Years of Life Lost by COVID-19 in Portugal and comparison with other European Countries in 2020

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Abstract

Background: The impact of the COVID-19 epidemic has been measured in different metrics mostly by counting deaths and impact on health services. Few studies have attempted to calculate Years of Life Lost (YLL) by COVID and compare it with YLL due to other causes, in different countries. By looking into the years of life lost we add the important dimension of the age at the time of death.

Methods: We calculated YLL due to COVID-19 from week 10 (March 2) to week 52 (27 December) in 2020 for 8 EU countries by the methods defined by WHO, subtracting age of death (age category Intermediate range point) to life expectancy for each country. We calculated excess YLL by subtracting the average YLL from 2017-2019 to 2020 YLL. Our analysis compares COVID-19 and Excess YLL-non-COVID-19 across countries in the European Union and the United Kingdom.

Results: About two thirds of the YLL were lost in average for all countries by deaths above the 60 years old. The Total YLL and the estimation of COVID-19 and Excess YLL-non-COVID19 was very heterogenous between countries in 2020. Countries with higher YLL due to COVID-19 were not those with higher Excess YLL-non-COVID YLL, as there was no evident association between COVID-19 YLL and Excess YLL-non-COVID in the analyzed countries.

Conclusion: This study generates hypothesis that different countries and underlying healthcare services have different capacities to give response COVID-19 pandemics, also respecting to premature non-COVID deaths. Further research is warranted to understand the impact of COVID-19 disease in population dynamics and health services that could increase non COVID-19 excess of YLL.

Keywords: Coronavirus, Disease Outbreaks, Mortality, Pandemics, Portugal

1 Background

Between March 2 and December 27, 2020, Portugal registered 394 573 cases and 6 619 deaths due to COVID-19, stretching the capacity of hospitals and intensive care units to the limit[1].

The situation has been equally serious across Europe and the World in general. During that period Europe registered 26 209 329 confirmed cases, and 558 149 deaths[2].

COVID-19 is a serious threat due to its high transmissibility and overall lethality (1.7% in Portugal; 2.1% in Europe and 2.2% in the World at 27 December 2020, not considering under-ascertainment)[1, 2]. This is only comparable to the Spanish flu, in the year 1918, for which worldwide lethality is estimated to have been above 2.5% [3].

COVID-19 affects elderly people more severely[4]. In Portugal, there have been relatively few deaths in patients under the age of 50, only 1.2% of the total number of recorded deaths. On December 27, around 67.7% of COVID-19 deaths were recorded among people aged 80+ years and 31.2% among those aged 50 to 79 years of age[1].

Cancer (CA), Cardiovascular Diseases (CVD) and Diseases of the Respiratory System (DRS) are the most common causes of death in Portugal and tend to kill those affected at a younger age[5]. As a result, one may expect that patients dying from these diseases account, on average, for a higher number of years of life lost than those dying from COVID-19. In 2017, cardiovascular diseases and cancer were the major causes of natural deaths for those aged 15 to 49 years, accounting for 1.26 and 1.06 million deaths worldwide, respectively. Diseases of the respiratory system represented the 11th cause of natural deaths for this age group, accounting for 63 thousand deaths, worldwide[6]. The DRS are the third cause of death for people aged 50-69 and people aged 70+ years, accounting, in 2017, for 1 million deaths and 3.96 million deaths registered worldwide, respectively. [6, 7].

The number of deaths is an imperfect measure of mortality, as it does not provide insight into the age distribution of deaths or how risk levels vary by age. It is equally important to measure premature deaths, in terms of years of life lost in relation to the patient´s life expectancy, and to account for the number of years lived with disability. These two dimensions of the burden of disease can be expressed in terms Potential Years of Life Lost due to premature death (Years of Life Lost -- YLL) and to years living with disability (Disability Adjusted Life Years -- DALYs)[8]. DALYs result from the sum of YLL to the years lived with disability - YLD (Years Lived with Disability)[9]. These calculations take into consideration the age at which a certain death occurred, which can be estimate for a certain disease or group of diseases, and the impact that these diseases have on the ability of these people to fulfill their life expectancy (LE), using the value of a LE as the reference for the years the person is expected to live. LE can be defined as the LE at birth (“*Average number of years that a newborn is expected to live if current mortality rates continue to apply*”) or Health Life Expectancy, *(“Average number of years that a person can expect to live in "full health" by taking into account years lived in less than full health due to disease and/or injury”*)[10]. DALYs result from the sum of YLL and years lived with disability - YLD (Years Lived with Disability)[9]. Higher YLLs can be due to larger numbers of death, deaths in younger ages, or some combination of the two.

