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Trends of Potential Years of Life Lost in Pavia Province (Italy) in the Period 2015-2021: The Impact of COVID-19

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The World Health Organization has declared the novel coronavirus disease, COVID-19, a pandemic from 2020 to 2023, causing more than 6.8 million deaths worldwide (updated March 2023). In record time, an anti-COVID-19 vaccine was created and large-scale mandatory vaccination was carried out. In Italy the first anti-COVID-19 vaccination started at the end of 2020. The work aimed to evaluate the impact of the COVID-19 on premature mortality in Pavia Province (Italy) with about 500,000 people in 2 different time points, during the pandemic without vaccination and with mandatory vaccination, in relation to the pre-pandemic period using Potential Years of Life Lost (PYLL). PYLL is a tool used to evaluate the effect of a specific disease on mortality for all causes. PYLLs were calculated for the 3 upper age limits (UAL): 70, 80, 90 years. The PYLL indicators showed the highest level of years of life lost in 2020, the period associated with the COVID-19 pandemic without vaccination and only other protective/preventive measures. The PYLLs decrease in 2021 to the pre-COVID-19 level may be associated with the introduction of mandatory vaccination.

Keywords: *PYLL, UAL, COVID-19, pandemic, Northern Italy*

Introduction

On March 11, 2020, the World Health Organization (WHO) declared a pandemic of a new coronavirus disease – COVID-19, which caused a huge number of deaths in many countries of the world, including Italy. The novel coronavirus spread rapidly. Globally, 759,408,703 confirmed cases and 6,866,434 deaths since the start of the pandemic (updated March, 2023) (WHO 2023). Italy has been one of the most severely affected countries in the world. There were 25,623,644 cases and 188,538 deaths due to COVID-19 in Italy (update March, 2023) (Ministry of Health, Italy 2023).

In record time, a vaccine against COVID-19 was created and large-scale mandatory vaccination was carried out, together with generally accepted measures such as lockdown, masks, distance, disinfection. Over 13 billion vaccine doses

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have been administered worldwide as of March, 2023 (WHO 2023). In Italy the first anti-COVID-19 vaccination started at the end of 2020.

Literature Review

The COVID-19 pandemic will certainly go down in human history as one of the most terrible pandemics. Boutsioli et al. (2022) noted that the scientific community quickly responded to the new infectious disease with numerous studies, publishing articles in the fields of health, sociology, economics, education and so on. In a short time, the main clinical signs of the disease were identified and diagnostic tests were created.

Papanikos (2021) evaluated the impact of lockdowns and vaccinations, the outcomes of atmospheric temperature on the number of deaths due to COVID-19 in Greece. The author concluded that the lockdown and vaccinations had the positive effect of decreasing the number of deaths and that "high weather temperatures reduce the infections and therefore the deaths from COVID-19".

One of tools useful to assess the overall impact of a specific disease on mortality is Potential Years of Life Lost (PYLL). The PYLL estimates the average time a person would have lived if he/she had not died prematurely. If life expectancy depends on mortality, PYLL depends on mortality and the age structure of the population (Islam et al. 2021).

Various methods are used to calculate PYLL: some authors used the standard life expectancy table (Yousefi et al. 2023, Quast et al. 2022); others (Vieira et al. 2021) used the formula proposed by Romeder and McWhinnie (1977) and Mitra et al. (2020). While Serpa Neto et al. (2021) calculated as "difference between the life expectancy for each sex in the year of inclusion and the actual age of the individual when they died".

