0.02	0.27	0.01	0.21	0.02	0.25	0.01	0.15	0.01	0.15	0.01	0.14
Respiratory system diseases	0.39	6.27	0.27	5.00	0.37	6.07	0.23	3.43	0.18	3.25	0.23	3.43
Chronic lower respiratory diseases	*0.21*	*3.35*	*0.12*	*2.30*	*0.19*	*3.18*	*0.07*	*1.08*	*0.06*	*1.09*	*0.07*	*1.08*
Remaining respiratory system diseases	*0.18*	*2.92*	*0.15*	*2.70*	*0.18*	*2.88*	*0.16*	*2.36*	*0.12*	*2.16*	*0.16*	*2.34*
COVID-19	0.22	3.64	0.25	4.65	0.23	3.82	0.22	3.32	0.24	4.37	0.23	3.41
Other natural causes of death	0.40	6.55	0.34	6.40	0.40	6.50	0.45	6.87	0.36	6.58	0.46	6.82
External causes of death	0.05	0.73	0.04	0.80	0.05	0.74	0.04	0.64	0.03	0.52	0.04	0.63
Accidental falls	*0.02*	*0.30*	*0.02*	*0.32*	*0.02*	*0.30*	*0.02*	*0.28*	*0.01*	*0.25*	*0.02*	*0.28*
Remaining external causes of death	*0.03*	*0.43*	*0.03*	*0.49*	*0.03*	*0.44*	*0.02*	*0.36*	*0.02*	*0.27*	*0.02*	*0.35*

Table 2. Age-standardised mortality rate (ASMR), per 1,000 persons aged 60+, by sex and educational level for: all deaths, Dementia-related diseases (DRD) mentioned anywhere on the death certificate (MCOD Dementia), and the Underlying cause of death (UCOD) with DRD as MCOD (also as a percentage of MCOD Dementia. Spain. 2016–2021. Source: Calculations based on data from the Spanish National Statistics Institute (see also main text). Bold values refer to totals and in italics to the UCOD sub-categories that were analysed.

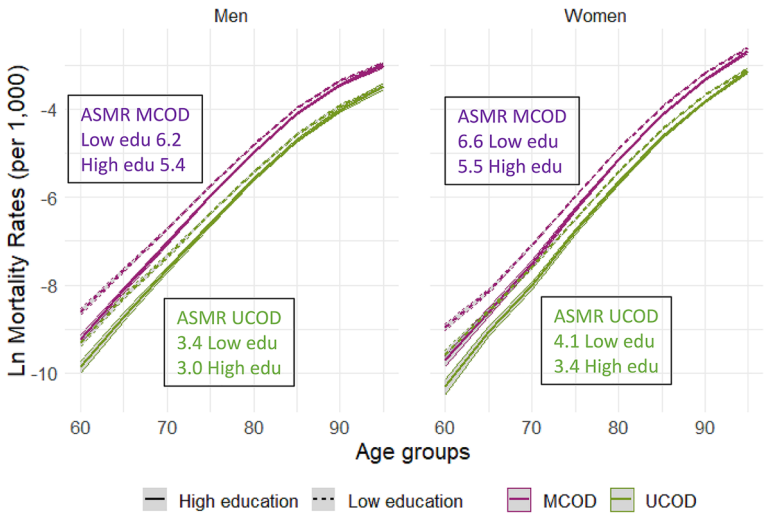

Fig. 1. Age-specific UCOD and MCOD* Dementia Ln mortality rates (x-axis) and age standardised mortality rates (ASMR) (in boxes#) per 1000 by sex and education. Age 60+. Spain (2016–2021). Note: *UCOD stands for underlying cause of death and MCOD for multiple causes of death. #The same ASMR values are shown in Table 2 (second and third rows).

with age (Fig. 2). While just 2% of the low-high educational gap in life expectancy among men is explained by dementia-related mortality when measured as MCOD in the first age group (ages 60–64), the contribution increases to 22% in the age group 90–94 years. In the case of women, the respective age percentages are 7% and 31%.

