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Underreporting of Cases in the COVID-19 Outbreak of Borriana (Spain) during Mass Gathering Events in March 2020: A Cross-sectional Study

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Abstract: Knowing the number of cases of an epidemic is the first function of epidemiological surveillance. An important underreporting of cases was observed in many places during the first wave of COVID-19 pandemic. To estimate this underreporting in the COVID-19 outbreak of Borriana (Valencia Community, Spain), during "Falles" mass gathering events in March 2020, a cross-sectional study was performed in June 2020 querying public health register. Logistic regression models were used. From a total of 468 symptomatic COVID-19 cases diagnosed in the outbreak by anti-SARS-CoV-2 serology, 36 cases were reported (7.7%), thus an underreporting of 92.3% (95% Confidence Interval [CI] 89.5%-94.6%), 13 unreported cases for every reported case. Only positive SARS-CoV-2 polymerase chain reaction cases were predominantly reported due to a limited testing capacity and following a national protocol. Significant factors associated with underreporting were no medical assistance for COVID-19 disease, adjusted odds ratio [aOR] 10.83 (95% CI 2.49-47.11), no chronic illness, aOR=2.81 (95% CI 1.28-6.17), middle and lower social classes, aOR=3.12 (95% CI 1.42-6.85), younger age, aOR=0.97 (95% CI 0.94-0.99), shorter duration of illness, aOR=0.98 (95% CI 0.97-0.99). To improve surveillance, studies of representative population samples are necessary to estimate the magnitude of future epidemics, and novel approaches are recommended.

Keywords: COVID-19; SARS-CoV-2; underreporting; cross-sectional; epidemiological surveillance; factors

1. Introduction

Knowing the number of cases of an epidemic is the first and crucial function of epidemiological surveillance meaning an accurate reporting of cases to public health authorities to take adequate measures to tackle an epidemic: “information is for action” [1,2].To measure the magnitude of the pandemic and their evolution, a typical surveillance of the COVID-19 pandemic was initially based on the reporting of cases, hospitalizations, mortality, and case-fatality. However, during the first wave of the COVID-19 pandemic, a substantial underreporting of cases and deaths was observed in many places with extensive variations [3–7].

This underreporting, considering underestimation for some authors [8], included under-ascertainment at community-level and underreporting at health care level, depended on multiple factors such as proportion of mild and asymptomatic cases, public health and healthcare system, demographic characteristics, socio-economic development and political systems [9–11].

Different methods to estimate underreporting of COVID-19 cases and deaths have been used, including case-fatality and mortality rates, hospitalization rates, syndromic surveillance, mathematical models from reported cases, SARS-CoV-2 screening surveys, seroprevalence surveys and online open surveys [12–19].COVID-19 seroprevalence surveys are based on the determination of anti-SARS-CoV-2 antibodies and can measure symptomatic and asymptomatic cases in large population samples [20–23]. In addition, it is of special interest in preparedness to future epidemics to adopt specific measures to know the causes and factors associated with the underreporting during the first wave of the COVID-19 pandemic.

In this context, the COVID-19 outbreak associated with the mass gathering events (MGEs) of Falles Festival in Borriana, Valencia Community (Spain), occurred between 6 and 10 March 2020 before lockdown took place. During May and June 2020, a population-based retrospective cohort study of a representative sample of exposed population, the Borriana COVID-19 cohort, was carried out to estimate the incidence of COVID-19 and its association with these MGEs, and a seroprevalence survey of anti-SARS-CoV-2 antibodies was performed [24].

Considering that few seroprevalence surveys on the community level have been made during the first wave of the COVID-19 pandemic and its usefulness for prepared of future epidemic, the objective of this study was to estimate the reported COVID-19 cases by the health authorities in the Borriana outbreak in March 2020, and those factors associated with the underreporting.