According to several published works (Vieira et al. 2021, Serpa Neto et al. 2021, Pifarré I Arolas et al. 2021), the increase in the number of deaths and as a consequence of PYLLs during the COVID-19 pandemic mainly occurred among the elderly population. Most studies showed that PYLL was higher in men than women during the COVID-19 pandemic. Specifically, Yousefi et al. (2023) found that men were responsible for 55% of the total number of PYLL for people living in the Khorasan-Rasavi Iranian province. Similarly, Pifarré I Arolas and co-authors (2021) in a multicentre studies involving 81 countries showed that in men had PYLL due to COVID-19 higher than in women. Chan et al. (2021) found that PYLL in the United States was mainly due to men rather than women (61% vs 39%). In Germany, a similarly study by Rommel et al. (2021) estimated again that men contributed to PYLL more than women (60.1% vs 39.9%). The French study by Haneef et al. (2023) showed that men are responsible for 57% of PYLL. Finally, Vieira et al. (2021) found that in the European countries investigated (France, Germany, Italy, Netherlands, Portugal, Spain, Sweden, United Kingdom) men had around 60% of PYLL due to COVID-19.

The evidence of PYLL caused by COVID-19 in Italy is sparse and lacking for Pavia Province.

Objective

The present work aims to evaluate the impact of the COVID-19 on premature mortality in Pavia Province placed in the Northern part of Italy, in the Lombardy region in two different time points, during the pandemic without vaccination and with mandatory vaccination, in relation to the pre-pandemic period using PYLL.

Materials and Methods

Study Setting, Population, Time Period

The study is carried out on the residents in Pavia Province in Lombardy Region, placed in the Po Valley (Northern part of Italy). The Lombardy is the most populated among Italian region. During the early stages of the COVID-19 pandemic it was the Region most affected by both COVID-19 deaths and Sars-Cov-2 positivity.

The study population was composed in average by 500,000 people by year. The study period was divided in three calendar period: 2015-2019 corresponding to pre-pandemic, 2020 to pandemic without vaccination and 2021 to pandemic with mandatory vaccination.

Endpoints and Variables

The endpoint was the combine of death with the age to death. The cases of death for all causes were of interest. The information on gender was also collected.

Sources of Data

Different data sources were used. Death cases and age to death were obtained from the Mortality Registry of the Local Health Agency of Pavia (in Italian Agenzia di Tutela della Salute of Pavia). Socio-demographic data on the Pavia Province population and on Italian population were extracted from the open website of the National Institute of Statistics (ISTAT) and DemoISTAT (ISTAT)[1].

Statistical Analysis

The study population was divided in ten age group ranging 10 years. PYLL was calculated for the 3 upper age limits (UAL): 70, 80, 90 years (yrs). The choice of upper age limits of 70 and 80 years was based on the works of Romeder and McWhinnie (1977) and Mitra et al. (2020). According this, the PYLL was calculated using the formula proposed by Romeder and McWhinnie (1977):

$$PYLL = \sum_{i=1}^{UAL-1} a_i \times d_i = \sum_{i=1}^{UAL-1} (UAL - i - 0.5) \times d_i$$

[1]Available at: http://dati.istat.it/; https://demo.istat.it/.

where *UAL* is upper age limit 70, 80, 90; a_i is the remaining years to live until the upper age limit; d_i is the number of observed deaths in each age group; i is the mid-point of the class interval of each age group; 0.5 is a constant when the mid-point is not a whole number.

The new upper age limit of 90 years was based on life expectancy in Italy, which was over 80 years (Worldometer 2023). PYLLs were calculated for age group, by sex and per person death. The total PYLL is the sum of all age- specific PYLLs.

PYLL rate and Standardized PYLL rate per 100,000 population were also estimated using the following formulas:

$$PYLL\ rate = PYLL/(population\ under\ UAL\ years) \times 100{,}000$$

$$Standardized\ PYLL\ rate = \sum_{i=1}^{UAL-1} (PYLL/P_i) \times (P_{ir}/N_r) \times 100{,}000$$

where *UAL* is equal to 70 or 80 or 90 yrs, P_i is the number of people in the age group i in the actual population, P_{ir} is the number of people in the age group $\boldsymbol{i}$ in the reference population (Italian), and N_r is the number of people between ages *1* and (*UAL – 1*) in the reference population (Ugarte et al. 2022).

Analyses were made using STATA 17.0 Statistical Software and Excel.