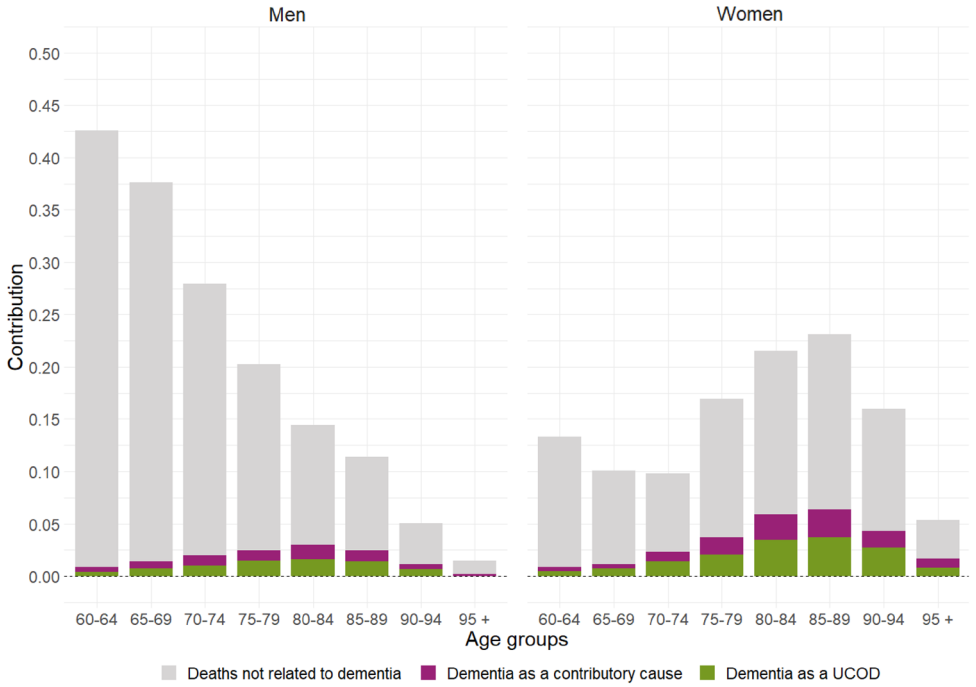

Fig. 2. Contribution of dementia-related diseases to the educational gap in years of life expectancy by age group. Population aged 60+. Spain (2016–2021). Note: Dementia-MCOD = Dementia as a UCOD + Dementia as a contributory cause. The total gap in life expectancy at age 60 between the low and high educational groups equals 1.61 years for men and 1.16 years for women. Dementia as an UCOD contributes 0.07 years (men) and 0.15 years (women) to this gap. As MCOD, this increases to, respectively 0.13 and 0.26 years. Source: Calculations based on data from the Spanish National Statistics Institute (see also main text).

Lastly, to ascertain whether the contribution of dementia-related mortality to educational inequalities in life expectancy changed over time, we conducted a sensitivity analysis by estimating the decomposition separately for three biannual estimates: 2016–2017, 2018–2019, and 2020–2021. The results showed that both the absolute and relative contributions of dementia-related mortality remained largely stable across these intervals when applying the MCOD approach. Even during the COVID-19 pandemic (2020-21)—when mortality increased and dementia was less frequently selected as the UCOD due to the emergence of COVID-19 (which accounted for approximately 10% of all deaths)—the total proportion of death certificates mentioning dementia-related diseases actually increased slightly. Furthermore, life expectancy at age 60 and the age distribution of the contribution of dementia-related mortality to the educational gap in life expectancy also remained consistent across time periods (see Supplementary Tables S1-S8 and Supplementary Figure S2).

Discussion

Summary of findings

The aim of this study was to examine dementia-related mortality in Spain using a MCOD approach between 2016 and 2021 by (i) assessing the contribution of dementia to educational inequalities in life expectancy at age 60, and (ii) analysing UCOD and MCOD patterns in dementia-related mortality, alongside other important UCOD. We found that dementia-related mortality differed significantly by educational groups. Measured using a MCOD approach, dementia accounted for 8.4% and 22.7% of the life expectancy gap at age 60 between low- and high-educated individuals among men and women, respectively. In terms of ASMR, the proportion of dementia-related mortality coded as an UCOD was 55.5% lower for men and 60.4% lower for women compared to when MCOD were used, with negligible differences by educational level.

