Excess total mortality during the Covid-19 pandemic in Italy: updated estimates indicate persistent excess in recent months

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Keywords: Covid-19; SARS-CoV-2; pandemic; working age

Abstract
Background: New releases of daily mortality data are available in Italy; the last containing data up to 31 January 2022. This study revises previous estimates of the excess mortality in Italy during the Covid-19 pandemic. Methods: Excess mortality was estimated as the difference between the number of registered deaths and the expected deaths. Expected deaths in March–December 2020, January–December 2021 and January 2022 were estimated separately by sex, through an over-dispersed Poisson regression model using mortality and population data for the period 2011–2019. The models included terms for calendar year, age group, a smooth function of week of the year and the natural logarithm of the population as offset term. Results: We estimated 99,334 excess deaths (+18.8%) between March and December 2020, 61,808 deaths (+9.5%) in 2021 and 4143 deaths (+6.1%) in January 2022. Over the whole pandemic period, 13,039 excess deaths (+10.2%) were estimated in the age group 25–64 years with most of the excess observed among men [10,025 deaths (+12.6%) among men and 3014 deaths (+6.3%) among women]. Conclusions: Up to 31 January 2022, over 165 thousand excess deaths were estimated in Italy, of these about 8% occurred among the working age population. Despite high vaccination uptake, excess mortality is still observed in recent months.

Introduction
Excess in total mortality is the most valid indicator of the impact of the Covid-19 pandemic on the population, since it captures not only the deaths attributed to Covid-19 but also those related to the disruption of the health system. Since June 2020, the Italian National Institute of Statistics has provided daily mortality data by sex, age and municipality of residence during the pandemic period along with historic data [1]. These data were used by several research groups to estimate the excess total mortality in Italy [2–7]. However, given the preliminary nature of the data due to possible delay in registration, the number of deaths changes when more updated data become available. In a previous study [6], we used data collected up to 31 August 2021 and we estimated an excess of around 35,000 deaths between January and August 2021, which given the epidemiological trend at that time would become 40 thousand by the end of the year. In a new data release which covers the whole year, the number of deaths registered in the first 8 months of 2021 was revised upward by 10,000 thousand deaths [1]. Thus,
in this work we provided a revision of the previous published data on excess mortality in Italy in 2021 disaggregated by sex and age groups.

**METHODS**

The work is based on daily mortality data from 1 January 2011 to 31 January 2022 (the last day of available mortality data) and resident population data of each year of the same period. The data are of public domain and were downloaded from the repositories of the National Institute of Statistics [1, 8]. Population data for 2022 was not yet available and it was estimated from historic data (2011-2021) using a Poisson regression model including age groups, calendar years and age group-by-calendar year interaction as predictors.

The excesses total mortality in March-December 2020, the whole 2021 and in January 2022 were computed through the difference between the number of deaths registered in the three periods and the expected deaths in the same periods, and also quantified as percent relative difference compared to the expected deaths.

Expected deaths were estimated separately by sex, through over-dispersed Poisson regression models using mortality and population data for the period 2011-2019 (before the Covid-19 outbreak). The model included a linear term for calendar year (to account for temporal trends in mortality), age groups (to capture the demographic changes over the period), a smooth function of week of the year (to capture seasonal variations), and the natural logarithm of the population as offset term. A natural spline was used as a smooth function with number of knots chosen on the basis of the quasi-Akaike Information Criterion (QAIC) [9]. Up to 10 equally spaced knots were tested.

Excess deaths were provided with 95% confidence intervals (CI) at all ages and by the age groups 0-24, 25-64, 65-79 and ≥80 years. We defined the working population as individuals aged 25-64 years, not including individuals who may still be in education, and those who are retired.

| Sex | Age group | Observed deaths | Expected deaths | Δ (observed - expected deaths) | Percentage difference |
|-----|-----------|----------------|----------------|--------------------------------|----------------------|
| Women | 0-24 | 892 | 955 | -63 | -6.6 |
| | 25-64 | 21,942 | 20,367 | 1575 | 7.7 |
| | 65-79 | 60,037 | 51,298 | 8739 | 17.0 |
| | 80+ | 238,484 | 201,930 | 36,554 | 18.1 |
| | All ages | 321,355 | 274,550 | 46,805 | 17.0 |
| Men | 0-24 | 1442 | 1634 | -192 | -11.8 |
| | 25-64 | 38,778 | 33,933 | 4845 | 14.3 |
| | 65-79 | 96,248 | 77,009 | 19,239 | 25.0 |
| | 80+ | 170,234 | 141,597 | 28,637 | 20.2 |
| | All ages | 306,702 | 254,173 | 52,529 | 20.7 |
| All sexes | 0-24 | 2334 | 2589 | -255 | -9.8 |
| | 25-64 | 60,720 | 54,300 | 6420 | 11.8 |
| | 65-79 | 156,285 | 128,307 | 27,978 | 21.8 |
| | 80+ | 408,718 | 343,527 | 65,191 | 19.0 |
| | All ages | 628,057 | 528,723 | 99,334 | 18.8 |