2. Materials and Methods

2.1. Study Cross-Sectional

A population-based cross-sectional study was designed, and was implemented by the Public Health Center of Castellon and the Hospital de la Plana in Vila-real, Valencia Community (Spain). The study population was the Borriana COVID-19 cohort, and detailed information of this cohort has been described by Domènech and co-authors [24]. The study took place from January to June 2020 and 536 laboratory-confirmed COVID-19 cases through seroprevalence survey with anti-SARS-CoV-2 IgM/IgG Nucleocapsid antibodies were diagnosed. Asymptomatic cases were excluded. The laboratory technique used was a qualitative detection of antibodies against SARS-CoV-2 by an electrochemiluminescence immunoassay (ECLIA) (Elecsys® Anti-SARS-CoV-2, Roche Diagnostics) in the Clinical Analysis and Microbiology Service of the Hospital de la Plana [25]. In addition, a telephone survey to obtain information about demographic characteristics, occupations, lifestyles, chronic illnesses, symptoms of the COVID-19 disease, illness duration and received medical assistance for COVID-19 disease was performed by the health staff of Public Health Center, Emergency Service of Hospital de la Plana, and the Health Centers of Borriana, Vila-real, Onda and La Vall d’Uixò all them located at the Health Department of la Plana in Vila-real, Castellon.

To obtain the reported COVID-19 cases, official register of notification COVID-19 cases at the Public Health Center of Castellon was queried, including the informatics application of epidemiological surveillance analysis (AVE), considering the period January-June Following a national protocol, patients with suspected SARS-CoV-2 infection were confirmed by a positive SARS-

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CoV-2 polymerase chain reaction (PCR) test or other adequate molecular test, and being those confirmed cases, most of our reported cases [26,27]. PCR tests COVID-19 cases were performed at Microbiology Service of the Hospital de la Plana by multiple techniques and manufacturers due to the shortage of tests and material at that time.

2.2. Statistical Analysis

To describe the characteristic of the study population, we calculated percentages, means and standard deviations. Comparisons of variables between reported and underreported COVID-19 cases were made by Chi2 and Fisher exact tests for qualitative variables and Kruskal-Wallis for quantitative variables.

We defined underreported COVID-19 cases as dependent variable and a predictive variable was has received medical assistance for COVID-19 disease. Independent variables were age, sex, chronic illnesses, COVID-19 illness duration in days, occupation as social class to upper class (group I higher managerial and professional occupations) versus middle and lower social classes (groups II –VI intermediate and skilled non-manual and manual occupations) [28], and lifestyles, including body mass index (kg/m^2), smoking habit, alcohol intake, habitual physical exercise and following a nutritional diet. Logistic regression models were applied to study the associations between underreporting COVID-19 cases and predictive and independent variables by odds ratio (OR) with a 95% Confidence Interval (CI). To control potential confounder factors a study of medical literature was addressed, and Directed Acyclic Graphics (DAGs) were employed [29]. Figure 1 describes the relations between the exposure (COVID-19 medical assistance), ancestors of exposure, and the outcome (COVID-19 reported). Statistical program Stata® 14 version 2 was used for all the calculation.

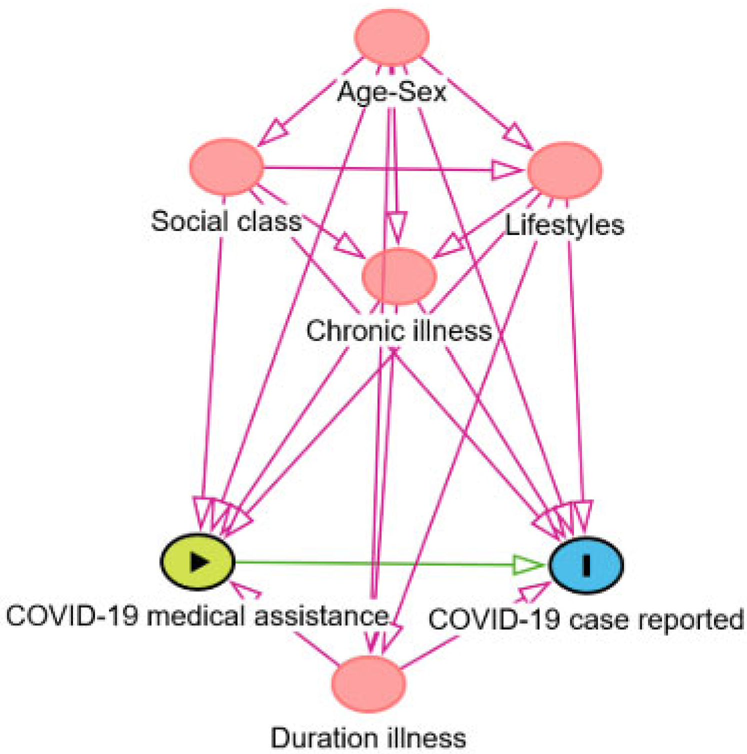

Figure 1. Directed Acyclic Graphs (DAGs) of COVID-19 medical assistance (exposure) effect on reported COVID-19 case (outcome).Ancestors of exposure (in red) and outcome (in blue). Based on DAGitty version 3.1.

