

## Estimation of COVID-19 outbreak size in Italy

Italy is currently experiencing an epidemic of COVID-19 which emerged in the Lombardy region.<sup>1</sup> During the interval between Feb 25–29, 2020, we identified 46 cases of COVID-19 reported in 21 countries in Europe, Africa, North America, and South America that were either in individuals with recent travel from Italy, or who had presumed infection by a traveller from Italy.<sup>2</sup> In six cases, in four of the affected countries (Switzerland, France, Austria, and Croatia), land travel was a likely route of introduction, or was documented to have been the route of introduction.<sup>2</sup>

We used air travel volume between Italian cities and cities in other countries as an index of connectedness, using data available from the International Air Transport Association for February, 2015, (2.61 million total departing international air passengers from Italy). We used the methods of Fraser and colleagues<sup>3</sup> to estimate the size of the underlying epidemic in Italy necessary for these cases to be observed with a reasonable probability. To estimate the time at risk of COVID-19 exposure for travellers departing Italy, we obtained data from the United Nations World Tourism Organization for the proportion of international travelers that are non-residents of Italy (63%)<sup>4</sup> and the average length of stay of tourists to Italy (3.4 days),<sup>5</sup> and assumed the Italian epidemic began 1 month preceding Feb 29, 2020.<sup>6</sup>

We also did sensitivity analyses in which we included outbound travel to all countries regardless of reported case importations, inflated travel volumes by 35%, to account for the relative increase in flight numbers from 2015–19, and excluded cases in bordering countries or which were documented to have been introduced by overland travel.

When all cases were considered we estimated a true outbreak size

	Estimate	95% CI	% Unreported*	Unreported range (%)*
All cases	3971	2907–5297	72	61–79
All cases (adjusted to 2019)	2937	2150–3917	62	48–71
Exclude bordering countries and overland travel	4533	3238–6172	75	65–82
Exclude bordering countries and overland travel (adjusted to 2019)	3352	2395–4564	66	53–75
Include travel to all countries	2099	1500–2859	46	25–60
Include travel to all countries (adjusted to 2019)	1552	1109–2114	27	0–47

\*Based on reported case count of 1128.

**Table: Estimated COVID-19 outbreak size, Italy, Feb 29, 2020**

of 3971 cases (95% CI 2907–5297), as compared with a reported case count of 1128 on Feb 29, 2020, suggesting non-identification of 72% (61–79%) of cases. In sensitivity analyses, outbreak sizes varied from 1552 to 4533 cases (implying non-identification of 27–75% of cases; table).

We have previously used similar methods to estimate a much larger epidemic size in Iran, with a far greater degree of under-reporting, based on many fewer exported cases. The reason for this difference relates to the relatively high volume of travel from Italy, relative to Iran.<sup>7</sup> In summary, we suggest that the numerous COVID-19 case exportations from Italy in recent days indicate an epidemic that is larger than official case counts suggest, and which is approximately on a par with that currently occurring in South Korea, which reported 3526 cases (and fewer deaths) as of Feb 29, 2020.<sup>2</sup> Since initial submission of this letter, aggressive case finding efforts combined with ongoing epidemic growth have resulted in a dramatic increase in reported cases in Italy, which as of March 12, 2020, stand at 15 113.<sup>8</sup>

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