Effects of COVID-19 confinement on the incidence and mortality of major osteoporotic fractures: an observational study in Catalonia, Spain

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Abstract
Summary There is little information on how the COVID-19 lockdown influenced the epidemiology of major osteoporotic fractures (MOF). We analyzed the incidence and mortality of MOF in 2020 compared with 2018–2019 in Catalonia, Spain. The incidence of MOF decreased steeply, and post-fracture mortality increased during the lockdown and throughout 2020. Purpose To analyze the effect of the COVID-19 pandemic and lockdown on major osteoporotic fracture (MOF) incidence and mortality in Catalonia in 2020 and describe how age, sex, and the prior comorbidity burden influenced the epidemiology of MOF types. Methods In this retrospective observational study, data on age and sex in people aged ≥50 years with a new diagnosis of MOF in 2018, 2019, and 2020 were collected. Average daily rates (ADR) were estimated overall and for five MOF: hip, distal forearm, proximal humerus, vertebrae, and pelvis. Morbidity was assessed using Adjusted Morbidity Groups. ADR in 2020 and the previous years were compared for overall and site-specific MOF in four consecutive time periods: pre-confinement, lockdown, deconfinement, and post-confinement. Thirty-day post-fracture mortality was assessed. COVID-19-related mortality was obtained from the Catalan COVID-19 register. Results From 2018 to 2020, there were 86,412 MOF. The ADR of MOF initially increased in 2020 before the pandemic, decreased steeply during lockdown, and remained lower in the rest of the year. The decrease was steeper in vertebral, pelvic and arm fractures, and lower in hip fractures. Differences were more pronounced in younger age groups and people with fewer comorbidities. Mortality increased throughout 2020, reaching a 2.5-fold increase during lockdown. Excess mortality was directly associated with COVID-19. Conclusions Mobility restrictions due to COVID-19 were associated with a reduction in MOF incidence in Catalonia, especially in younger people and in non-hip fractures. Post-fracture mortality was higher than in previous years due to the high COVID-19 mortality in the elderly.

Keywords COVID-19 · Lockdown · Osteoporosis · Fractures · Mortality

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Introduction

During the first months of the 2020 COVID-19 pandemic, many countries implemented social distancing measures following World Health Organization recommendations. The first case of COVID-19 in Catalonia, a region with 7.7 M inhabitants in the northeast of Spain, was confirmed on February 25 and the first associated death on March 6. In Spain, a state of alarm was decreed on March 14, which limited the free movement of citizens except for basic services such as essential health care and lasted 100 days [1]. Confinement measures were strict from March 14 to April 28. From then on, some conditions were established to allow gradual mobility until June 21, when the state of alarm ended and a “new normality” was declared.

The effects of lockdown on the incidence of hip and other fragility and high-trauma fractures have been described in Spain and other European countries. Most studies are single or multicenter and hospital-based. Reported hospitalizations for hip fractures (HF) during lockdown decreased [2–7] or remained stable [8–11]. Information about other fractures is scarce, with most data showing a decrease in their incidence [12–17] and information about overall major osteoporotic fractures (MOF) and comparative data between them is lacking. To our knowledge, there is only one reported nation-wide (MOF) and comparative data between them is lacking. Data source

Materials and methods

Selection of patients and definition of time periods

We identified database records for people aged ≥50 years with MOF using ICD-10-MC codes, grouped in five categories: hip, distal forearm, vertebrae, proximal humerus, and pelvic fractures. Vertebral and pelvic fracture records were searched for across primary care visits, emergency room episodes, and hospitalization; arm and forearm fractures through emergency visits and hospitalizations and HF were identified only through hospital discharge data. An algorithm to exclude duplicates was constructed, as explained in the aforementioned article [18]. Patients were categorized by sex, age groups (50–59 years, 60–69 years, 70–79 years, 80–89 years, and ≥90 years), and baseline comorbidity status using Adjusted Morbidity Groups (AMG) [20]. AMG is a morbidity stratification tool developed by the Catalan Health Services which assigns each person a degree of comorbidity based on their diseases, the number of systems affected, and the complexity of each disease. Patients were classified into four AMG strata based on their morbidity-associated risk. The baseline risk was assigned to the AMG score range encompassing the healthier 50% of the total population. Subsequent cut-offs at 70%, 85%, and 95% were used to define the population at low, moderate, and high risk, respectively. AMG has been used to stratify populations for the risk of severe SARS-CoV-2 infection [21] and to analyze expenditure, morbidity, and mortality in patients with HF [22]. Four periods were considered: 

Fractures were identified through ICD-10-CM codes in the CHSS. Pathological fractures were excluded and refractures in the same site were included in the analysis (Supplementary material additional file 1 shows the list of ICD-10-MC codes included). For this analysis, data on incident MOF from January 1, 2018, to November 30, 2020, were extracted from the CHSS by staff members of the Information Unit. December 2020 was discarded, as hospital registration is based on discharges and many incident fractures in December might not have been discharged as of December 31. Mortality after fracture was obtained through official data from the Spanish National Institute of Statistics (https://www.ine.es/). COVID-19-related mortality was obtained from the Catalan COVID-19 register, a free access official database that brings together data from official mortality statistics in Catalonia from the Institute of Statistics of Catalonia, information from civil registries, and declarations of funeral homes to the Department of Health of Catalonia. COVID-19 diagnoses were identified according to molecular (positive PCR or serological test) or clinical/epidemiological criteria (i.e., reported as COVID-19 case in the electronic health records, based on the criteria of the European Centre for Disease Prevention and Control in force at diagnosis), as officially established in the Aggregated Healthcare Registry for COVID-19 (RSACovid-19) [19].

Materials and methods

Data source

The methods for analyzing MOF incidence in the Catalan Health Department have recently been described [18].
Pre-C (January 1 to March 14), lockdown (March 15 to April 28), gradual DC (April 29 to June 21), and Post-C (from June 22 onwards). Age- and sex-specific average daily rates (ADR) overall and for each type of fracture were calculated by dividing the number of fractures observed in the period by the number of days in each time period, taking into account that 2020 was a leap year. For example, the overall major osteoporotic fracture ADR during 2020 lockdown was the result of dividing 2114 (number of overall fractures observed) by 46 (lockdown days).