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The study had the approval of the director of the Public Health Center of Castellon and the management of the Health Department of La Plana, where the COVID-19 outbreak took place. On the other hand, this study was exempt from the Ethics Review Board approval´s protocol following the Spanish legislation as part of the public health surveillance of the COVID-19 pandemic.

3. Results

Of a total 536 laboratory-confirmed symptomatic COVID-19 cases in the outbreak, 67 asymptomatic cases were excluded, and one case showed missing information. As a result of this, 468 cases were included in the study (99.8%). Only 36 (7.7%) cases were reported as COVID-19 cases by Public Health Center, thus case underreporting was 92.3% (95% CI 89.5%-94.6%), 13 unreported cases for every reported case. 34 cases (94.4%) were confirmed by PCR tests, and 2 cases were confirmed through anti-SARS-CoV-2 antibody serology. All the unreported cases were laboratory confirmed only by anti-SARS-CoV-2 antibody serology.

Characteristics of reported and unreported COVID-19 cases are shown in Table 1 Unreported cases were younger than reported cases (p=0.001), a higher proportion without medical assistance for COVID-19 disease, 54.6% versus 5.6% (p=0.000), and shorter illness duration, 10.5±14.9 days versus 24.2±21.9 (p=0.000). Not having a chronic illness was higher in the unreported cases 68.3% versus 38.8% (p=0.001). Middle and lower social classes were predominant in the unreported cases, 87.4% versus 69.4% (p=0.009). Other factors concerning lifestyles such as obesity, smoking, alcohol intake, habitual physical exercise, and following a nutritional diet were not associated with the underreporting.

Table 1. Characteristics of reported and unreported COVID-19 cases in the Borrriana COVID-19 cohort. January-June 2020.

Variables	Reported cases N=36 (%)	Unreported cases N=432 (%)	p-value
Age (years)±SD[1]	45.7±16.4	37.2±16.5	0.001
Male	14 (38.8)	162 (37.5)	0.860
No received medical assistance for COVID-19 disease	2 (5.6)	236 (54.6)	0.000
Duration illness (days)±SD[1,2]	24.2±21.9	10.5±14.9	0.000
No chronic illness[4]	14 (38.8)	295 (68.3)	0.001
Middle and lower social classes[5,6]	25 (69.4)	375 (87.4)	0.009
Body mass index (kg/m^2)±SD[1,7]	26.4±5.8	25.0±5.0	0.183
Obesity ≥30 kg/m^2±SD[1,8]	10 (27.8)	69 (16.1)	0.102
Current smoker[9]	3 (8.3)	64 (15.3)	0.333
Alcohol intake yes[10]	11 (30.6)	100 (23.8)	0.417
Habitual physical exercise yes	17 (47.2)	256 (59.3)	0.164
Nutritional diet yes[11]	10 (27.8)	75 (17.4)	0.121

[1] Standard deviation.[2] Missing answer from 48 participants.[3] Missing answer from 5 participants.[4] Missing answer from 4 participants.[5] Higher managerial and professional occupations (group I).[6] Missing answer from 3 participants.[7] Missing answer from 4 participants.[8] Missing answer from 4 participants.[9] Missing answer from 13 participants.[10] Missing answer from 11 participants.[11] Missing answer from 1 participant.

Crude and adjusted logistic regression analysis of factors associated with underreporting is shown in Table 2 Significant factors associated with underreporting were younger age (aOR=0.97 95% CI 0.94-0.99), no medical assistance for COVID-19 disease (aOR=10.83 95% CI 2.49-47.11), shorter durationn illness in days (aOR=0.98 95% CI 0.97-0.99), and not having a chronic illness (aOR=2.81 95%

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CI 1.28-6.17). In addition, middle and lower social classes were significantly more related to underreporting versus higher class (aOR=3.12 95% CI 1.42-6.85). Lifestyle factors were not significantly associated with underreporting COVID-19 cases.

Table 2. Factors associated with unreported COVID-19 cases in the Borriana COVID-19 cohort by logistic regression. Crude and adjusted odds ratio (OR) and (aOR). 95% Confidence Interval (CI).