Interpretation of key findings

Our main findings on the positive contribution of dementia to educational differences in life expectancy can be explained by several underlying factors. For instance, higher educational attainment is associated with better cognitive performance and increased cognitive reserve, which may delay the onset of dementia or slow its progression[15,48]. Education is also associated with lower exposure to dementia risk factors, including hypertension, hearing impairment, smoking (men only), obesity, depression, physical inactivity, diabetes, and infrequent social contact[49–52]. Additionally, higher-educated individuals are generally better equipped to make informed health decisions[53] and access health services[54]. Educational inequalities in Spain also help contextualise our findings. Education is a key determinant of SEP, as it strongly influences individuals' future labour market positions and access to health-promoting resources. Higher education facilitates access to more stable and rewarding careers and greater exposure to cognitively demanding work, which are believed to be protective against dementia even

decades after retirement[55]. As among older Spanish cohorts—especially women—educational attainment was generally low, with few individuals continuing beyond primary school in the mid-20th century[56], the small (highly selected) group of older higher-educated women may have experienced disproportionately better cognitive and health outcomes, compared to their lower-educated peers.

Furthermore, our results showed that the contribution of dementia-related mortality to the educational gap in life expectancy increased with age. This finding is particularly noteworthy because it diverges from the broader pattern typically observed for all-cause mortality, where educational inequalities tend to narrow in older ages (as illustrated in Fig. 2). Among individuals aged 60–74, life expectancy differences primarily stem from chronic diseases such as cancer and heart disease[57], which contribute less to inequality at very advanced ages. However, dementia prevalence increases exponentially with age, and its mortality burden falls disproportionately on lower-educated groups. As a result, its relative contribution to educational disparities becomes more important in older age groups. This apparent divergence from the broader narrowing pattern of mortality inequality with age aligns with previous findings showing that it is health deterioration, not age itself, that narrows socioeconomic mortality differences[58]. When health status is accounted for, SEP disparities in mortality remain stable across ages and only converge in the presence of severe illness. In our case, dementia—being both age-related and socially patterned—appears to reinforce, rather than reduce, educational inequalities in old-age mortality.

Our analysis also highlighted that dementia-related diseases often coexist with other health conditions, particularly Parkinson's disease, diabetes, COVID-19, cardiovascular and respiratory system diseases. Individuals with dementia-related diseases—particularly those with Alzheimer's disease—experience excess morbidity and mortality, which complicates efforts to reduce deaths from other. This reflects both the higher risk of death associated with dementia itself and the high likelihood of individuals with dementia having other comorbidities. These coexisting conditions complicate clinical management, worsen prognosis, and ultimately influence mortality rates[59].

Importantly, our decomposition analysis showed that relying on UCOD alone underestimates dementia's contribution to educational differences in life expectancy by almost half. This finding reinforces the value of the MCOD approach, as it captures a broader burden of dementia-related mortality, particularly in the context of comorbidity by including cases where dementia contributed to death but was not selected as the underlying cause.

Comparison to previous literature

Our findings for Spain align with international research indicating that dementia-related diseases contribute significantly to socioeconomic inequalities in old-age mortality and are associated with poorer health outcomes in lower socioeconomic positions[48,60]. The role of comorbidities, particularly Parkinson's disease, is consistent with prior work highlighting the high disease burden experienced by individuals with dementia[59].

The strong educational gradient in dementia-related mortality we observed—especially among women—mirrors previous research indicating that the socioeconomically disadvantaged face higher exposure to dementia risk factors such as depression, social isolation, and chronic stress, factors that are more common among women[61]. Together, these patterns may help explain why the association between education and dementia-related mortality appear stronger among women than in men.

Policy and public health implications

Analysing dementia-related diseases from a MCOD perspective is highly informative for policy-making, as it better captures the impact of dementia on mortality recorded in death certificates—including cases where dementia contributes to death but is not designated as the underlying cause of death. A clearer understanding of comorbidities among individuals who died from dementia-related causes can help guide the design of both prevention strategies and integrated care approaches. Recognizing the broader health impact of dementia — including its role in conjunction with other chronic conditions—enables more effective allocation of health care resources. This is particularly important given that people with dementia are less likely to consult primary care providers[49]. The educational inequalities observed in dementia-related mortality in Spain also underscore the importance of addressing dementia risk factors through a sociodemographic lens, ensuring that policies are tailored to reach vulnerable populations with limited educational backgrounds.