In addition, since many older people died from this disease during the first wave of the COVID-19 pandemic, there could be a competing risk in which death would have prevented these subjects from sustaining an osteoporotic fracture. Therefore, we estimated the number of expected overall and HFs in people who died from COVID-19 during each period. To do this, we consulted the Catalan registry of mortality from COVID-19 for each period. First, the sum of all deaths from COVID-19 in people aged ≥50 years was obtained before the end of each period. The fracture rate adjusted for sex and 5-year age groups corresponding to the days contained in each period was then applied to this number (Supplementary Table 1 for general fractures and Table 2 for hip fractures [18]). The 30-day mortality rate was the percentage of patients with incident fractures who died within 30 days of the fracture divided by all patients who had a fracture in each period.

**Statistical analysis**

Categorical variables were described as frequencies and percentages and continuous variables as means and standard deviation (SD). After confirming that age followed a non-normal distribution (Shapiro–Wilk test for normality), we used the non-parametric Kruskal–Wallis test to investigate differences between periods. The ADR and mortality rates were calculated for each period overall and for each type of MOF and by sex, age group, and AMG group. Incidence rate ratios with 95% confidence intervals were estimated between 2018–2019 and 2020 for the four periods (Pre-C, lockdown, DC, and Post-C) through Poisson regression. Secondary analysis with stratification by sex, age group, and AMG was also made. Categorical variables were compared using the chi-square test. The threshold for statistical significance was set at a 2-sided α-value of 0.05. All analyses were carried out using R v4.0.3.

**Ethics**

The study used retrospective anonymized data from the Catalan Health Surveillance System and RSA Covid-19 register. The study complied with the ethical guidelines of the Declaration of Helsinki. For this type of study, formal consent is not required. The study was approved by the Ethics Committee, Hospital General de Granollers (2022/032).

**Results**

### Overall MOF incidence

On January 1, 2020, the population of Catalonia aged ≥50 years was 3 million, of whom 54% were female, 49% were aged ≥64 years (46% of males and 52% of females), and 8% were aged ≥85 years (10% of females and 6% of males) [23]. From January 1, 2018, to November 30, 2020, 86,412 new MOF were found in people aged ≥50 years: 76.1% were in females and 23.9% in males. HF was the most frequent MOF (n = 25,634), followed by forearm (n = 18,012), clinical vertebral (17,741), pelvic (n = 13,382), and humerus fractures (n = 11,643). Tables 1 and 2 show the description of the entire population with MOF in the four periods of 2018–2019 and 2020 by sex, age groups, and AMG. Before confinement, in 2020, the ADR for overall MOF was 89.5, higher than the 83.5 in 2018–2019 (RR 1.072 (1.040–1.105), p < 0.001). Some days before lockdown, the daily number of fractures fell rapidly and bottomed out in mid-April (Fig. 1). The ADR for overall MOF during lockdown was 46, compared with 81.3 in 2018–2019 (RR 0.57 (0.54–0.60), p < 0.001) (Table 1). The overall ADR was 43% lower than in the previous 2 years. The number of people aged ≥50 who died in Catalonia due to COVID-19 during lockdown was 10,713 [24]. The expected number of incident MOF in people who had died would have been 39 overall fractures (11 in males and 28 in females). The drop in the number of MOFs in 2020 compared with the 2018–2019 average during lockdown was 1627 cases. From then on, the daily number of fractures gradually rose until mid-June and remained stable for the rest of the year, although below the previous 2 years. By periods, this difference was reduced to 11% in DC and 6% in Post-C (both differences, p < 0.001). The crude reduction in the number of fractures observed was also much higher than that expected in people who had died of COVID-19 (53 in DC and 221 in Post-C, following the same rule). The median age (IQR) of people with a new MOF during lockdown was 85 years (10% of females aged ≥85 years, 8% of males aged 85 years). 30% of females aged ≥85 years were aged ≥85 years (10% of females aged ≥85 years, 8% of males aged ≥85 years), and 8% were aged ≥85 years (10% of females aged ≥85 years, 6% of males aged ≥85 years) [23]. From January 1, 2018, to November 30, 2020, 86,412 new MOF were found in people aged ≥50 years: 76.1% were in females and 23.9% in males. HF was the most frequent MOF (n = 25,634), followed by forearm (n = 18,012), clinical vertebral (17,741), pelvic (n = 13,382), and humerus fractures (n = 11,643). Tables 1 and 2 show the description of the entire population with MOF in the four periods of 2018–2019 and 2020 by sex, age groups, and AMG. Before confinement, in 2020, the ADR for overall MOF was 89.5, higher than the 83.5 in 2018–2019 (RR 1.072 (1.040–1.105), p < 0.001). Some days before lockdown, the daily number of fractures fell rapidly and bottomed out in mid-April (Fig. 1). The ADR for overall MOF during lockdown was 46, compared with 81.3 in 2018–2019 (RR 0.57 (0.54–0.60), p < 0.001) (Table 1). The overall ADR was 43% lower than in the previous 2 years. The number of people aged ≥50 who died in Catalonia due to COVID-19 during lockdown was 10,713 [24]. The expected number of incident MOF in people who had died would have been 39 overall fractures (11 in males and 28 in females). The drop in the number of MOFs in 2020 compared with the 2018–2019 average during lockdown was 1627 cases. From then on, the daily number of fractures gradually rose until mid-June and remained stable for the rest of the year, although below the previous 2 years. By periods, this difference was reduced to 11% in DC and 6% in Post-C (both differences, p < 0.001). The crude reduction in the number of fractures observed was also much higher than that expected in people who had died of COVID-19 (53 in DC and 221 in Post-C, following the same rule). The median age (IQR) of people with a new MOF during lockdown was 83 years [72–88], higher than the 80 years [70–87] in the previous 2 years (p < 0.001). By sex, during Pre-C, males showed a 9% increase in the number of overall MOF, compared with 6% in females (Table 1). In ages between 50 and 79, a significantly higher incidence was found (14% higher in 50–69 years, and 17% in 70–79 years) but not above 79 years. However, the effect of lockdown was much greater in younger groups, with a clear gradient that ranged from a 56% drop in the incidence of MOF at ages up to 69 years, which progressively fell to 23% above 89 years. Comparing the incidence in Pre-C and lockdown in people aged < 70 years in 2020, there was a 62% decline in the incidence of overall MOF. These age ranges.
differences were not maintained after lockdown, when mobility restrictions were gradually withdrawn. The AMG subanalysis showed a similar pattern, with more pronounced falls in people in the healthier groups compared with the higher risk groups. People in the low-risk group showed a 73% reduction in the incidence of MOF during strict lockdown, while in people at high risk the reduction was only 27% (both significant with \( p < 0.001 \)).