Variable	OR	95% CI	aOR	95% CI	p-value
Age (years)[1]	0.97	0.95-0.99	0.97	0.94-0.99	0.003
Male[2]	0.94	0.47-1.89	1.16	0.94-2.35	0.690
No medical assistance for COVID-19 disease[3]	17.6	4.86-86.30	10.83	2.49-47.11	0.001
Duration illness (days)[4]	0.98	0.96-0.99	0.98	0.97-0.99	0.037
No chronic illness[5]	3.34	1.66-6.72	2.81	1.28-6.17	0.010
Middle and lower social classes,[6]	3.06	1.42-6.56	3.12	1.42-6.85	0.005
Body mass index (kg/m^2)[7]	0.94	0.88-1.01	0.98	0.91-1.06	0.651
Obesity ≥30 kg/m^2 [7]	0.50	0.33-1.08	0.64	0.28-1.47	0.294
Current smoker[8]	1.98	0.59-6.67	2.14	0.62-7.41	0.228
Alcohol intake yes[9]	0.70	0.34-1.49	0.59	0.26-1.33	0.203
Habitual physical exercise[10] yes	1.63	0.2-3.21	1.91	0.91-4.00	0.085
Nutritional diet yes[11]	0.55	0.25-1.18	0.65	0.29-1.48	0.307

[1] Adjusted for sex.[2] Adjusted for age.[3] Adjusted for age, sex, social class, chronic illness, illness duration.[4] Adjusted for age, sex, chronic illness, smoking, alcohol intake, physical exercise, nutritional diet, body mass index.[5] Adjusted for age, sex, social class, smoking, alcohol intake, physical exercise, nutritional diet, body mass index.[6] Adjusted for age, sex.[7] Adjusted for age, sex, social class, smoking, alcohol intake, physical exercise, nutritional diet.[8] Adjusted for age, sex, social class, alcohol intake, physical exercise, nutritional diet, body mass index.[9] Adjusted for age, sex, social class, smoking, physical exercise, nutritional diet, body mass index.[10] Adjusted for age, sex, social class, smoking, alcohol intake, nutritional diet, body mass index [11] Adjusted for age, sex, social class, smoking, alcohol intake, physical exercise, body mass index. .

4. Discussion

Our results suggest that the underreporting of symptomatic COVID-19 cases in the Borriana COVID-19 cohort was very high during the first wave of COVID-19 pandemic. Factors associated with this underreporting of cases were younger age, no medical assistance for COVID-19 disease, shorter illness duration, not suffering from a chronic illness, and belonging to middle and lower social classes.

This COVID-19 outbreak took place during mass gathering events with a massive exposition of SARS-CoV-2, and an attack rate of 39.2%. [24].This exposition occurred between 6 and 10 March, five days before the lockdown was enforced. A higher proportion of cases had a milder illness, the medical assistance was limited, and cases were not reported to epidemiological surveillance in line with a Spanish official publication of the first wave COVID-19 pandemic [27]. This type of COVID-19 outbreak may illustrate how the COVID-19 epidemic spread in some places, and mass gathering events of last February and early March could have played an important role in Spain and in other countries [30–35].

Estimations of underreporting of cases and deaths presented important geographic variations, but this underreporting was very elevated during the first wave of the COVID-19 pandemic in most countries [4,36–39]. In seroprevalence studies, different methodologies and analytic techniques have been employed to estimate the dimensions of the COVID-19 pandemic and the proportion of asymptomatic cases [23,40].Considering some population-based seroprevalence surveys with detection anti-SARS-CoV-2 antibodies, the number of unreported cases for every reported COVID-19 case presented considerable differences: 2.8 cases in Santiago de Chile [41] 4 cases in Munich [42], 5 cases in Ethiopia [43], 6.5 cases in the United States [20], 8.9 cases in Finland, [44], 11.6 cases in Geneva [21], and 25.5 cases in Eswatini, Southern Africa [45]. Our results are consistent with the study of Sierra and co-authors [46], where the sensitivity of Spanish surveillance system was 9.7% (95% CI 8.96-10.29) with 13 unreported cases for every reported case following the national seroprevalence survey of Pollan and coauthors [22].