The Centers for Disease Control and Prevention refers to Excess Deaths (or Excess Mortality) to “*the difference between the observed numbers of deaths in specific time periods and expected numbers of deaths in the same time periods*”[11].

EUROMO counted excess mortality in 2020 across 26 European countries, including that directly attributed to COVID-19 pandemic[12]. However, not all excess deaths were directly caused by COVID-19. Because healthcare systems had to adapt to the overwhelming demands of the pandemic, patients with other common and

serious diseases may have been left behind, without receiving the level and quality of care that they would have received under normal circumstances. By late May 2020, England and Wales, Italy and Spain had already reported that they were observing excess mortality and that 28,8%, 32,5%, 61,8% and 51,9% of the excess mortality, respectively, was not due to COVID-19, often referring to it as Excess Mortality non-COVID-19 or Collateral Mortality[13, 14]. In Portugal, the percentage of non-COVID-19 excess mortality fluctuated over time, from 51% between march and mid-April to 92% in July and to no excess registered in the month of December[13, 15, 16].

The estimation of the number of years of life lost (YLL) due to COVID-19 and due to other causes adds to the estimation of the respective excess mortality. Several authors have developed models for estimating the YLL due to COVID-19[17], namely in Italy, where they estimated that the number of YLLs per patient due to COVID-19 death was 13 years per male and 11 years per female patient, when adjusted to the number and type of long-term conditions.

This study has three main objectives:

First, to estimate the burden of COVID-19 in terms of years of life lost due to premature deaths (YLL), for Portugal and for other European countries.

Second, to estimate the years of life lost (YLL) in excess due to premature deaths caused by other causes, as we will call it YLL in Excess without COVID-19 deaths (Exc-YLL-non-Cvd), for selected European countries (France, Germany, Italy, Netherlands, Portugal, Spain, Sweden, and United Kingdom), between March 2 and December 27, 2020.

Third, to estimate the excess in years of life lost (YLL) in 2020 due to CA, CVD, and DAR in selected countries during this pandemics period, or the Exc-YLL non-Cvd by disease.

2 Methods

Years of life lost -- YLL

To calculate YLLs, we adapted the traditional method, taking in consideration the scarcity of information on causes of mortality by age[9]. The calculations were made as follows:

$$\mathbf{YLL = \Sigma_i M_i * (LE - IRP_i)}$$

Where

YLL - Years of Life Lost

M - Number of deaths registered in each age class

LE - Life Expectancy

IRP - Intermediate Range Point of the age class

$_i$ – Age classes with deaths

Accessible data of the age at the time of deaths by country is grouped in 5- or 10-years ranges, including those due to COVID-19. All calculations for YLL were performed for the counting deaths below the 80 years old, once the values of LEs were slightly above of that age range and this is an upper limit recommend by other study for these calculations[18]. By using 80 years as the upper limit for counting deaths, this study states conservative values for the estimated years of life lost. Only data for COVID-19 deaths in Scotland and Northern Ireland was not performed in this way, due to the upper age class was 74-85, making the inclusion of deaths recorded in this range with values above Life Expectancy contribute to some reduction in the estimate of the final YLL for this range.

Total YLL by COVID-19

To calculate the YLL by COVID-19, M_i was replaced by the number of deaths due to COVID-19, by age. Information was retrieved from the INED[19] for all

countries and by INED and NISRA[20] for the United Kingdom (INED for Scotland, England and Wales and NISRA for Northern Ireland). For this calculations, it was considered the formula with the LE value being the latest known for each country without considering gender differentiation (France 82.90; Germany 81.00; Italy 83.4; Netherlands 81.90; Portugal 81.50; Spain 83.5; Sweden 82.60; United Kingdom 81.30)[21].

To estimate the percentage of YLL by COVID-19 by gender for each country data about LE for males and for females was also retrieved from the same reference and for the latest value known (France Female-79.7, Male-85.9; Germany Female-83.3, Male-78.6; Italy Female-85.6, Male 81.2; Netherlands Female-83.4, Male-80.3; Portugal Female-84.5, Male-78.3; Spain Female 86.3, Male 80.7; and United Kingdom Female-83.1, Male-79.5)[21]. This calculation was not possible for Sweden due to lack of data.

Excess YLL-non-Cvd *in 2020, by country*

Exc-YLL-non-Cvd for each country for the period in study was calculated using the following formula:

$$\text{Exc YLL non Cvd}_{YLL} = Total_{YLL2020} - Average_{YLL2017.2019} - COVID_{YLL2020}$$

For comparative purposes, we calculated the rates of YLL by country population in order to achieve YLL per 10 000 habitants for each country[22].

We also calculated the ratio for each country between the Excess-YLL-non-Cvd / YLL COVID-19.