**Differences by fracture type**

As shown in Figs. 1 and 2, the HF rate declined the least, compared with other MOF. During Pre-C, HF incidence did not increase compared with the previous 2 years and during lockdown the reduction was 13% (RR 0.87 (0.80–0.94), \( p < 0.001 \)). The decrease was more pronounced in males than in females and showed a gradient with lower rates in younger and healthier people, without significant differences in the very old (Table 1, Supplementary Table 3). In crude numbers, there were around 145 fewer HF cases during lockdown than in previous years. The number of HF expected for people who died due to COVID-19 would be 15, following the same rule as for overall fractures. During DC, HF did not show significant differences in the ADR, while in Post-C a lower ADR was found (23.3 vs 24.7; RR 0.94 [95% CI 0.91–0.98], \( p < 0.003 \)), which was explained only to a small extent by the number of fractures expected by deaths from COVID-19 (196 out of 993).

Distal forearm and proximal humerus fractures showed a similar pattern, with a higher incidence in the Pre-C period, fell by 54% during lockdown, with a gradual change in the trend, coinciding with the DC data (Fig. 2, Table 2). Pelvic and vertebral fractures showed the most pronounced changes, with a reduction of >50% during lockdown. Pelvic fractures, which did not show differences in the Pre-C period, fell by 54% during lockdown, with a gradual increase, which did not reach previous figures. The rate of vertebral fractures started from higher figures in Pre-C and fell very rapidly by 70% during lockdown compared with 2018–2019 (RR 0.30 (0.26–0.34), \( p < 0.001 \)) (Fig. 2, Table 1). During DC, there was a clear upward trend to values similar to those of the previous 2 years (Table 2).

### Table 1 Number of fractures (n) and average daily rates for overall and site-specific MOF from January 1 to March 14 (Pre-C) and March 15 to April 28 (lockdown) in 2018–2019 and 2020 by sex, fracture site, age groups, and AMG

|                  | January 1 to March 14 (Pre-C) | March 15 to April 28 (lockdown) |
|------------------|--------------------------------|----------------------------------|
|                  | 2018–2019 | 2020 | RR | LCI | UCI | \( p \) | 2018–2019 | 2020 | RR | LCI | UCI | \( p \) |
|                  | n | ADR | n | ADR |    |       | n | ADR | n | ADR |    |       |
| **Overall**      | 12,017 | 83.5 | 6,530 | 89.5 | 1.07 | 1.04 | 1.10 | <0.001 | 7,482 | 81.3 | 2,114 | 46.0 | 0.57 | 0.54 | 0.59 | <0.001 |
| **Fracture site**|        |     |     |     |    |       |     |     |     |     |    |       |     |     |     |       |
| Hip              | 3,700  | 25.7 | 1,842 | 25.2 | 0.98 | 0.93 | 1.04 | NS    | 2,177 | 23.7 | 944  | 20.5 | 0.87 | 0.8  | 0.94 | <0.001 |
| Distal forearm   | 2,307  | 16.0 | 1,293 | 17.7 | 1.11 | 1.03 | 1.18 | 0.004 | 1,397 | 15.2 | 376  | 8.2  | 0.54 | 0.48 | 0.6  | <0.001 |
| Proximal humerus | 1,692  | 11.8 | 987  | 13.5 | 1.15 | 1.06 | 1.24 | <0.001 | 981   | 10.7 | 258  | 5.6  | 0.53 | 0.46 | 0.6  | <0.001 |
| Pelvis           | 1,898  | 13.2 | 1,000 | 13.7 | 1.04 | 0.96 | 1.12 | NS    | 1,237 | 13.4 | 285  | 6.2  | 0.46 | 0.4  | 0.52 | <0.001 |
| Vertebral        | 2,420  | 16.8 | 1,408 | 19.3 | 1.15 | 1.07 | 1.23 | <0.001 | 1,690 | 18.4 | 251  | 5.5  | 0.3  | 0.26 | 0.34 | <0.001 |
| **Sex**          |        |     |     |     |    |       |     |     |     |     |    |       |     |     |     |       |
| Men              | 2,981  | 20.7 | 1,650 | 22.6 | 1.09 | 1.03 | 1.16 | 0.004 | 1,815 | 19.7 | 517  | 11.2 | 0.57 | 0.52 | 0.63 | <0.001 |
| Women            | 9,036  | 62.8 | 4,880 | 66.8 | 1.07 | 1.03 | 1.10 | <0.001 | 5,667 | 61.6 | 1,597 | 34.7 | 0.56 | 0.53 | 0.60 | <0.001 |
| **Age groups (years)** |        |     |     |     |    |       |     |     |     |     |    |       |     |     |     |       |
| 50–59            | 1,188  | 8.3  | 684  | 9.4  | 1.14 | 1.03 | 1.25 | 0.008 | 717   | 7.8  | 164  | 3.6  | 0.46 | 0.39 | 0.54 | <0.001 |
| 60–69            | 1,841  | 12.8 | 1,063 | 14.6 | 1.14 | 1.06 | 1.23 | <0.001 | 1,141 | 12.4 | 258  | 5.6  | 0.45 | 0.40 | 0.52 | <0.001 |
| 70–79            | 2,792  | 19.4 | 1,663 | 22.8 | 1.17 | 1.11 | 1.25 | <0.001 | 1,759 | 19.1 | 457  | 9.9  | 0.52 | 0.47 | 0.58 | <0.001 |
| 80–89            | 4,378  | 30.4 | 2,204 | 30.2 | 0.99 | 0.94 | 1.05 | NS    | 2,758 | 30.0 | 811  | 17.6 | 0.59 | 0.54 | 0.64 | <0.001 |
| >89              | 1,818  | 12.6 | 916  | 12.5 | 0.99 | 0.92 | 1.08 | NS    | 1,107 | 12.0 | 424  | 9.2  | 0.77 | 0.68 | 0.86 | <0.001 |
| **AMG**          |        |     |     |     |    |       |     |     |     |     |    |       |     |     |     |       |
| Baseline risk    | 289    | 2.0  | 137  | 1.9  | 0.94 | 0.76 | 1.15 | NS    | 164   | 1.8  | 22   | 0.5  | 0.27 | 0.17 | 0.42 | <0.001 |
| Low risk         | 1,645  | 11.4 | 779  | 10.7 | 0.93 | 0.86 | 1.02 | NS    | 972   | 10.6 | 189  | 4.1  | 0.39 | 0.33 | 0.45 | <0.001 |
| Moderate risk    | 5,250  | 36.5 | 2,676 | 36.7 | 1.01 | 0.96 | 1.05 | NS    | 3,278 | 35.6 | 783  | 17.0 | 0.48 | 0.44 | 0.52 | <0.001 |
| High risk        | 4,833  | 33.6 | 2,938 | 40.2 | 1.20 | 1.15 | 1.26 | <0.001 | 3,068 | 33.3 | 1,120 | 24.3 | 0.73 | 0.68 | 0.78 | <0.001 |

