Effect of national and local lockdowns on the control of COVID-19 pandemic: a rapid review

Effetto dei lockdown nazionali e locali sul controllo della pandemia da COVID-19: una rapid review

Silvia Caristia,[1] Margherita Ferranti,[2,3] Edlira Skrami,[4] Elena Raffetti,[5] Daniela Pierannunzio,[6] Raffaele Palladino,[7] Flavia Carle,[4] Rodolfo Saracci,[8] Chiara Badaloni,[2] Francesco Barone-Adesi,[1,9] Valeria Belleudi,[2] AIE working group on the evaluation of the effectiveness of lockdowns,* Carla Ancona[2]

[1] Department of Translational Medicine, University Piemonte Orientale, Novara (Italy)
[2] Department of Epidemiology, Lazio Regional Health Service, Local Health Unit 1, Rome (Italy)
[3] Department of Woman and Child Health and Public Health, Public Health Area, University Polyclinic Foundation "A. Gemelli" IRCCS, Rome (Italy)
[4] Centre of Epidemiology and Biostatistics, Università politecnica delle Marche, Ancona (Italy)
[5] Epidemiology and public health intervention research group (EPHIR), Department of Global Public Health, Karolinska Institutet, Solna (Sweden)
[6] National centre of disease prevention and health promotion, Italian National Health Institute, Rome (Italy)
[7] Department of Public Health, ``Federico II'' University, Naples (Italy)
[8] Former President of the International Epidemiological Association
[9] Research Center in Emergency and Disaster Medicine (CRIMEDIM), University Piemonte Orientale, Novara (Italy)
* **AIE working group on the evaluation of the effectiveness of lockdowns:** Carla Ancona, Chiara Badaloni, Francesco Barone-Adesi, Valeria, Belleudi, Silvia Caristia, Flavia Carle, Manuela De Sario, Andrea Faragalli, Luigi Ferrante, Margherita Ferranti, Rosaria Gesuita, Enrica Lapucci, Raffaele Palladino, Daniela Pierannunzio, Elena Raffetti, Rodolfo Saracci, Edlira Skrami, Simona Vecchi.

Corresponding author: Edlira Skrami; e.skrami@staff.univpm.it

WHAT IS ALREADY KNOWN

- **No evidence about effectiveness of lockdown in controlling the spread of COVID-19.**
- **Evidence from past epidemics (SARS, MERS) showed effectiveness of some policies like quarantine and isolation of infected, hand hygiene, personal protective equipment.**

WHAT THIS STUDY ADDS

- **Containment measures had positive effect on the control of spread of COVID-19 pandemic.**
- **Validity of indicators and quality of data collection could limit the comparison among countries.**
- **Future studies are warranted to evaluate which approach is the most effective in each stage of the COVID-19 pandemic and in specific social contexts.**

ABSTRACT

OBJECTIVES: to describe and compare the effectiveness of national and local lockdowns in controlling the spread of COVID-19.

METHODS: a rapid review of published and grey literature on COVID-19 pandemic was conducted following predefined eligibility criteria by searching electronic databases, repositories of pre-print articles, websites and databases of international health, and research related institutions and organisations.

RESULTS: of 584 initially identified records up to 5 July 2020, 19 articles met the inclusion criteria and were included in the review. Most of the studies (No. 11) used the reproduction number (R_t) as a measure of effect and in all of them a reduction of the estimated value at post-intervention period was found. The implementation of lockdown in 11 European countries was associated with an average 82% reduction of R_t, ranging from a posterior R_t of 0.44 (95%CI 0.26-0.61) for Norway to a posterior R_t of 0.82 (95%CI 0.73-0.93) for Belgium. Changes in infection rates and transmission rates were estimated in 8 studies. Daily changes in infection rates ranged from -0.6% (Sweden) to -11.3% (Hubei and Guangdong provinces). Additionally, other studies reported a change in the trend of hospitalizations (Italy, Spain) and positive effects on the doubling time of cases (Hubei, China) after lockdown.

CONCLUSIONS: results of this rapid review suggest a positive effect of the containment measures on the spread of COVID-19 pandemic, with a major effect in countries where lockdown started early and was more restrictive. Rigorous research is warranted to evaluate which approach is the most effective in each stage of the epidemic and in specific social contexts, in particular addressing if these approaches should be implemented on the whole population or target specific risk groups.

Keywords: COVID-19, SARS-CoV-2, containment measures, effectiveness

RIASSUNTO

OBIETTIVO: identificare e descrivere l'effetto dell'introduzione di *lockdown* sulla diffusione del COVID-19.