To estimate the excess of YLL-non-Cvd by country, we estimated the average number of YLL expected in 2020, based on the mortality registered in 2017-2019 and compared it with that registered in 2020. We retrieved the mortality data

for all deaths by all-causes and by age between March 2 (week 10) and December 27 (week 52) for the years 2017, 2018 and 2019, from the Eurostat data base[23]. This period was chosen because it was the time when deaths registered by COVID-19 began to be more expressive in Europe. When the data exact for the day 27 was not available, the data was retrieved from the closest day available. Exception was made for Italy, where this was only performed till the week 49, as the data for 2020 was available. The same procedure was performed for the year of 2020, to achieve the Total YLL in 2020, for the same weeks in consideration. All estimations were performed with the latest LE values known as mentioned above.

After, we analyzed if there was any correlation between the YLL by COVID-19 and YLL Exc-YLL-non-COVID-19 found in the selected countries through the Pearson's test, with a statistical significance of 95%.

Excess YLL *by disease non-COVID in 2020, by country*

Because mortality statistics by age and specific cause (as International Classification of Diseases[24]) for many countries are only available till 2016[25], we estimated the YLL for each disease in 2020 basing on percentual data from previous years (2012-2016).

First, we calculate the percentage of YLL attributed to each disease, using the data between 2012 and 2016 through the following formula:

$$Average\ \%\ of\ YLL\ for\ a\ disease = \frac{\frac{\text{YLL for a disease 2012}}{\text{All YLL 2012}} + (\dots) + \frac{\text{YLL for a disease 2016}}{\text{All YLL 2016}}}{5}$$

The LE used for YLL calculation was the value found for each country in each year, as stated in the PORDATA[21]. LE for each period considered can be found in the Appendix 1. Then, we calculated the percentage of YLL from premature deaths due to the selected group of diseases per year in relation to all YLL in that

year. In this way, we thereby estimate the average burden of each group of selected diseases (Cancer, Cardiovascular and Respiratory Diseases) on those 5 years.

Finally, we estimated the Excess YLL for each group of diseases in 2020 through the equation:

$$Excess\ YLL\ for\ a\ disease_{2020} = Exc\ YLL\ non\ Cvd * Average\ \%\ of\ YLL\ for\ a\ disease$$

This calculation was only performed when Exc YLL non Cvd was positive value and assumes that the proportion of YLL by disease remained the same across the years.

3 Results

1. Burden of COVID 19 in terms of years of life lost (YLL)

Between March 2 and December 27, 2020, Portugal registered 394 573 cases and 6 619 deaths due to COVID-19, stretching the capacity of hospitals and intensive care units to the limit. Given the age at the time of death, these deaths accounted for 25 394 years of life lost due to COVID-19 in just 10 months (Table 1). During that period, the total number of years of life lost due to premature death attributed to all-natural causes was 611 104 YLL. Of these, 4.2 percent were registered as due to COVID-19.

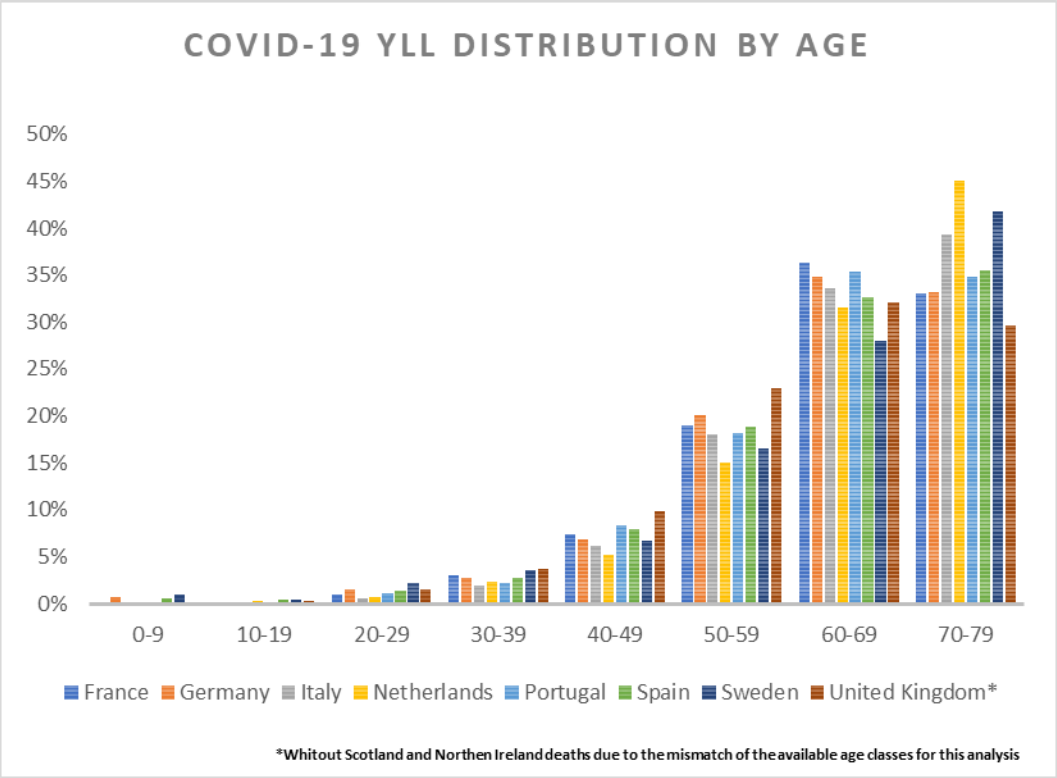
Table 1. Number of Deaths and Years of Life Lost in Portugal during the COVID-19 Pandemic (March 2-December 27, 2020)