We can address some caused in Spain, responsible for the low reporting considering an unprecedented situation with a new disease and the countrywide lockdown. The causes may include the high proportion of milder and asymptomatic infections, an insufficient following of infected cases and contacts, restrictions and barriers for medical care access, limited capacity of SARS-CoV-2 laboratory testing, prioritization of medical assistance and laboratory SARS-CoV-2 PCR testing for patients with severe illness, predominant reported COVID-19 cases with positivity SARS-CoV-2 PCR, restriction in population mobility, and social isolation in a context of subordinate public health [4,11,27,47]. This underreporting could be associated with a delay of the health authorities to carry out mitigation strategies [48]. An official government document [49] indicated that the Spanish system of health was not sufficiently prepared for the COVID-19 pandemic, not having stock of material necessary to tackle a pandemic respiratory virus, the weakness of information systems and the insufficient diagnostic recourses. In addition, the healthcare system was overwhelmed and critical services were saturated during this first wave [27].

Factors associated with underreporting such as, no medical assistance for COVID-19 disease, younger age without a chronic illness, and shorter illness duration suggest a milder illness and few severe cases; which aligns with other studies[42,45,50]. In addition, patients belonging to middle and lower social classes were more underreported than upper class cases suggesting better access to healthcare to the latter. Less reporting of COVID-19 cases in manual occupations as waiter or taxi-has been observed in Norway [51]. Lifestyle factors were not associated with underreporting, but in some studies, obesity was associated with higher possibility to be tested and to be COVID-19 positive [52].

Our study presents some strengths and limitations. As strengths, we include that the Borriana COVID-19 cohort was a representative sample of the population exposed to SARS-CoV-2 during the Falles Festival with a high participation. This study was carried out during May-June 2022 in the first wave of the epidemic, and control of potential confounding factors was done by logistic regression models, sensitivity and specificity of the technique for Anti-SARS-CoV-2 antibodies were elevated, and asymptomatic COVID-19 cases were excluded in the estimation. Our proportion of asymptomatic cases was low, 12%, compared with reviews and meta-analysis studies [53]. As limitations, we include that the underreporting was studied during a COVID-19 outbreak, this is an unusual situation, and considering the elapsed time between the exposition and the start of the study, some recall and misclassification biases could be occurring. On the other hand, anti-SARS-CoV-2 antibodies decline over time. However, the study was implemented three months after the mass gathering events, and a 99% of anti-SARS-CoV-2 antibody persistence was found in a new study of this cohort in October 2020 [54].

In the public health arena many voices have indicated the necessity of a change in order to improve the surveillance of infectious diseases [46,55–58], and a critical review of the surveillance methods was performed in England [59]. In addition, considering that the possibility of future epidemics is not remote, novel approaches to surveillance used during the COVID-19 pandemic are recommended. Five areas could be contemplated. First, community approach with continued studies of representative population samples and household survey, including studies of incidence of infectious diseases and serological surveys, attendance to emergency departments, hospitalizations, primary health care, syndromic surveillance and high risk groups determination [59–61].Secondly, digital surveillance which experimented a high developing during the COVID-19 pandemic [62], including online self-reported population survey or digital apps[63], population-based surveillance application [64], mobile apps with different uses such as risk assessment and contact tracing [65,66], and big data and infodemiology to obtain useful public health information [67]. Thirdly, mathematical models to estimate the true dimensions of epidemics, including the asymptomatic infections with appliance of artificial intelligence, could be useful to complete the traditional epidemiological [68,69]. Some practical approaches are being implemented as a new surveillance index [70], and calculated refined reproduction number [71]. Fourthly, wastewater surveillance with determining the presence of SARS-CoV-2 in sewage system has had a considerable development considering its use in epidemic detection [72,73]. And lastly, an area of particular interest is Genomic surveillance that permits to detect new viral variants to make valuable use against SARS-CoV-2 in household transmission, outbreaks detections and national variants surveillance [74–78]. In addition, cycle threshold of SARS-CoV-2 RNA PCR results could be useful to forecast COVID-19 epidemics [79].

5. Conclusions

During the first wave of COVID-19 pandemic, the underreporting of COVID-19 cases was very high, indicating insufficient preparedness for large epidemics. New approaches to epidemiological surveillance are necessary to tackle future epidemics.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki. The study was part of the epidemiological surveillance of the COVID-19 outbreak in the Falles Festival in Borriana, which was exempted from Ethics Review Board approval's protocol according to the Spanish legislation and regulations, including [80] the General Law of Health, [81] the Law of Cohesion and Quality of the National System of Health, and [82] the Law General of Public Health.

Informed Consent Statement: All participants or the parents of minors provided the informed written consent to be included in the study.
Data Availability Statement: Data of the study can be consulted if the authors are requested.

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Conflicts of Interest: The authors declare no conflicts of interest.

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