Pre-C pre-confinement, ADR average daily rate, RR rate ratio, LCI lower confidence interval, UCI upper confidence interval, AMG Adjusted Morbidity Groups. “\( p \)” value refers to the RR and indicates the rate difference in each period of 2020 compared with 2018–2019.
MOF-related mortality

Table 3 shows mortality rates in the different periods by sex, age groups, and AMG. It also shows COVID-19-related deaths in each period of 2020. The overall 30-day mortality rate of MOF increased throughout 2020 compared with 2018–2019, with a more than 2.5-fold increase during lockdown (3.7% 30-day mortality in 2018–2019 vs 9.5% in 2020, RR 2.57 [95% CI 2.14–3.08], \( p < 0.001 \)). Overall 30-day mortality increased significantly during the rest of the year. During lockdown in 2020, 115 out of 201 (57%) of deaths were directly related to COVID-19, while in the remaining periods the percentage ranged from 6% in DC to 11% in Pre-C and Post-C. By age groups and AMG, differences in mortality were only significant in people aged >70 years and in moderate-to-high comorbidity groups. By fracture type, the mortality rate was increased at all sites, but the difference was only significant in hip, humerus, and pelvic fractures during lockdown. The percentage of mortality due to COVID-19 varied from 10.4% in vertebral fractures to 21.3% in humerus fractures (Table 4).

Discussion

Overall MOF incidence

We estimated the daily incidence and 30-day mortality rates for overall and site-specific MOF in people aged \( \geq 50 \) years in Catalonia in 2020, the year the COVID-19 pandemic broke out, and compared it with the previous 2 years. We analyzed four periods to differentiate the effect of various states of mobility restriction. In the first 2 months of 2020, prior to the pandemic declaration by the WHO on March 12, the crude incidence of overall MOF was higher in Catalonia compared with 2018 and 2019. The increase was slightly higher in males and in people aged <80 years. Consistent with this age difference, the upward trend was only found for fractures that typically occur in people with mean ages closer to 70 years, but not for fractures of the hip or pelvis. HF standardized rates have shown a downward trend, especially in females, in many western countries [25, 26] and in Catalonia [27, 28] in recent decades. Data on non-hip fragility

Table 2 Number of fractures (n) and average daily rates for overall and site-specific MOF from April 29 to June 21 (DC) and June 22 onwards (Post-C) in 2018–2019 and 2020 by sex, fracture site, age groups, and AMG