1 Estimated from 2011-2019 mortality and population data, separately by sex, through an over-dispersed Poisson regression model including a linear term for calendar year (to account for the temporal improvement in mortality), age groups as categorical variable (to capture the demographic changes over the period), a smooth function of week of the year with 7 equally spaced knots (to capture seasonal variations), and the natural logarithm of the population as offset. Values were rounded up to the smallest integer.

LCL: Lower Confidence Limit; UCL: Upper Confidence Limit.
RESULTS

Table 1 shows the excess deaths computed for March-December 2020 by sex and age groups. Corresponding figures for the whole 2021 and for January 2022 are reported in Table 2 and Table 3, respectively.

Between March and December 2020, we estimated an excess total mortality of 99,334 deaths (+18.8%), mainly occurring at ages ≥65 years (93,169 deaths), while 6420 excess deaths (+11.8%) were estimated at working ages. In 2021, the excess was 61,808 deaths (+9.5%) with 55,324 deaths registered at ages ≥65 and 6643 deaths (+10%) estimated at working ages. In January 2022, 4143 excess deaths (+6.1%) were estimated in the whole population based on provisional data, while no excess was detected among the working age population. Excess mortality was consistently higher among men than women during all the periods considered.

In the months where Omicron was the main circulating SARS-CoV-2 variant (December 2020-January 2021), 21,338 excess deaths were estimated (+8.4%), though part of the excess is likely attributable to the Delta variant.

Figure 1 shows the trend in the difference between observed and expected deaths during the whole pandemic period by month, sex and age groups. For the age group 25-64, four peaks in the excess deaths were identified corresponding to the months of March 2020, November 2020, April 2021 and August-September 2021. For older ages, excess deaths peaked in March 2020, November 2020 and March-April 2021. The highest excesses were observed in March and November 2020 with values above 60%.

Figure 2 shows a comparison between the estimated excess total mortality, the number of Covid-19 deaths and the number of cases registered by month from the outbreak of the pandemic up to January 2022. During the outbreak of the pandemic (March-April 2020), our estimates of excess mortality suggest an important under-registration of Covid-19 deaths, which was observed also during

| Sex     | Age group | Observed deaths | Expected deaths | Δ(observed - expected deaths) | Percentage difference |
|---------|-----------|----------------|----------------|------------------------------|-----------------------|
|         |           |                |                | Estimate | 95% LCL | 95% UCL | Estimate | 95% LCL | 95% UCL |
| Women   | 0-24      | 1122           | 1147           | -25     | -79     | 27      | -2.2     | -6.9     | 2.4     |
|         | 25-64     | 26,727         | 25,090         | 1637    | 1327    | 1942    | 6.5      | 5.3      | 7.7     |
|         | 65-79     | 70,503         | 62,182         | 8321    | 7897    | 8743    | 13.4     | 12.7     | 14.1    |
|         | 80+       | 265,176        | 248,663        | 16,513  | 15,084  | 17,932  | 6.6      | 6.1      | 7.2     |
|         | All ages  | 363,528        | 337,082        | 26,446  | 24,229  | 28,644  | 7.8      | 7.2      | 8.5     |
| Men     | 0-24      | 1817           | 1951           | -134    | -204    | -68     | -6.9     | -10.5    | -3.5    |
|         | 25-64     | 46,262         | 41,256         | 5006    | 4601    | 5410    | 12.1     | 11.2     | 13.1    |
|         | 65-79     | 107,434        | 92,338         | 15,096  | 14,526  | 15,662  | 16.3     | 15.7     | 17.0    |
|         | 80+       | 189,994        | 174,600        | 15,394  | 14,339  | 16,440  | 8.8      | 8.2      | 9.4     |
|         | All ages  | 345,507        | 310,145        | 35,362  | 33,262  | 37,444  | 11.4     | 10.7     | 12.1    |
| All sexes | 0-24      | 2939           | 3098           | -159    | -283    | -41     | -5.1     | -9.1     | -1.3    |
|         | 25-64     | 72,989         | 66,346         | 6643    | 5928    | 7352    | 10.0     | 8.9      | 11.1    |
|         | 65-79     | 177,937        | 154,520        | 23,417  | 22,423  | 24,405  | 15.2     | 14.5     | 15.8    |
|         | 80+       | 455,170        | 423,263        | 31,907  | 29,423  | 34,372  | 7.5      | 7.0      | 8.1     |
|         | All ages  | 709,035        | 647,227        | 61,808  | 57,491  | 66,088  | 9.5      | 8.9      | 10.2    |