Results

The total amount of deaths in Pavia Province during the study period was 51,339, greater in the 2020 pandemic year without vaccination (9,246 deaths) with respect to the others years (6,947 deaths in average during pre-pandemic 2015-2019, 7,357 deaths in pandemic year with vaccination). It was found that men and women showed a different structure of death by age-class (see Table 1). In men deaths occurred prevalently over 60 years (about 90%), on the contrary in women over 70 years.

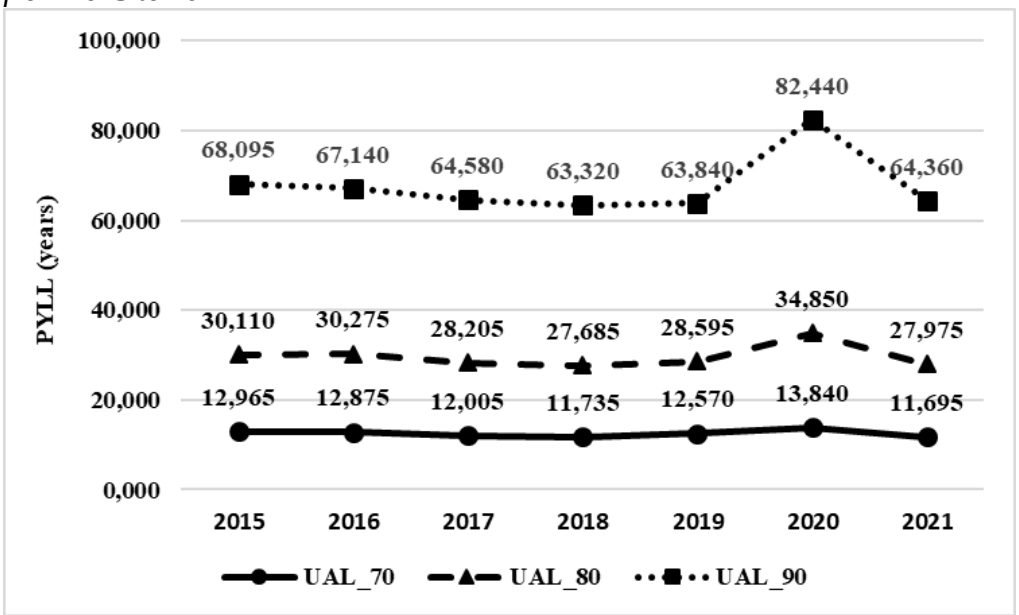
The PYLLs showed a stable trend until 2019 then increased in 2020 in all the UALs (see Figure 1). The pattern was similar from the period before pandemic to 2021 by all UALs. In average the PYLL for the 5 years before pandemic (2015-2019) was 12,430, 28,974 and 65,395 years a respectively for 70, 80 and 90 UAL. After an increase of 11.3%, 20.3% and 26.1%, respectively for 70, 80 and 90 UAL, occurred in 2020, but the PYLLs dropped to the same pre-pandemic level in 2021.

Table 1. *Death Structure (%) by Sex and Age-classes for Each Calendar Year in the Study Period*