	Nº of deaths	% of deaths	Nº of YLL	% of YLL
Total	99 368	100.0	611 104	100

COVID-19	6 619	6.7	25 394	4.2
Non COVID-19	92 749	93.3	585 710	95.8

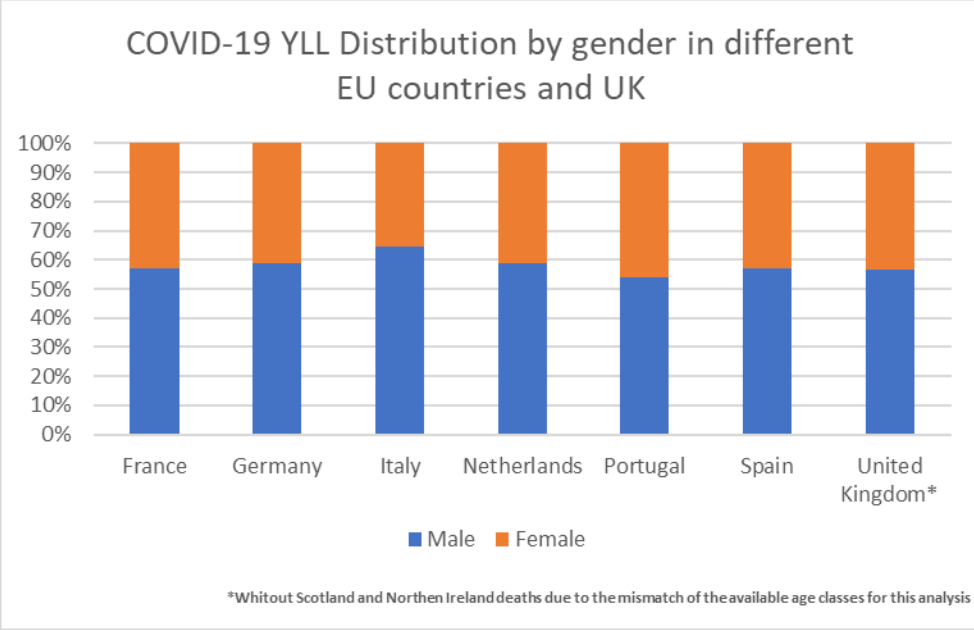
COVID-19 affected older people disproportionately, both in terms of the death rates and years of life lost per 10 000 population. Deaths from COVID-19 among people aged 60 and more account for 70% of all years of life lost due to COVID-19. In France, those aged between 60-69 account for the largest share of YLL, followed by Portugal. In Netherlands and Sweden, peopled aged 70+ account for the largest share of years of life lost due to COVID-19 (Figure 1.)

Figure 1. Distribution of YLL by COVID-19 by age and EU countries and the UK



COVID-19 affected men disproportionately accounting for most of the number of YLL in every country considered in this study. Portugal is the country where there seems to be more of a gender balance (Figure 2.)

Figure 2. COVID-19 YLL Distribution by gender in different EU countries and UK



2. Excess years of life lost due to COVID-19 (COVID-19 YLL) and other causes (YLL-non-Cvd) during the pandemic in 2020

A previous report[26] found that between March 2 and December 31, 2020, Portugal had an excess of 11 736 deaths by natural causes over what would have been expected, considering mortality for the same period between 2015 and 2019.