1 Estimated from 2011-2019 mortality and population data, separately by sex, through an over-dispersed Poisson regression model including a linear term for calendar year (to account for the temporal improvement in mortality), age groups as categorical variable (to capture the demographic changes over the period), a smooth function of week of the year with 7 equally spaced knots (to capture seasonal variations), and the natural logarithm of the population as offset. Values were rounded up to the smallest integer. LCL: Lower Confidence Limit; UCL: Upper Confidence Limit.
In January-February 2021, Covid-19 deaths exceeded excess total mortality, while the two values got closer thereafter, although excess total deaths were always slightly higher than the Covid-19 deaths in the most recent months. In January 2022, when the spread of the Omicron variant led to a surge in the number of cases (close to 5 million of cases registered), less than 5000 excess deaths were estimated, while about 9000 Covid-19 deaths were registered.

**Discussion**

This study provides updated estimates of the excess mortality in Italy during the Covid-19 pandemic. We estimated more than 165,000 excess deaths up to January 2022, of these 13,000 were among the working-age population.

The excess deaths observed among the working-age population represents a small share of the total excess and a minor contributor to the loss in life expectancy at birth (-1.25 years among men and -1 year among women) documented in Italy in 2020 as a consequence of the excess mortality due to the Covid-19 [10]. However, it has important implications not only for individuals and families but also for the whole society in terms of loss of productivity resulting from workforce depletion due to premature deaths.

Our results also highlight the crucial role of the successful vaccination campaign in the containment of further excesses in the second half of 2021. Indeed, the excess mortality observed in 2020 when vaccines were not available halved in 2021 (from +18.8 to +9.5%), despite the fact that the impact of vaccines was limited in the first part of 2021. At the beginning of July, about 60% of the eligible population had received one dose and 35% two doses of vaccine.

### Table 3. Observed, expected deaths and excess total deaths in Italy in January 2022, disaggregated by sex and age group

| Sex   | Age group | Observed deaths | Expected deaths | Δ (observed - expected deaths) | Percentage difference |
|-------|-----------|----------------|-----------------|-------------------------------|-----------------------|
|       |           |                | Estimate | 95% LCL | 95% UCL | Estimate | 95% LCL | 95% UCL |
| Women | 0-24      | 89             | 116      | -27    | -33    | -22      | -23.3   | -28.4   | -19.0   |
|       | 25-64     | 2389           | 2587     | -198   | -231   | -166     | -7.7    | -8.9    | -6.4    |
|       | 65-79     | 6814           | 6528     | 286    | 238    | 334      | 4.4     | 3.6     | 5.1     |
|       | 80+       | 27,760         | 26,747   | 1013   | 845    | 1180     | 3.8     | 3.2     | 4.4     |
|       | All ages  | 37,052         | 35,978   | 1074   | 819    | 1326     | 3.0     | 2.3     | 3.7     |
| Men   | 0-24      | 174            | 191      | -17    | -24    | -11      | -8.9    | -12.6   | -5.8    |
|       | 25-64     | 4261           | 4087     | 174    | 133    | 216      | 4.3     | 3.3     | 5.3     |
|       | 65-79     | 10,516         | 9406     | 1110   | 1047   | 1173     | 11.8    | 11.1    | 12.5    |
|       | 80+       | 19,888         | 18,086   | 1802   | 1682   | 1920     | 10.0    | 9.3     | 10.6    |
|       | All ages  | 34,839         | 31,770   | 3069   | 2838   | 3298     | 9.7     | 8.9     | 10.4    |
| All sexes | 0-24 | 263            | 307      | -44    | -57    | -33      | -14.3   | -18.6   | -10.7   |
|         | 25-64     | 6650           | 6674     | -24    | -98    | 50       | -0.4    | -1.5    | 0.7     |
|         | 65-79     | 17,330         | 15,934   | 1396   | 1285   | 1507     | 8.8     | 8.1     | 9.5     |
|         | 80+       | 47,648         | 44,833   | 2815   | 2527   | 3100     | 6.3     | 5.6     | 6.9     |
|         | All ages  | 71,891         | 67,748   | 4143   | 3657   | 4624     | 6.1     | 5.4     | 6.8     |