|                        | April 29 to June 21 (DC) |                |                |                |                |                |                |                |                |                |                |                |                |                |                |
|------------------------|--------------------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
|                        | 2018–2019                | 2020           | RR  | LCI         | UCI         | 2018–2019     | 2020           | RR  | LCI         | UCI         | 2018–2019     | 2020           | RR  | LCI         | UCI         |
|                        | n  | ADR  | n  | ADR  |            | n  | ADR  |            | n  | ADR  |            | n  | ADR  |            | n  | ADR  |            |
| Overall                | 8808 | 81.6 | 3905 | 72.3 | 0.89 | 0.85 | 0.92 | <0.001 | 32,675 | 84.7 | 12,881 | 79.5 | 0.94 | 0.92 | 0.96 | <0.001 |
| Fracture site          |                      |                |                |                |                |                |                |                |                |                |                |                |                |                |                |
| Hip                    | 2413 | 22.3 | 1226 | 22.7 | 1.02 | 0.95 | 1.09 | NS    | 9550  | 24.7  | 3782  | 23.3 | 0.94 | 0.91 | 0.98 | 0.003 |
| Distal forearm         | 1789 | 16.6 | 859  | 15.9 | 0.96 | 0.88 | 1.04 | NS    | 7201  | 18.7  | 2790  | 17.2 | 0.92 | 0.88 | 0.96 | <0.001 |
| Proximal humerus       | 1135 | 10.5 | 567  | 10.5 | 1.0  | 0.9  | 1.1  | NS    | 4314  | 11.2  | 1709  | 10.5 | 0.94 | 0.89 | 0.99 | 0.043 |
| Pelvis                 | 1482 | 13.7 | 546  | 10.1 | 0.74 | 0.67 | 0.81 | <0.001| 5052  | 13.1  | 1882  | 11.6 | 0.89 | 0.84 | 0.94 | <0.001 |
| Vertebral              | 1989 | 18.4 | 707  | 13.1 | 0.71 | 0.65 | 0.77 | <0.001| 6558  | 17.0  | 2718  | 16.8 | 0.99 | 0.94 | 1.03 | NS    |
| Sex                    |                      |                |                |                |                |                |                |                |                |                |                |                |                |                |                |
| Men                    | 2116 | 19.6 | 902  | 16.7 | 0.85 | 0.79 | 0.92 | <0.001| 7615  | 19.7  | 3069  | 18.9 | 0.96 | 0.92 | 1.00 | NS    |
| Women                  | 6692 | 62.0 | 3003 | 55.6 | 0.90 | 0.86 | 0.94 | <0.001| 25,060| 64.9  | 9812  | 60.6 | 0.93 | 0.91 | 0.95 | <0.001 |
| Age groups (years)     |                      |                |                |                |                |                |                |                |                |                |                |                |                |                |                |
| 50–59                  | 895  | 8.3  | 387  | 7.2  | 0.86 | 0.77 | 0.97 | 0.017 | 3451  | 8.9   | 1362  | 8.4  | 0.94 | 0.88 | 1.00 | NS    |
| 60–69                  | 1401 | 13.0 | 620  | 11.5 | 0.89 | 0.81 | 0.97 | 0.011 | 5116  | 13.3  | 2203  | 13.6 | 1.03 | 0.98 | 1.08 | NS    |
| 70–79                  | 2163 | 20.0 | 958  | 17.7 | 0.89 | 0.82 | 0.96 | 0.002 | 7885  | 20.4  | 3204  | 19.8 | 0.97 | 0.93 | 1.01 | NS    |
| 80–89                  | 3204 | 29.7 | 1364 | 25.3 | 0.85 | 0.80 | 0.91 | <0.001| 11,650| 30.2  | 4284  | 26.4 | 0.88 | 0.85 | 0.91 | <0.001|
| >89                    | 1145 | 10.6 | 576  | 10.7 | 1.0  | 0.91 | 1.11 | NS    | 4573  | 11.8  | 1828  | 11.3 | 0.95 | 0.90 | 1.01 | NS    |
| AMG                    |                      |                |                |                |                |                |                |                |                |                |                |                |                |                |                |
| Baseline risk          | 205  | 1.9  | 73   | 1.4  | 0.71 | 0.55 | 0.93 | 0.013 | 745   | 1.9   | 262   | 1.6  | 0.84 | 0.73 | 0.96 | 0.014 |
| Low risk               | 1140 | 10.6 | 421  | 7.8  | 0.74 | 0.66 | 0.83 | <0.001| 4164  | 10.8  | 1600  | 9.9  | 0.92 | 0.86 | 0.97 | 0.003 |
| Moderate risk          | 3846 | 35.6 | 1607 | 29.8 | 0.84 | 0.79 | 0.89 | <0.001| 14,040| 36.4  | 5241  | 32.4 | 0.89 | 0.86 | 0.92 | <0.001|
| High risk              | 3617 | 33.5 | 1804 | 33.4 | 1.00 | 0.94 | 1.06 | NS    | 13,726| 35.6  | 5778  | 35.7 | 1.00 | 0.97 | 1.03 | NS    |

DC deconfinement, Post-C postconfinement, ADR average daily rate, RR rate ratio, LCI lower confidence interval, UCI upper confidence interval, AMG Adjusted Morbidity Groups. "p" value refers to the RR and indicates the rate difference in each period of 2020 compared with 2018–2019.
fractures are scarcer, with some evidence pointing to a general decrease [29, 30], a steady [31] or increasing trend [32], especially for some fracture types, such as forearm [33] and pelvic fractures [34]. The possible rise in the trend we found needs to be considered with caution, given the short period analyzed and the lack of age-standardization. During the

Fig. 1 Daily average number of overall and hip fractures in Catalonia during four different periods of the year. Comparison between 2018–2019 and 2020
week before lockdown, there was already a small region in Catalonia with a high number of cases, which led to a local confinement, with increasing social alarm. Official data, as of March 7, had reported 73 COVID-19-related deaths in people aged >50 years. This may have affected the general population and reduced overall mobility prior to lockdown, accompanied by a rapid fall in daily MOF incidence.

During lockdown, the incidence decreased for overall MOF and each skeletal site, especially in younger people. There may be some explanations for this. Younger people tend to have a greater degree of social and occupational mobility than older people. As fracture occurrence is closely related to mobility, a decree that substantially reduced mobility would affect them more. Furthermore, MOF that more frequently affect younger adults, such as those of the forearm and humerus, tend to occur more frequently outside the home. In contrast, most HFs occur indoors and in very old people [35]. Therefore, it is likely that confinement changed the usual pattern of incidence of fragility fractures more in younger adults than in the very old. Another possible explanation is the competing risk with COVID-19 mortality. Global mortality from COVID-19 peaked during the first period of lockdown, especially in older people living in nursing homes. Nevertheless, as MOFs are more frequent among this group, this increase in mortality would not explain the greater decrease in the rate of fractures in younger patients, as was the case. As stated, the effect of excess mortality on fracture rate reduction appeared to be very limited.

Differences by fracture type

There were differences in the reduction in MOF according to type. HF incidence fell 13% compared with the previous 2 years. This was similar to the 11% fall described in the only reported nationwide retrospective cohort study from the French national hospitals database, which compared data from patients with the same age range as ours from January to July 2019 and January to July 2020 [7]. The study found the same age-related pattern, with larger declines in males and younger ages, and without significant differences in people aged ≥90 years. Other studies based upon small samples from single or various hospitals have shown conflicting results with either a reduction [2–6] or stability of HF numbers [8–11, 36]. In Spain, single-center studies have described a marked reduction in the incidence of HF during the first 2 months of lockdown in Madrid [4], Córdoba [2], and Tenerife [16]. In contrast, a Valencian single-center study found a 58.8% reduction in overall fractures, with a decline in upper and lower limb fractures but not in vertebral fractures and HF, which remained unchanged [36]. These differences may be explained by the different age groups, sources of information and periods analyzed and differences in the intensity of the lockdown measures adopted in each