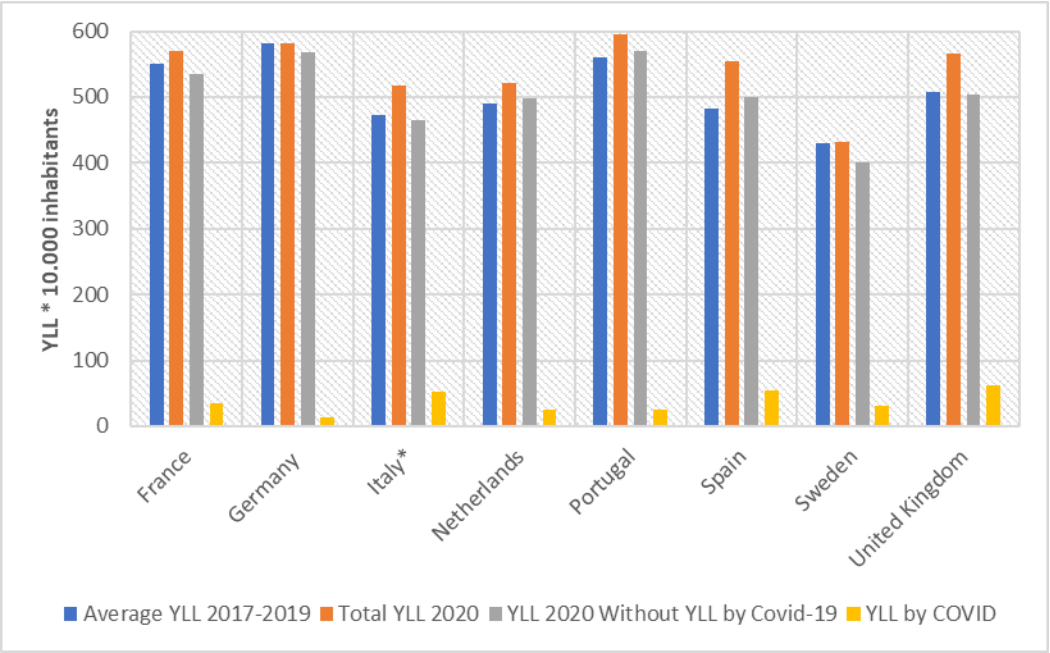
Between March 2 and December 27, 2020, Portugal registered 38 308 deaths due to all causes, among people aged less than 80. During that period, the country registered 2 140 deaths due COVID-19 below the 80 years, or 5.6% of deaths by all causes.

Based on the mortality rates between 2017 and 2019, we estimate that in the absence of the COVID-19 pandemic, Portugal would have registered 575 594 YLL due to all causes (the average). However, we calculated an excess of 35 510 years of life lost (+6.2%), of which 72% would have been due to COVID-19 and 28% due to other non-COVID-19 natural causes, respectively.

In figure 3 we can see that Portugal registered the highest rate (595) of Total

years of life lost per 10 000 inhabitants in 2020, followed by Germany (582), France (569), and United Kingdom (567). However, United Kingdom (62), Spain (55) and Italy (53) have the highest YLL per 10 000 inhabitants directly lost by COVID-19.

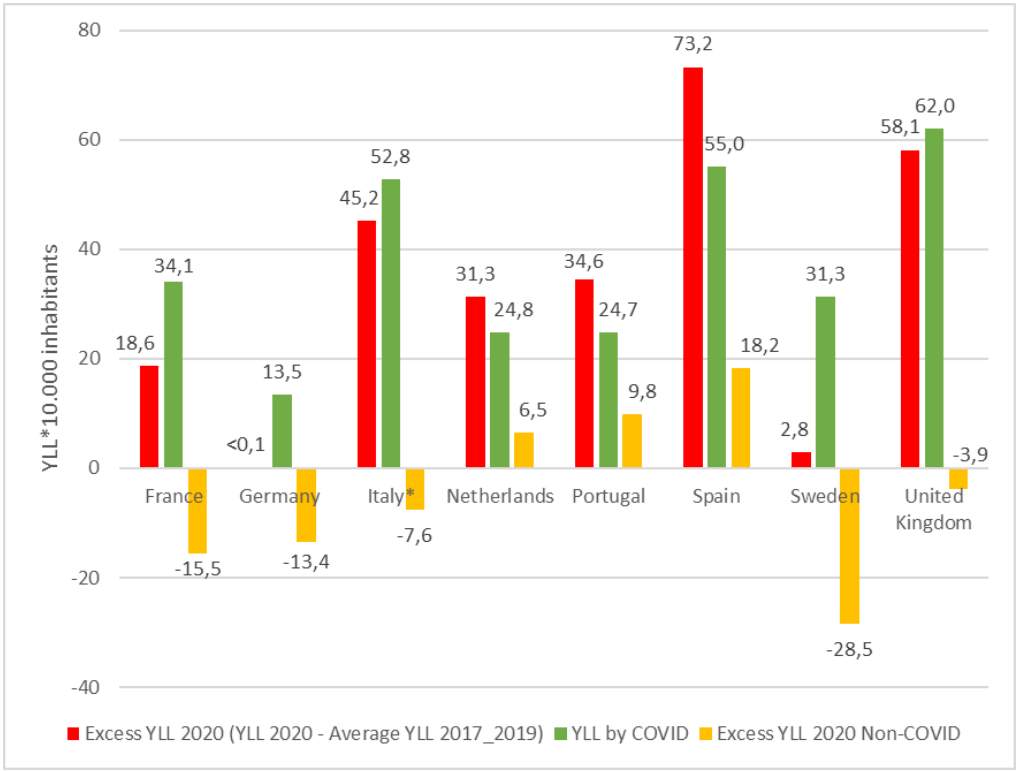
Figure 3. YLL by country between the week 10th and 52th of 2020, with and without COVID-19