	Males						
Age classes	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
≤9	0.22	0.20	0.23	0.27	0.30	0.15	0.25
10-19	0.09	0.07	0.13	0.20	0.13	0.17	0.06
20-29	0.60	0.41	0.42	0.33	0.49	0.35	0.38
30-39	0.60	0.47	0.58	0.50	0.85	0.25	0.38
40-49	1.93	2.81	2.00	1.96	1.64	1.51	1.89
50-59	5.97	6.15	5.69	5.72	5.75	5.16	6.05
60-69	**11.13**	**13.29**	**11.44**	**11.67**	**10.87**	**11.78**	**10.96**
70-79	**26.04**	**26.61**	**24.23**	**24.71**	**24.11**	**26.62**	**24.51**
80-89	**38.50**	**37.83**	**40.06**	**40.24**	**38.36**	**39.64**	**38.97**
≥90	**14.92**	**12.17**	**15.22**	**14.40**	**17.50**	**14.37**	**16.54**
	Females						
Age classes	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
≤9	0.22	0.06	0.05	0.09	0.17	0.08	0.11
10-19	0.03	0.06	0.03	0.09	0.08	0.04	0.08
20-29	0.14	0.14	0.08	0.11	0.06	0.10	0.11
30-39	0.35	0.28	0.30	0.17	0.22	0.23	0.22
40-49	0.95	1.05	0.85	1.08	1.05	0.85	0.71
50-59	2.91	3.44	3.25	2.68	3.14	2.48	2.51
60-69	5.27	5.81	4.86	5.65	5.87	5.21	5.84
70-79	**15.73**	**15.57**	**14.52**	**14.64**	**13.31**	**14.41**	**13.87**
80-89	**42.02**	**40.98**	**41.29**	**41.97**	**40.19**	**40.43**	**40.91**
≥90	**32.40**	**32.61**	**34.77**	**33.52**	**35.92**	**36.16**	**35.64**

Source: Mortality Registry of the Local Health Agency of Pavia 2015-2021. Author's calculation.

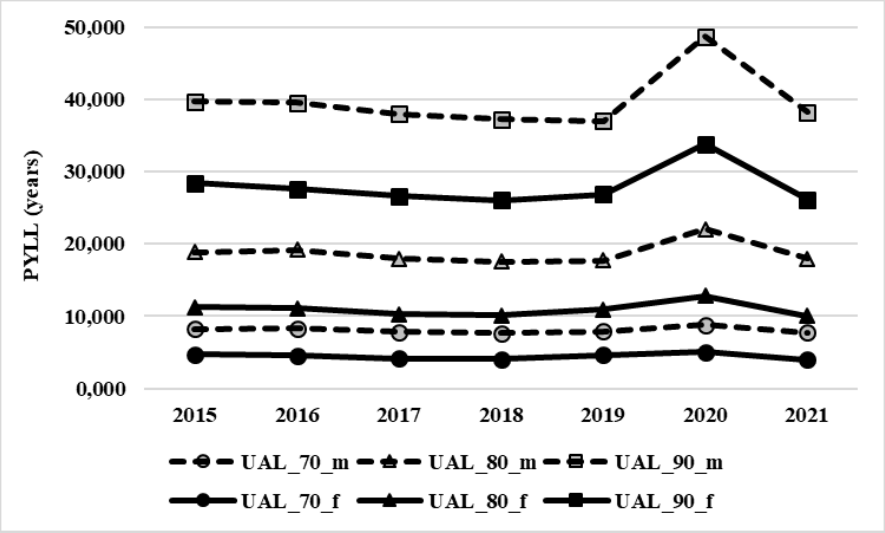
Figure 1. *Trend of PYLLs in the Province of Pavia for Three Upper Age Limits from 2015 to 2021*



Source: Mortality Registry of the Local Health Agency of Pavia. Author's calculation.

The PYLL was higher in males than females in all three UALs (see Figure 2). In UALs 80 and 90 the PYLL was highest in 2020 both for men and women: the excess with respect 2019 in men was 31.7% while in women of 25.7% in UALs 90 yrs, 24.5% and 17.6% respectively in UALs 80 yrs. The increase was less relevant for UAL 70 yrs: 11% in males and 8.4% in females.