METODI: è stata condotta una *rapid review* di articoli pubblicati e letteratura grigia, seguendo predefiniti criteri di eleggibilità e consultando *database* elettronici, *repository* di articoli non ancora pubblicati, siti web e *database* di centri di ricerca internazionali sulla salute.

RISULTATI: dei 584 *record* inizialmente identificati fino al 5 luglio 2020, 19 articoli sono stati inclusi nella revisione. Molti studi (No. 11) hanno utilizzato il numero di riproduzione (R_t) come misura d'effetto e, di questi, tutti hanno mostrato una riduzione dell'R_t successivamente all'introduzione di misure di contenimento. L'implementazione di *lockdown* in 11 nazioni europee si è tradotta in una riduzione media dell'82% dell'R_t, con valori posteriori di R_t che variavano da 0.44 (IC95% 0.26-0.61) in Norvegia a 0.82 (IC95% 0.73-0.93) in Belgio. Otto studi hanno valutato i cambiamenti dei tassi di infettività e di trasmissione della malattia. Il cambiamento giornaliero dei tassi di infettività variava da -0,6% in Svezia a -11,3% nelle province cinesi di Hubei e Guangdong. Altri studi riportavano una riduzione del numero dei ricoveri ospedalieri associati al COVID-19 (Italia, Spagna) ed effetti positivi sul tempo di raddoppio del numero di casi (Hubei, Cina) dopo l'introduzione di *lockdown*.

CONCLUSIONI: i risultati di questa rassegna suggeriscono un effetto positivo delle misure di contenimento sulla diffusione del COVID-19 nei vari paesi studiati, maggiore nei paesi che hanno implementato il *lockdown* prima e in modo più restrittivo. La conduzione di ricerca di alta qualità è necessaria per valutare quale strategia sia più efficace nelle diverse fasi dell'epidemia e nei diversi contesti sociali e se questi interventi debbano essere indirizzati all'intera popolazione o a specifici gruppi a rischio.

Parole chiave: COVID-19, SARS-CoV-2, misure di contenimento, efficacia

INTRODUCTION

Coronavirus disease 2019 (COVID-19) is a rapidly emerging disease caused by the novel SARS-CoV-2, a virus that follows human-to-human transmission.[1] The first COVID-19 case was notified in China (Hubei province) in December 2019 but the emergency rapidly escalated to pandemic level, as declared by the World Health Organisation (WHO) on March 11, 2020.[2] As of 17 July 2020, 15,296,926 confirmed COVID-19 cases worldwide and 628,903 confirmed deaths have been reported in more than 200 countries.[3] Fever and influenza-like symptoms are the most common clinical features of SARS-CoV-2 infection. Most confirmed cases appear to have a mild and slow-onset disease. About 14% of patients develop severe disease and breathing difficulties, requiring hospitalization, and 5% needs admission to an intensive care unit. COVID-19 can be complicated by acute respiratory distress syndrome (3-5%), sepsis (10-20%) and multi-organ failure, which may often result in death.[4] Despite previous experiences of epidemics caused by other Betacoronaviruses,[5] the COVID-19 pandemic has revealed the weaknesses and unpreparedness of the health systems worldwide and requires extraordinary efforts to be tackled.

Irrespective of the impressive amount of ongoing clinical research, at present no vaccine or specific therapeutics are available to prevent or treat COVID-19.[6] Thus, nonpharmacological preventive measures learned from previous epidemics,[7] including hand hygiene, social distancing, travel bans, border and school closures, and contact tracing currently represent the only strategies to contain the spread of COVID-19.[8] During the first phase of the pandemic several countries implemented strict containment measures, such as the implementation of national lockdowns. The effect of such exceptional interventions in curbing COVID-19 epidemic still needs to be fully evaluated. Understanding the impact of the containment measures implemented so far is pivotal to inform future public health decisions during the next phases of pandemic. For this reason, we performed a rapid review of the available literature to describe and compare the effectiveness of national and local lockdowns in controlling the spread of COVID-19.