1 Estimated from 2011-2019 mortality and population data, separately by sex, through an over-dispersed Poisson regression model including a linear term for calendar year (to account for the temporal improvement in mortality), age groups as categorical variable (to capture the demographic changes over the period), a smooth function of week of the year with 7 equally spaced knots (to capture seasonal variations), and the natural logarithm of the population as offset. Values were rounded up to the smallest integer.

LCL: Lower Confidence Limit; UCL: Upper Confidence Limit.
Figure 1. Monthly trend in percentage differences between observed and expected total deaths in Italy in the age group 25-64 (Panel a), 65-79 (Panel b), 80+ (Panel c) and at all ages (Panel d), by sex. Period: March 2020-January 2022.

Figure 2. Number of Covid-19 cases (bars) registered in Italy between March 2020 and January 2022, estimated difference in total mortality and number of COVID deaths registered in the same period (lines).
Starting in mid-December 2021, the Omicron variant of SARS-CoV-2 caused a surge in the number of infections due to its high transmissibility and capacity to escape immunity provided by both prior infection and vaccination [11]. Almost 40% of the cases observed during the whole pandemic period were registered in a single month, even though the true circulation of the virus was likely higher than that estimated by surveillance data. Indeed, surveillance data mainly depend on test availability and indications, thus most asymptomatic ad mild cases were left uncounted [12].

Thanks to the protection conferred by vaccines and the milder disease caused by Omicron as compared to other SARS-CoV-2 variants [13], the surge in the number of cases was not followed by an increase in the number of deaths. Indeed, lower risks of hospitalization due to severe Covid-19 and death have been reported for Omicron as compared to the Delta variant, thus indicating a lower case fatality rate of Omicron [14]. Although a 6% excess can still be observed in January 2022, despite almost 80% of the population aged 5 years and over received two doses and 60% received three doses of the SARS-CoV-2 vaccine [15]. This indicates that even if Omicron infection generally causes a milder disease as compared to the original strain and previous variants of SARS-CoV-2 it can still be a deadly condition even in a population with high vaccine uptakes [13]. There was, however, no excess deaths in the working-age population. This confirms the less severe clinical pattern of Omicron vs Delta and previous variants, and indicates that most Omicron-related deaths are in the elderly frail population.

In January 2022 and in all the winter 2020-2021 there was no influenza in Italy. On average, 17 to 20,000 deaths are attributed to influenza and related syndromes each year in Italy. Thus, the real Covid-19-related excess death in January 2021 and 2022 is greater than the one registered.

Our results are based on provisional estimates provided by the National Institute of Statistics that may change when updated data are released, especially for the most recent months. Causes-of-death data during the pandemic period are not available, thus we could not separately quantify the excess mortality due to Covid-19 from that attributable to non-Covid-19 causes. In this regard, a study based on the first two months of the pandemic in Italy (March-April 2020) found an 11% increase in mortality from non-Covid-19 deaths that reached 64% in Lombardy (the region most severely hit during the first wave of Covid-19) [16]. Important excesses were observed in mortality from non-respiratory causes including hypertensive, ischemic and cerebrovascular diseases, diabetes, dementia and Alzheimer’s disease.

Our estimate of 160,000 deaths in 2020-2021 is greater than the figure of 137,402 Covid-19 deaths officially registered by the end of 2022 [15]. They are however substantially lower than the estimate of 259,000 excess deaths in 2020-2021 estimated by the Covid-19 Excess Mortality Collaborators (CEMC) using a Bayesian model [17]. The overestimate by the CEMC does not apply only to high-income countries, but also to middle-income ones, such as India, for which 4.07 million deaths were estimated as compared to 3.2 million of a nationally representative survey [18].

**Conclusions**

The availability of complete and timely data on total mortality in Italy allowed a close monitoring of the impact of the Covid-19 pandemic and of the effectiveness of vaccines and containment measures. These data are still important now that the Italian Government is leaving the state of emergency and relaxing several containment measures.

**Funding:** This research was supported by internal funds of the University of Milan (Fondazione Invernizzi) and the project CHANCES (Fondazione Cariplo)

**Declaration of Interest:** The authors declare no conflict of interest.

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