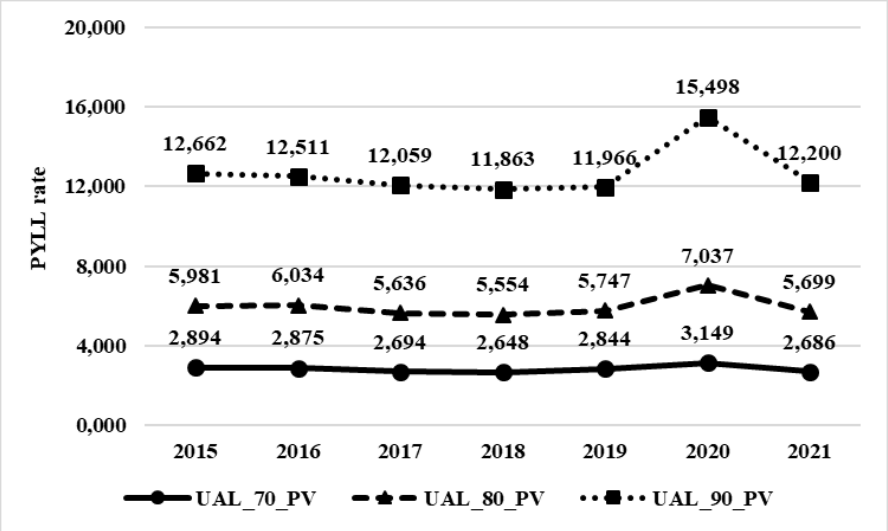
Figure 2. *Trend of PYLLs in the Province of Pavia for Three Upper Age Limits from 2015 to 2021, Separately by Sex (See the Data in the Appendix Table A1)*



Source: Mortality Registry of the Local Health Agency of Pavia. Author's calculation.

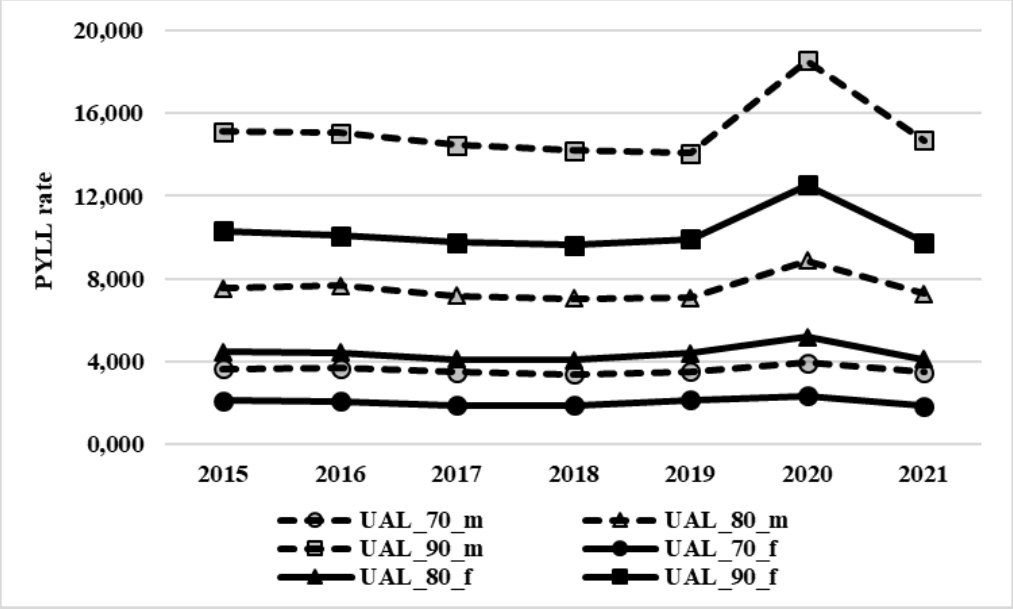
Similarly, the PYLL rate and the Standardized PYLL rate showed for all three UALs a stable trend until 2019, an increase in 2020 with a maximum, and a decrease in 2021 to the same pre-pandemic level for the whole population and separately by sex (see Figures 3-6).