Methodological contribution and its strengths and weaknesses

Our study demonstrates that adopting a MCOD approach—alongside advancements in classification systems such as ICD-10—provides a more complete picture of dementia-related mortality than traditional UCOD-based analyses. But while the need to incorporate multiple causes in mortality statistics—reflecting increasing multimorbidity and complex causation patterns—is widely recognized internationally[62], limitations remain. Despite dementia's high prevalence and ICD-10's explicit recognition as a valid UCOD, it is still inconsistently selected as such on death certificates, as the number of deaths attributed to dementia remains lower than clinical prevalence estimates owing to underreporting and variations in death certification practices. These include limited awareness among certifying physicians regarding the importance of dementia as a cause or contributor to death[23,62]. In addition, physicians may choose not to report dementia—even when they are aware of its severity—if they do not perceive it as the underlying or contributing cause of death. This often occurs when complications of advanced dementia, such as pneumonia, are recorded as the more immediate cause of death. Moreover, comorbid disorders common in older adults—such as heart disease, stroke, hip fractures, and chronic obstructive lung disease—are generally more accepted and routinely recoded as causes of death, leading to the underrepresentation of dementia in mortality statistics[63]. In a Spanish study, even among participants clinically diagnosed with dementia before death, dementia was only reported as the primary (i.e. underlying) cause of death in 20.8% of cases[64]. Similarly, a Canadian study found that just 14.3% of patients with Alzheimer's disease

had any dementia-related illness recorded as the UCOD and 41.8% had it mentioned anywhere on the death certificate[65]. A Dutch study further demonstrated the added value of using MCOD: it increased the proportion of deaths with dementia from 10.8% (UCOD) to 17.9% (MCOD). With the sequential addition of the long-term care, hospital discharge, dispensed medicines, hospital claims and specialized mental care data to the individual mortality data, the proportion rose another 6.1–24.0%[66]. Unfortunately, such comprehensive linkage with national health register data is not (yet) possible in Spain. However, enabling this kind of data integration would be highly recommended to improve the accuracy and completeness of dementia mortality estimates.

Lastly, while our study is based on a comprehensive, population-level dataset covering all deaths in Spain, findings may not generalise to other countries due to differences in healthcare systems, diagnostic criteria, and cause-of-death certification practices.

Conclusion

To conclude, to mitigate the challenges of underreporting, we analysed dementia coded as both underlying and contributory cause of death, following prior research[17,21,59]. By applying a MCOD approach, we obtained a more realistic estimate of the impact of dementia-related diseases on life expectancy than if we had only considered UCOD, as well as insights into their interaction with other chronic diseases. This approach was applied to assess dementia's contribution to educational inequalities in life expectancy in Spain and the results revealed persistent educational inequalities in dementia-related mortality, with lower-educated individuals experiencing a higher burden. Even as dementia's importance as a UCOD temporarily declined during the pandemic, its contribution to educational differences in life expectancy remained significant. Addressing this underrecording and acknowledging dementia's complex role in end-of-life health trajectories is critical to improving the accuracy of mortality surveillance and to developing more equitable and effective public health strategies.

Data availability

The results presented in this paper are based on the analysis of secondary and anonymized data provided by the Spanish National Statistics Institute (INE). To obtain the data the user is first required to fill out a form on their website (https://ine.es/infoine/?L=1) after which its user service department contacts the corresponding production units to generate the requested data. Although users do not have the permission to publish the raw data, the authors can make the R-code written for the analyses available upon request. More detailed results can also be found in the supplementary information files.

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Author contributions
JS, JAC, STL, ER and GD contributed to the study conception and design. Material preparation, data collection and analysis were performed by JAC with support from STL. The first draft of the manuscript was written by JS. All authors commented on previous versions of the manuscript and read and approved the final manuscript.

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Declarations

Competing interests
The authors declare no competing interests.

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