*Analysis only performed till week 49th.

The Total of years of life lost by all causes was higher in 2020 than in 2017-2019 in every country considered in this study (excepting for Germany, where it was nearly even (0,04%)) (Figure 4).

Figure 4. Excess YLL in 2020 due to COVID-19 and non-COVID -19 per 10 000 inhabitants in the selected countries



*Analysis only performed till week 49th.

In addition to registering an excess of YLL lost due to COVID-19, Portugal, Spain, and Netherlands also registered an excess of YLL per 10 000 population due to other causes beyond COVID-19 (Excess YLL non-COVID-19). In all countries considered here, COVID-19 accounts for most of the excess in years of life lost in 2020. However, Portugal is the country among those considered in this study that report the higher ratio (40%) between the Excess YLL due to other non-COVID-19 causes and COVID-19 YLL (Table 2). This means that for every YLL by COVID-19, there was 0.4 YLL by other causes.

Table 2. Ratio between Excess YLL due to other causes non COVID-19 and COVID-19 related YLL and per country in 2020.

	France	***Germany***	***Italy***	***Netherlands***	***Portugal***	***Spain***	***Sweden***	***United Kingdom***
Ratio in 2020 (Exc YLL-Non-COVID / YLL COVID) *	**-46%**	**-100%**	**-14%**	**26%**	**40%**	**33%**	**-91%**	**-6%**

No correlation was found between the YLL by COVID-19 and Exc-YLL-non-COVID among countries ($r^2 = 0.240$, $p = 0.568$).

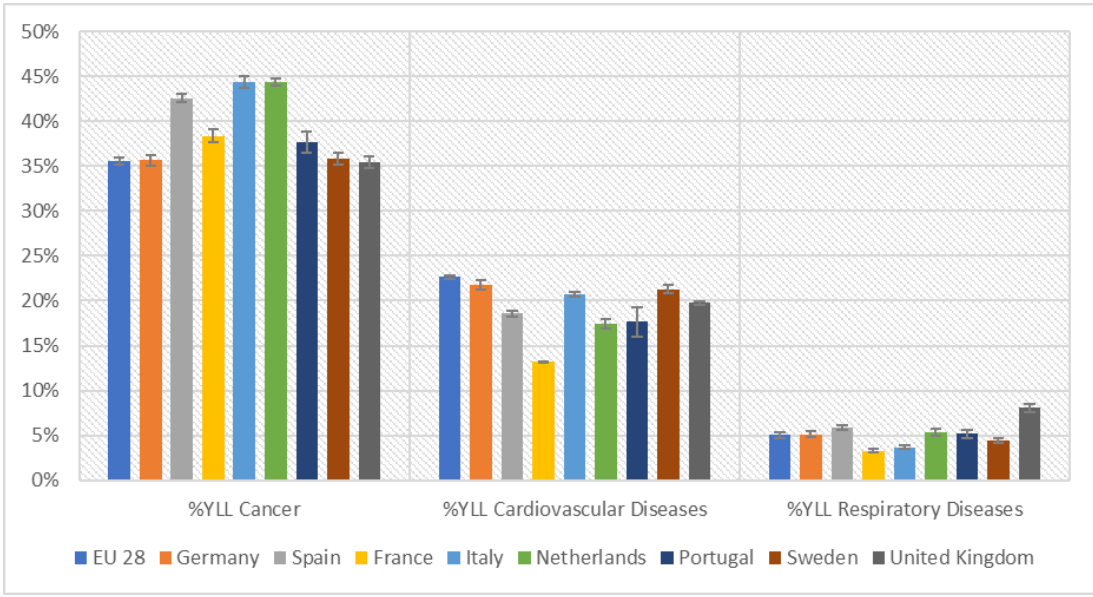
3. Estimation of Excess years of life lost due to cancer (CA), cardiovascular diseases (CVD and diseases of the respiratory system (DRS)

We estimate the percentage of YLL for each group of diseases using data by age and by specific cause from the most recent years available.