Fig. 2 Daily average number of distal forearm, humerus, vertebral, and pelvic fractures in Catalonia during four different periods of the year. Comparison between 2018–2019 and 2020
Table 3  Overall and COVID-19 related deaths and 30-day mortality rate/100 in people with MOF during different periods of the year by sex, age groups, and AMG

| Period                     | Population | Fractures | Deaths | Mortality rate | RR  | LCI | UCI | p     |
|----------------------------|------------|-----------|--------|----------------|-----|-----|-----|-------|
|                            |            | 2018–2019 | 2020   | 2018–2019/100  | 2020/100 |     |     |      |
|                            | Overall    | 12,017   | 6530   | 491           | 287 | 33  |     | 4.09  |
|                            | COVID-19   |          |        | 4.40          | 1.08 | 0.93 | 1.24 | NS    |
|                            | Sex        |          |        |               |     |     |     |       |
|                            | Men        | 9036     | 4880   | 312           | 154 | 20  |     | 3.45  |
|                            |            |          |        |               |     |     |     | 3.16  |
|                            | Women      | 2981     | 1650   | 179           | 133 | 13  |     | 6.00  |
|                            |            |          |        |               |     |     |     | 8.06  |
|                            | Age groups (years) | | | | | | | |
|                            | 50–59      | 1188     | 684    | 10            | 3   | 1   |     | 0.84  |
|                            |            |          |        |               |     |     |     | 0.44  |
|                            | 60–69      | 1841     | 1063   | 20            | 5   | 0   |     | 1.09  |
|                            |            |          |        |               |     |     |     | 0.47  |
|                            | 70–79      | 2792     | 1663   | 40            | 25  | 5   |     | 1.43  |
|                            |            |          |        |               |     |     |     | 1.50  |
|                            | 80–89      | 4378     | 2204   | 218           | 125 | 14  |     | 4.98  |
|                            |            |          |        |               |     |     |     | 5.67  |
|                            | > 89       | 1818     | 916    | 203           | 129 | 13  |     | 11.17 |
|                            |            |          |        |               |     |     |     | 14.08 |
|                            | AMG        |          |        |               |     |     |     |       |
|                            | Baseline risk | 289   | 137    | 0             | 1   | 0   |     | 0.00  |
|                            | Low risk   | 1645     | 779    | 16            | 8   | 0   |     | 0.97  |
|                            | Moderate risk | 5250  | 2676   | 133           | 56  | 8   |     | 2.53  |
|                            | High risk  | 4833     | 2938   | 342           | 222 | 25  |     | 7.08  |
|                            |            |          |        |               |     |     |     | 7.56  |
|                            | March 15 to April 28 (lockdown) | | | | | | | |
|                            | Overall    | 7482     | 2114   | 277           | 201 | 115 |     | 3.70  |
|                            | COVID-19   |          |        | 9.51          | 2.57 | 2.14 | 3.08 | <0.001|
|                            | Sex        |          |        |               |     |     |     |       |
|                            | Men        | 5667     | 1597   | 177           | 131 | 72  |     | 3.12  |
|                            |            |          |        |               |     |     |     | 8.20  |
|                            | Women      | 1815     | 517    | 100           | 70  | 43  |     | 5.51  |
|                            |            |          |        |               |     |     |     | 13.54 |
|                            | Age groups (years) | | | | | | | |
|                            | 50–59      | 717      | 164    | 2             | 3   | 3   |     | 0.28  |
|                            |            |          |        |               |     |     |     | 1.83  |
|                            | 60–69      | 1141     | 258    | 7             | 2   | 0   |     | 0.61  |
|                            |            |          |        |               |     |     |     | 0.78  |
|                            | 70–79      | 1759     | 457    | 32            | 21  | 17  |     | 1.82  |
|                            |            |          |        |               |     |     |     | 4.60  |
|                            | 80–89      | 2758     | 811    | 121           | 102 | 64  |     | 4.39  |
|                            |            |          |        |               |     |     |     | 12.58 |
|                            | > 89       | 1107     | 424    | 115           | 73  | 31  |     | 10.39 |
|                            |            |          |        |               |     |     |     | 17.22 |
|                            | AMG        |          |        |               |     |     |     |       |
|                            | Baseline risk | 164   | 22     | 0             | 0   | 0   |     | 0.00  |
|                            | Low risk   | 972      | 189    | 8             | 3   | 2   |     | 0.82  |
|                            | Moderate risk | 3278  | 783    | 70            | 49  | 29  |     | 2.14  |
|                            | High risk  | 3068     | 1120   | 199           | 149 | 84  |     | 6.49  |

Note: NS = Not Significant
| Period                  | Population | Fractures | Deaths | Mortality rate | RR   | LCI   | UCI   | p       |
|------------------------|------------|-----------|--------|----------------|------|-------|-------|---------|
|                        |            | 2018–2019 | 2020  | Overall        | COVID-19 |       |       |        |
| April 29 to June 21 (DC) | Overall    | 8808      | 3905  | 283            | 167  | 11    | 3.21  | 4.28    | 1.33  | 1.10  | 1.61  | 0.003 |
|                        | Sex        |           |        |                |       |       |       |         |       |       |       |       |
|                        | Men        | 6692      | 3003  | 173            | 108  | 7     | 2.59  | 3.60    | 1.39  | 1.09  | 1.77  | 0.007 |
|                        | Women      | 2116      | 902   | 110            | 59   | 4     | 5.20  | 6.54    | 1.26  | 0.92  | 1.73  | NS    |
|                        | Age groups (years) |       |        |                |       |       |       |         |       |       |       |       |
|                        | 50–59      | 895       | 387   | 3              | 1    | 0     | 0.34  | 0.26    | 0.77  | 0.08  | 7.41  | NS    |
|                        | 60–69      | 1401      | 620   | 16             | 6    | 0     | 1.14  | 0.97    | 0.85  | 0.33  | 2.17  | NS    |
|                        | 70–79      | 2163      | 958   | 21             | 12   | 2     | 0.97  | 1.25    | 1.29  | 0.63  | 2.62  | NS    |
|                        | 80–89      | 3204      | 1364  | 136            | 66   | 4     | 4.24  | 4.84    | 1.14  | 0.85  | 1.53  | NS    |
|                        | > 89       | 1145      | 576   | 107            | 82   | 5     | 9.34  | 14.24   | 1.52  | 1.14  | 2.03  | 0.004 |
|                        | AMG        |           |        |                |       |       |       |         |       |       |       |       |
|                        | Baseline risk | 205      | 73    | 0              | 0    | 0     | 0.61  | 0.48    | 0.77  | 0.16  | 3.72  | NS    |
|                        | Low risk   | 1140      | 421   | 7              | 2    | 0     | 0.61  | 0.48    | 0.77  | 0.16  | 3.72  | NS    |
|                        | Moderate risk | 3846     | 1607  | 75             | 43   | 2     | 1.95  | 2.68    | 1.37  | 0.94  | 2.00  | NS    |
|                        | High risk  | 3617      | 1804  | 201            | 122  | 9     | 5.56  | 6.76    | 1.22  | 0.97  | 1.52  | NS    |
### Table 3 (continued)