Figure 3. *Trend of PYLL Rate x 100,000 Population for Province of Pavia for Three UALs*



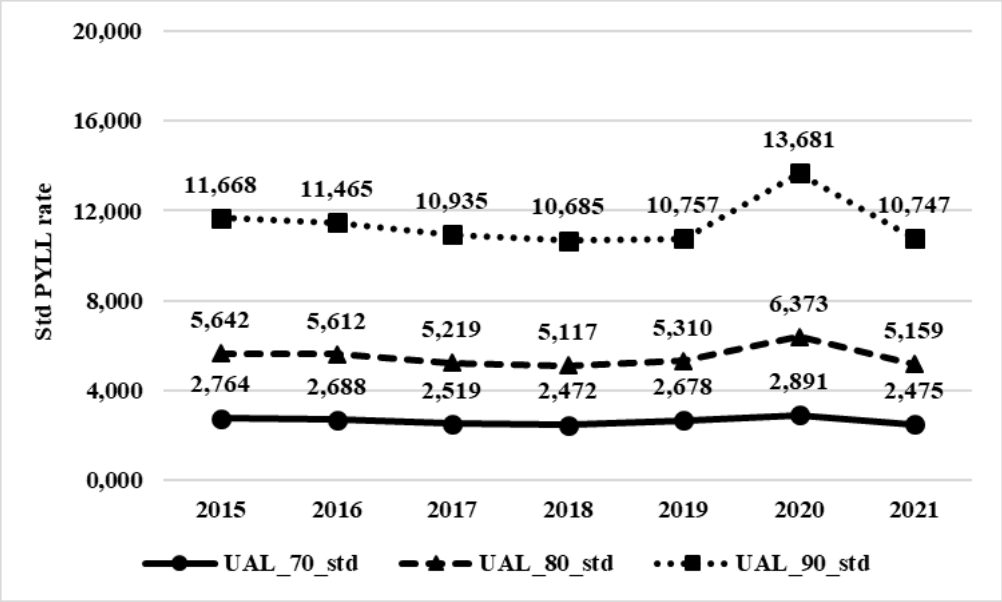
Source: Mortality Registry of the Local Health Agency of Pavia. Author's calculation.

Figure 4. *Trend of PYLL rate x 100,000 Population for Province of Pavia for three UALs, Separately by Sex (See the Data in the Appendix Table A2)*



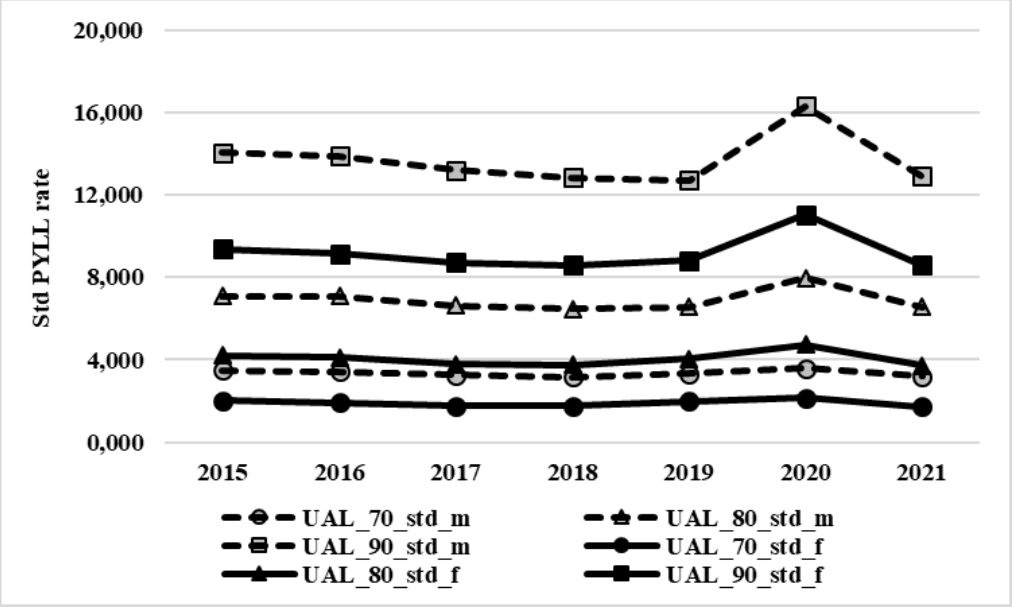
Source: Mortality Registry of the Local Health Agency of Pavia. Author's calculation.