Between 2012 and 2016, 235 133 people below the 80 years old died in Portugal. Cancer (CA), cardiovascular diseases (CVD) and diseases of the respiratory systems (DRS) contributed in average to 37,3 %, 22,7 % and 7,3 % of all deaths for all causes below the age of 80.

For that same period, CA, CVD and DRS contributed, respectively, to 37,6 %, 17,7 % and 5,2 % of all years of life lost among people aged less than 80 years (Figure 5). This relative distribution is similar in all other countries in study, with some variations between countries at maximum of 9%.

Figure 5. Distribution of average percentage of YLL by disease and Standard Deviation between 2012 and 2016 in several countries and EU28.



*EU28 – The 28 Countries of European Union before 2020.

Cancer account for a higher proportion of YLL in Portugal than in the average 28 European Union Countries. Conversely, Cardiovascular diseases have a smaller proportion of the years of life lost in Portugal than in the 28 European Union countries.

Applying the relative distribution of the years of life lost per cause observed in 2012-2016 to the years of life lost due to non-COVID-19 deaths during this period of the pandemic, we estimate that the number of YLL due to CA, CVD and DRS through March 2 till December 27, 202, in Portugal would have been 3 805.3, 1 786.3 and 524.5, respectively (Table 3).

Table 3. Estimative of Excess YLL by other diseases non-COVID-19.

	Total Excess YLL No COVID	***YLL by Cancer***	***YLL by Cardiovascular Diseases***	***YLL by Respiratory Diseases***
France	No YLL Excess Without YLL by COVID-19			
Germany	No YLL Excess Without YLL by COVID-19			

Italy	No YLL Excess Without YLL by COVID-19			
Netherlands	11 257.5	4 998.9	1 963.3	605.0
Portugal	10 115.0	3 805.3	1 786.3	524.5
Spain	85 926.47	36 608.3	15 942.6	5 043.8
Sweden	No YLL Excess Without YLL by COVID-19			
United Kingdom	No YLL Excess Without YLL by COVID-19			

4 Discussion

In this paper, we estimate that Italy, United Kingdom and Spain had the greatest amount of YLL directly by COVID-19 and that Spain, Portugal and Netherlands were countries having the most Excess YLL per capita by other causes non COVID-19.

Few studies have tried to estimate the YLL with and without COVID-19 in the year of 2020[18, 27, 28].

This paper does not calculate the Years Lived with Disability (YLD) and, consequently, the DALY (Disability-Adjusted Life Years)[9] for COVID-19. However Years Lived with Disability due to COVID-19 long term consequences may prove to be of relevance but is still no for the understanding of long-term effects of this disease[29, 30]. Some data points to COVID-19 survivors being troubled with fatigue or muscle weakness, sleep and concentration difficulties(brain fog), and anxiety or depression and long term anosmia[31]. Other knowledge on incresead risks for other health problems after the infections is still scarce. On one hand, COVID-19 is an acute, short-lived disease that causes few symptoms and disability in younger people , still the possible medium and long-term consequences of the disease are not yet known. The most severe forms seem to affect mainly older people, many of whom have significant comorbidities. The increased disability

during weeks of acute disease however, should add little to what is learned by calculating the YLL.

Since YLD were not calculated, any value was not discounted or weighted[8].

In a recent study[27] it was found that man lost about 45% more YLL than women. This is close to our findings in the European countries, where we state that man lost around 60% of all YLL by COVID-19. An higher average age-at-death for women and a higher number of affected man with COVID-19 are factors that may account for this results[27].

The assumption that the mortality by age and cause (CA, CVD and DRS) registered between 2012 and 2016 would apply to 2020 if COVID-19 had not occurred is fair. Cancer, cardiovascular diseases, and diseases of the respiratory system are chronic and degenerative issues that do not change over short periods of time, except in cases of major events that drastically change the environmental, social and economic determinants of health. It does not seem that in 2020 there was a radical change in the determinants of CVD, CA and DAR. However it is possible that CVD is more sensitive, in the short term, to changes in healthcare follow-up and changes in health seeking behavior, for example related to late activation of emergency services for acute myocardial infarction or differences in acute and chronic care.7

This paper´s results can compare well with those done in other countries, because it used the conventional methods of calculating years of life lost. This study focused in only 8 European countries because it was difficult to get the number of COVID-19 deaths by age and gender for many other countries. Our estimates of years of life lost may have some degree of error because mortality statistics by age and gender is available only up to 2017. It may be possible that the results in this study are even more conservative due to an expected decrease in the proportion of

deaths by other non-natural causes, as traffic accidents. In fact, in a summary analysis, we found that deaths by non-natural causes in Portugal were about 1.7%, 1.6% and 1.5% in 2017, 2018 and 2019, respectively, and 1.3% in 2020[33].