| Period            | Population | Fractures | Deaths | Mortality rate 2020/100 | RR LCI UCI | p  |
|-------------------|------------|-----------|--------|-------------------------|------------|----|
|                   |            | 2018–2019 | 2020   |                         |            |    |
|                   | Overall    | 32,675    | 12,881 | 1183                    | 524        | 57 | 3.62 | 4.07 | 1.12 | 1.01 | 1.25 | 0.026 |
|                   | COVID-19   |           |        |                         |            |    |
| Sex               |            |           |        |                         |            |    |
| Men               |            | 25,060    | 9812   | 698                     | 330        | 26 | 2.79 | 3.36 | 1.21 | 1.06 | 1.38 | 0.005 |
| Women             |            | 7615      | 3069   | 485                     | 194        | 31 | 6.37 | 6.32 | 0.99 | 0.84 | 1.17 | NS    |
| Age groups (years)|            |           |        |                         |            |    |
| 50–59             |            | 3451      | 1362   | 18                      | 7          | 1  | 0.52 | 0.51 | 0.99 | 0.41 | 2.36 | NS    |
| 60–69             |            | 5116      | 2203   | 31                      | 13         | 0  | 0.61 | 0.59 | 0.97 | 0.51 | 1.86 | NS    |
| 70–79             |            | 7885      | 3204   | 116                     | 57         | 9  | 1.47 | 1.78 | 1.21 | 0.88 | 1.66 | NS    |
| 80–89             |            | 11,650    | 4284   | 544                     | 217        | 19 | 4.67 | 5.07 | 1.08 | 0.93 | 1.27 | NS    |
| > 89              |            | 4573      | 1828   | 474                     | 230        | 28 | 10.37| 12.58| 1.21 | 1.04 | 1.42 | 0.016 |
| AMG               |            |           |        |                         |            |    |
| Baseline risk     |            | 745       | 262    | 0                       | 1          | 0  |      |      |      |      |      |      |
| Low risk          |            | 4164      | 1600   | 29                      | 7          | 0  | 0.70 | 0.44 | 0.63 | 0.28 | 1.43 | NS    |
| Moderate risk     |            | 14,040    | 5241   | 289                     | 122        | 13 | 2.06 | 2.33 | 1.13 | 0.92 | 1.40 | NS    |
| High risk         |            | 13,726    | 5778   | 865                     | 394        | 44 | 6.30 | 6.82 | 1.08 | 0.96 | 1.22 | NS    |

Pre-C pre-confinement, DC deconfinement, Post-C post-confinement, RR rate ratio, LCI lower confidence interval, UCI upper confidence interval, AMG Adjusted Morbidity Groups. “p” value refers to the RR and indicates the mortality rate difference in each period in 2020 compared with 2018–2019.
country. Consistent with our results, a single-center Israeli study found an age-dependent decrease in HF during March and April 2020 compared with 2019, without any difference in nonagenarians. As for overall fractures, the decrease in HF cannot be fully explained by the increase in mortality. Forearm and humerus fractures showed a nearly 50% reduction compared with previous years. A single-center Polish study showed a similar decrease in arm fractures (45.8%) and HF (13.4%) but a smaller reduction in forearm fractures (18.4%) during 77 days of lockdown [12]. Another study that focused on proximal humerus fractures in three Italian hospitals during the first 10 weeks of national lockdown found a 37.5% decrease compared with 2019, which was especially related to a fall in accidents on the road and at work [15]. The results for vertebral and pelvic fractures are somewhat surprising. We found a reduction of 54% in pelvic fractures and 70% in VF during the spread of the pandemic. Few studies have analyzed these types of fracture. A two-center study in Spain during a similar period of time (March 15 to May 15, 2020) found no differences in the incidence of vertebral fractures compared with the previous 2 years, although the number of fractures attended was small [36]. Vertebral fractures have been reported to occur mainly indoors and are less related to falls than hip and other fragility fractures [35]. Consequently, the incidence would be expected to be less affected by lockdown. Vertebral fractures may be associated with different degrees of pain and even be symptomless. Most radiological fractures have not been clinically diagnosed [37]. However, people with an incident radiographic vertebral fracture without a clinical diagnosis have shown a greater risk of back pain compared with those without [38]. Although there was no explicit prohibition on consulting the emergency room or primary care, it is likely that the difficulty in contacting the health system and the fear of contracting COVID-19 may have increased the number of people with mild pain related to incident vertebral fracture who decided to stay at home, thus increasing the number of clinically unrecognized fractures. Reinforcing this hypothesis, the diagnosis of other diseases also fell during the first pandemic months. For example, new diagnoses of cancer fell by 45% in Catalonia during lockdown in a primary care-based time-series [39]. In addition, a mean fall of 38% in stroke diagnoses was reported in a prospective observational cohort single-center study in New Jersey during the first 6 weeks of 2020. The decline was not seen in patients with cortical signs suggesting large vessel occlusion, so the

Table 4 Overall and COVID-19 related deaths and 30-day mortality rate/100 in people with MOF by fracture site in different periods of 2018–2019 and 2020