Figure 5. *Trend of Standardized PYLL Rate x 100,000 Population for Province of Pavia for Three UALs*



Source: Mortality Registry of the Local Health Agency of Pavia. ISTAT. Author's calculation.

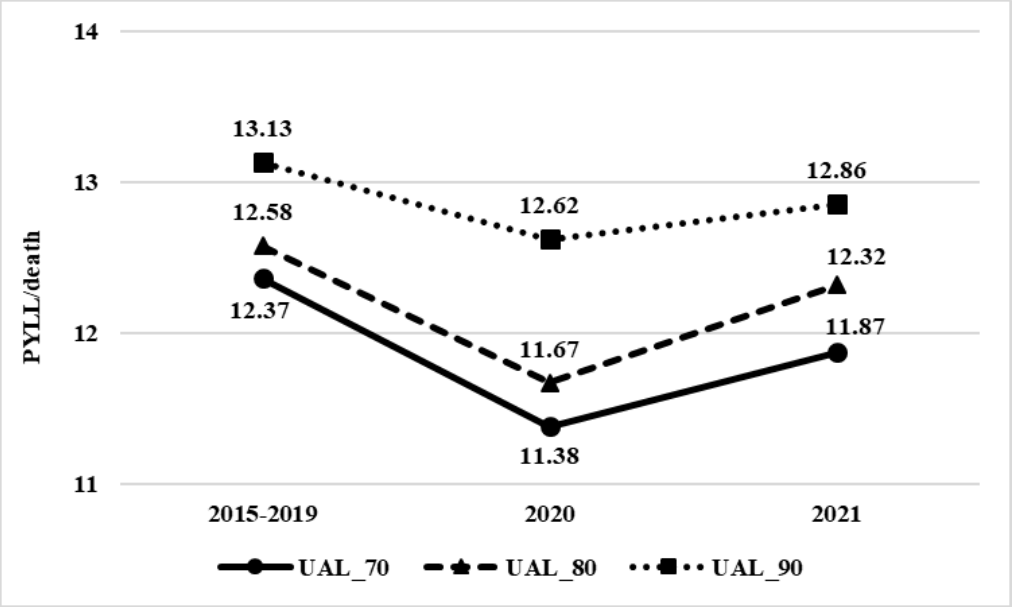
Figure 6. *Trend of Standardized PYLL Rate x 100,000 Population for Province of Pavia for Three UALs, Separately by Sex (See the Data in the Appendix Table A3)*



Source: Mortality Registry of the Local Health Agency of Pavia. ISTAT. Author's calculation.

As expected the average PYLL per death was greater for UAL 90 than for UAL 70 and 80 in all the three studied periods (see Figure 7). The average PYLL/ death presented a similar pattern across UALs with a marked reduction during pandemic period with respect pre-pandemic in UAL 80 (-7.2%) and UAL 70 (-8%).

Figure 7. *Trend of Average PYLL/Death by Three Time Periods*



Source: Mortality Registry of the Local Health Agency of Pavia. Author's calculation.

Discussion

The main findings from present work are:

- the highest level of years of life lost in 2020, the period associated with the COVID-19 pandemic without vaccination and only other protective/ preventive measures
- years of life lost decrease to the pre-COVID-19 level estimated in 2021, the pandemic period with mandatory vaccination
- the men contributed more to PYLLs than women
- a greater reduction of PYLL/death in 2020 in over 70 and over 80 years (UALs 70 and 80 yrs, respectively) than in over 90 years (UAL 90 yrs).

Our results are comparable with other studies, despite different methods for calculating PYLL (Vieira et al. 2021, Ferenci 2021, Rangachev et al. 2022). Higher PYLL values may be associated with more numbers of death or deaths at a younger age.