. The capacity of each country´s healthcare system to manage the COVID and non-COVID patients may partly explain the difference in excess years of life lost by COVID-19 and other natural causes. Also, a lower intensity flu season in the analyzed countries may be in part responsible for the lower mortality by non COVID-19 causes found in some countries[34]. From all countries, Portugal stands out as having the highest ratio on Exc-YLL-non-COVID / COVID-19 YLL. This means that for every 1 YLL lost by COVID-19 there was around 0.4 YLL in excess by other causes. This is important because the relative success of some countries in protecting the population from COVID-19 and non-COVID premature death and from the pressure it exerted in the healthcare system on managing other diseases non-COVID-19.

In the USA, it was estimated that by early July there were already 1.2 million YLL due to COVID-19 and that by October the number already exceeded 2.5 million[35], 76.16 YLL/10 000 inhabitants. This rate is much higher than rates observed in European Union countries and the United Kingdom, where the highest rate was registered in the UK 62.00 YLL / 10 000.

In Portugal, as a result of the COVID-19 pandemic, there was a radical change in the availability and use of health services[15], because a significant part of the capacity of the national health system is reserved for the treatment of patients with COVID-19 and because of changes in health-seeking behavior.

Due to its contagiousness and seriousness, COVID-19 exerts a strong pressure on the human and technical resources of the entire health system[36]. A relevant part of the pre-hospital care facilities, consultations, diagnostic facilities, general inpatient beds, and intensive care are occupied or reserved for patients with

COVID-19[15]. As it is impossible to increase the supply of these resources in proportion to the growth in demand, patients with other pathologies such as CVD, CA or DAR end up having their consultations, exams, hospitalizations, and scheduled surgeries postponed, sometimes *sine die*. It is reasonable to assume that the delay or lack of care may have had an impact on the health and survival of these patients.

This study needs to be replicated later, as since January 2021 the number of cases and deaths by COVID-19 greatly increased in all Europe[37].

The increase of incidence of COVID-19 may end up with YLL beyond the expected values, even beyond the direct burden of this disease, parallel to control the pandemics. Countries need to be aware that Excess-YLL-non-COVID can increase if there are no strong efforts to care for short- and long-term management of other diseases. This is probably related to the lack of clinical follow-up, screenings, postponing surgeries, diagnostics, and health care seeking hesitancy.

The interpretation of the results in this study need caution. At first glance, it may seem obvious that countries with higher average life expectancy are more heavily penalized in the calculations of YLL. However, some of the characteristics that cause countries to obtain higher average life expectancy are also factors that contribute to a better control of deaths at younger ages and lower YLDs, such as a possible better organization and responsiveness of the National Health Systems, socioeconomic factors and/or better health literacy levels - which can assist in the adoption of more preventive and responsible behavior by their populations in controlling the dissemination of the virus[38, 39]. The YLL is a different measure and it may be very different when comparing to overall mortality. Even if much more people die in a period or in one country in relation to other, this calculation only takes in consideration those who died below the life´s expectancy.

Also, the degree of under-ascertainment in covid-19 deaths certification

across Europe are not free of some error[40]. Finally, some data from the Eurostat dataset of mortality in 2020 was provisory.

5 Conclusion

This study generates hypothesis that different countries, populations and underlying healthcare services have different capacities to give response COVID-19 pandemics, also respecting to premature deaths of both COVID-19 and non COVID. Further research is warranted to understand the impact of COVID-19 disease in population dynamics and health services that could increase Excess of YLL non COVID-19.

Availability of data and materials

The datasets generated and/or analyzed during the current study are available in the datasets mentioned in the Methods section.

Competing interests

The authors declare that they have no competing interests.

Funding

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Key points

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Appendix 1.

Life Expectancy between 2012 and 2016 for selected countries (PORDATA[21]).

	2012	2013	2014	2015	2016
Germany	80.7	80.6	81.2	80.7	81
France	82.1	82.4	82.9	82.4	82.7
Italy	82.4	82.9	83.2	82.7	83.4
Netherlands	81.2	81.4	81.8	81.6	81.7
Spain	82.5	83.2	83.3	83	83.5
Portugal	80.6	80.9	81.3	81.3	81.3
Sweden	81.8	82	82.3	82.2	82.4
United Kingdom	81	81.1	81.4	81	81.2
EU28 - European Union (28 Countries)	80.3	80.5	80.9	80.6	81