| Type of fracture | Period | Fractures Pre-C 2018–2019 | Deaths Pre-C 2018–2019 | Mortality rate/100 Pre-C 2018–2019 | RR | LCI | UCI | p |
|-----------------|-------|--------------------------|------------------------|----------------------------------|----|-----|-----|----|
| Hip             |       |                          |                        |                                  |    |     |     |    |
|                 | Early | 3700                     | 1842                   | 310                              | 178 | 22  | 8.38 | 9.66 | 1.15 | 0.96 | 1.39 | NS  |
|                 | Lockdown | 2177                   | 944                    | 164                              | 147 | 86  | 7.53 | 15.57 | 2.07 | 1.65 | 2.58 | <0.001 |
|                 | DC    | 2413                     | 1226                   | 177                              | 110 | 6   | 7.34 | 8.97 | 1.22 | 0.96 | 1.55 | NS  |
|                 | Post-C | 9550                    | 3782                   | 768                              | 352 | 40  | 8.04 | 9.31 | 1.16 | 1.02 | 1.31 | 0.023 |
| Distal forearm  | Pre-C | 2307                     | 1293                   | 17                               | 17  | 2   | 0.74 | 1.31 | 1.78 | 0.91 | 3.49 | NS  |
|                 | Lockdown | 1397                   | 376                    | 11                               | 7   | 4   | 0.79 | 1.86 | 2.36 | 0.92 | 6.1  | NS  |
|                 | DC    | 1789                     | 859                    | 12                               | 7   | 2   | 0.67 | 0.81 | 1.21 | 0.48 | 3.09 | NS  |
|                 | Post-C | 7201                    | 2790                   | 31                               | 22  | 2   | 0.43 | 0.79 | 1.83 | 1.06 | 3.16 | 0.03 |
| Humerus         | Pre-C | 1692                     | 987                    | 29                               | 18  | 3   | 1.71 | 1.82 | 1.06 | 0.59 | 1.92 | NS  |
|                 | Lockdown | 981                    | 258                    | 24                               | 13  | 9   | 2.45 | 5.04 | 2.06 | 1.05 | 4.04 | 0.036 |
|                 | DC    | 1135                     | 567                    | 16                               | 13  | 0   | 1.41 | 2.29 | 1.63 | 0.78 | 3.38 | NS  |
| Pelvis          | Pre-C | 1898                     | 1000                   | 78                               | 43  | 4   | 4.11 | 4.3  | 1.05 | 0.72 | 1.52 | NS  |
|                 | Lockdown | 1237                   | 285                    | 44                               | 24  | 11  | 3.56 | 8.42 | 2.37 | 1.44 | 3.89 | 0.001 |
|                 | DC    | 1482                     | 546                    | 51                               | 26  | 2   | 3.44 | 4.76 | 1.38 | 0.86 | 2.22 | NS  |
|                 | Post-C | 5052                    | 1882                   | 171                              | 66  | 8   | 3.38 | 3.51 | 1.04 | 0.78 | 1.38 | NS  |
| Vertebrae       | Pre-C | 2420                     | 1408                   | 57                               | 31  | 2   | 2.36 | 2.2  | 0.93 | 0.6  | 1.45 | NS  |
|                 | Lockdown | 1690                   | 251                    | 34                               | 10  | 5   | 2.01 | 3.98 | 1.98 | 0.98 | 4.01 | NS  |
|                 | DC    | 1989                     | 707                    | 27                               | 11  | 1   | 1.36 | 1.56 | 1.15 | 0.57 | 2.31 | NS  |
|                 | Post-C | 6558                    | 2718                   | 114                              | 53  | 3   | 1.74 | 1.95 | 1.12 | 0.81 | 1.55 | NS  |
authors hypothesized that patients with milder stroke symptoms could have avoided seeking care [40]. Other reports have shown similar results in stroke and other cardiovascular events. Pelvic fractures commonly occur in traffic crashes in younger patients and after a fall in older patients. While the former might have decreased in relation to limited mobility, we hypothesized that some minor pelvic fractures might have gone undiagnosed, as occurred with vertebral fractures.

Studies have described the epidemiology of MOF during lockdown but, to our knowledge, none has investigated beyond that period. The COVID-19 pandemic had a huge impact on the health system, affecting the care of patients with osteoporosis [41]. In addition, other consequences of lockdown, such as reduced physical activity [42], could have increased the risk of falls. Therefore, an increase in the incidence of fractures after lockdown was feared. However, the incidence of MOF tended to grow but remained at significantly lower values than in 2018–2019 in the period of gradual DC and the months that followed. Despite most restrictions being lifted in late June, normal mobility was not restored for the rest of 2020 as stay-at-home advice continued. Cumulative excess mortality in the elderly contributed partially to this lower rate. However, the possible harmful effects of poor management of osteoporosis appearing in the long term cannot be ruled out. Therefore, a strict follow-up of the evolution of cases will be necessary.

MOF-related mortality

Mortality after fracture increased in 2020, especially during lockdown, when there was a more than 2.5-fold increase and this was directly related to COVID-19, as mortality in patients with COVID-19 infection and HF was high [43]. If COVID-19-related deaths were excluded, the 2018–2019 aggregated data and 2020 would be quite similar. The median age of people with MOF in 2020 was older than in 2018–2019, and this could have contributed to increased mortality. Hospital mortality due to acute coronary syndrome and acute heart failure also increased during the first pandemic wave in Catalonia, although the comorbidity index of patients admitted in 2020 was lower than in the same period in 2019 [44].

The study had some limitations; some related to the case-seeking strategy have been previously described [18]. The comparison of incidence rates between 2020 and the previous 2 years could have been affected by the lack of standardization by age, although the short time analyzed suggests a small impact on the age distribution. Regarding the influence of excess mortality on the incidence of MOF, the expected number of fractures that people who died might have sustained was calculated as if all deaths had occurred at the beginning of each period, which might have led to an overestimate. However, this downgrades the potential competing risk effect of COVID-19 mortality in reducing fracture rates. Finally, the CHSS registry only collects information from the public health system. During confinement there may have been variations in the number of cases attended in the public and private health systems. In any case, the Catalan population has a very high rate of care in the public health system, which is universal and free. For example, 88% of hip fractures were treated in the public health system in 2017. In addition, any hospital admission transferred from a public center to a private one is also registered in the CHSS. As strengths, the study gathered information from hospitalizations, emergency room discharges, and primary care registers of the entire population and analyses focused on the epidemics of overall and each single MOF throughout 2020, including the Post-C period.

In conclusion, the COVID-19 pandemic reduced the incidence of MOF overall and each type individually with different intensity. This effect was seen especially during lockdown but was subsequently maintained with less strength during 2020. Older people and HF were less affected by this phenomenon. Post-fracture mortality increased significantly, in direct relation to the lethality of the virus in older people. As the pandemic has worsened the clinical management of osteoporosis, the long-term effect on the incidence of MOF will require close monitoring in the future.

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Data availability The data underlying this article are available in the article and in its online supplementary material. Other complementary data will be shared on reasonable request to the corresponding author.

Declarations

Conflicts of interest None.

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