The reduction of deaths recorded in 2021 to the pre-pandemic level may be associated with the introduction of mandatory vaccination. Instead, the less marked reduction of PYLL/death in UAL 90 yrs may be due to the fact that the people over 90 years have been already "died" for other causes since they are generally more frail. On the contrary people over 70 yrs and over 80 yrs having a drop in PYLL/death doubled with respect to over 90 yrs may be characterised by comorbidities and so remaining life expectancy is shorter than the average person's remaining life expectancy. This different comorbidity distribution introduced a selection bias which consequently biased the estimates. Some authors' supposed that total PYLL in COVID-19 pandemic may be an overestimate by different mortality risk due to comorbidities (Palmieri et al. 2020, Robilotti et al. 2020, Chen et al. 2020).

The present work shows the great importance of vaccination not only to prevent hospitalization of infected people, but also to reduce deaths in agreement with published evidences (Machado et al. 2022, Hulíková Tesárková and Dzúrová 2022, Rachaniotis et al. 2022): the maximum number of deaths and years of life lost occurs during the period without mandatory vaccination.

Our study has some limitations first of all, we cannot use on COVID-19 deaths and so we may not estimate the direct contribution of COVID-19 to PYLL. Our findings may underestimate PYLLs.

Conclusions

In our opinion, the approach used in the present work may serve as a useful tool for studying the effects of vaccination on PYLL. Similar to life expectancy, the PYLL is a good measure for an overall health of an area. Unlike many other health statistics, the PYLL places additional emphasis on death of younger peoples, helping the efficacy and effectiveness of local sanitary system.

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Appendix

Table A1. *PYLLs in the Province of Pavia for Three Upper Age Limits from 2015 to 2021*

	2015	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
UAL_70_m	8,260	8,300	7,850	7,635	7,920	8,800	7,710
UAL_80_m	18,880	19,155	17,940	17,560	17,690	22,030	17,940
UAL_90_m	39,710	39,540	37,980	37,250	36,970	48,675	38,245
UAL_70_f	4,705	4,575	4,155	4,100	4,650	5,040	3,985
UAL_80_f	11,230	11,120	10,265	10,125	10,905	12,820	10,035
UAL_90_f	28,385	27,600	26,600	26,070	26,870	33,765	26,115

Notes: **UAL** is upper age limits, **70, 80, 90** are the age for UALs, **m** is male, **f** is female.

Table A2. *PYLL Rate x 100,000 Population for Province of Pavia for Three UALs, Separately by Sex*

	2015	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
UAL_70_m	3,656	3,671	3,482	3,399	3,531	3,946	3,490
UAL_80_m	7,528	7,650	7,169	7,030	7,082	8,862	7,281
UAL_90_m	15,117	15,058	14,458	14,190	14,059	18,551	14,694
UAL_70_f	2,119	2,063	1,886	1,875	2,137	2,328	1,858
UAL_80_f	4,447	4,423	4,103	4,071	4,401	5,198	4,104
UAL_90_f	10,317	10,071	9,750	9,611	9,932	12,525	9,771

Notes: **UAL** is upper age limits, **70, 80, 90** are the age for UALs, **m** is male, **f** is female.

Table A3. *Standardized PYLL Rate x 100,000 Population for Province of Pavia for Three UALs, Separately by Sex*

	2015	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
UAL_70_std_m	3,480	3,421	3,265	3,173	3,344	3,590	3,196
UAL_80_std_m	7,083	7,094	6,639	6,465	6,556	7,959	6,552
UAL_90_std_m	14,048	13,871	13,193	12,821	12,686	16,303	12,894
UAL_70_std_f	2,029	1,933	1,749	1,746	1,984	2,161	1,721
UAL_80_std_f	4,197	4,121	3,784	3,749	4,038	4,748	3,730
UAL_90_std_f	9,384	9,130	8,726	8,572	8,824	11,031	8,571

Notes: **UAL** is upper age limits, **70, 80, 90** are the age for UALs, **std** is standardadized, **m** is male, **f** is female.