METHODS

The present work was carried out following the WHO guide for rapid reviews[9] and written according to the Preferred reporting items for systematic reviews and metanalyses (PRISMA) statement for reporting of systematic review.[10]

ELIGIBILITY CRITERIA

We selected studies that evaluated the effect of national or local lockdowns (or similar public health policies) implemented to control the spread of COVID-19. Studies were selected according to the following criteria:

- Population: any population/country/region/province/municipality in which a public health policy of social distancing or lockdown was implemented between January and July 2020.
- Intervention: we defined lockdown or social distancing as a set of different policies simultaneously implemented to control COVID-19 spread involving several sectors of the society (e.g., travel limitation, mobility restriction in- and/or across municipalities/regions, school closure, smart working or job interruption, public events bans, shop closure, and so on). We excluded studies assessing only single policies (e.g., only school closure).
- Control: period before the implementation of lockdown.
- Outcomes: we considered any outcome related to the spread of the epidemic (e.g., number of new cases, number of hospital admissions or deaths for COVID-19, reproduction number, doubling time). We excluded impact measures (e.g., number of avoided cases), health outcomes not directly related to COVID-19 (e.g., effects of policies on mental health, cardiovascular diseases, and tumour outcomes), and socioeconomic outcomes of policies. We also did not consider scenario analyses, forecasts of the possible evolution of the epidemic and projections of the future effects of lockdowns.
- Study design: we included any type of observational and quasi-experimental study, in particular time-series studies and mathematical modelling studies (e.g., SIR/SEIR).
- Language: English and Italian
- Period: papers published before 5 July 2020.

In addition, we excluded articles and reports not providing sufficient information to evaluate and summarize evidence (e.g., did not report estimates). Finally, we excluded reviews, guidelines, letters, and editorials.

SEARCH STRATEGY

For this rapid review we searched studies of both published and grey literature (i.e., unpublished papers, preprinted / pre-reviewed articles) on Medline, Embase, repositories of pre-reviewed articles (Epidemiologia & prevenzione repository, medRxiv.org, bioRxiv.org, arXiv.org, EPICx Lab), Google, Research Gate, European cen-

tral bank database, Organisation for economic co-operation and development (OECD) database, Imperial college London website, Proceedings of the national academy sciences (PANS), and other Italian websites (i.e., Istituto superiore di sanità).
The search was performed independently by three non-blinded reviewers: one reviewer conducted a first search on Medline, Embase, medRxiv.org, bioRxiv.org, and arXiv.org on May 17^{th}, 2020 (search 1); other two reviewers searched grey literature and other published articles on the remained sources and pre-reviewed repositories (search 2); finally, the search was updated in PubMed, Embase, medRxiv.org, bioRxiv.org, and arXiv.org on 5 July 2020 (search 3, 4).
All searches were conducted using different combinations of the following key words: lock-down, lockdown, distanc*, "social distancing", clos*, quarantine, isolation, model, evaluation, effect*, impact, COVID-19, Coronavirus, SARS-CoV-2.
Finally, we used a snowball method consulting references of a Cochrane rapid review[11] and a systematic review[12] found with searches 1 and 2. For major details about search strategy, see supplementary materials.

STUDY SELECTION AND DATA EXTRACTION

Once the records retrieved by the search were checked for duplicates, three reviewers conducted a screening by title and abstract. Records passed for full-text eligibility were assessed also by another expert reviewer. Disagreements were discussed in the wider team when needed. Four reviewers extracted data. Data extraction was not dually performed, but each doubt was discussed in the wider team. We collected data as presented in each paper on: setting of the intervention (countries/regions/municipalities), type of policy analysed, method used for evaluation, sources of data, outcomes, observation period before and after the implementation of the intervention main results, conclusions, and study limitations.

RISK OF BIAS OF THE INDIVIDUAL STUDIES

Because of the substantial heterogeneity of the included studies, we did not use any specific tool to systematically evaluate their methodological quality. Rather we carried out a descriptive evaluation of their possible points of strength and weakness.

DATA SYNTHESIS

We synthesized results narratively and in tabular form. Because of the heterogeneity of available studies, we did not perform a quantitative synthesis of results (i.e., metanalysis).

RESULTS

The initial search on Medline, PubMed, and Embase generated 411 articles, whereas 208 additional records were identified through other sources (websites, repositories of pre-reviewed articles, and systematic reviews). After duplicates were removed, we screened by title and abstract 584 articles; of them 500 were excluded because they were not pertinent to the review aim. Out of 84 articles assessed for eligibility by reading their full-texts, we excluded 31 articles because they were based on forecast modelling, 15 addressed specific interventions (e.g., travel limitations, quarantine of infected or climate) or specific populations (No. 2), 5 did not evaluate outcomes of interest, 3 were reviews, 6 did not provide sufficient information to evaluate and summarize evidence, and one was not an evaluation study. In addition, we excluded one letter and a paper written in Chinese. Therefore, 19 articles evaluating the effect of lockdown or social distancing on the spread of COVID-19 were included in this rapid review. At the time when search was performed, out of the 19 articles herein included 10 were pre-printed articles.[13-22] Fully selection process is represented in Figure 1.

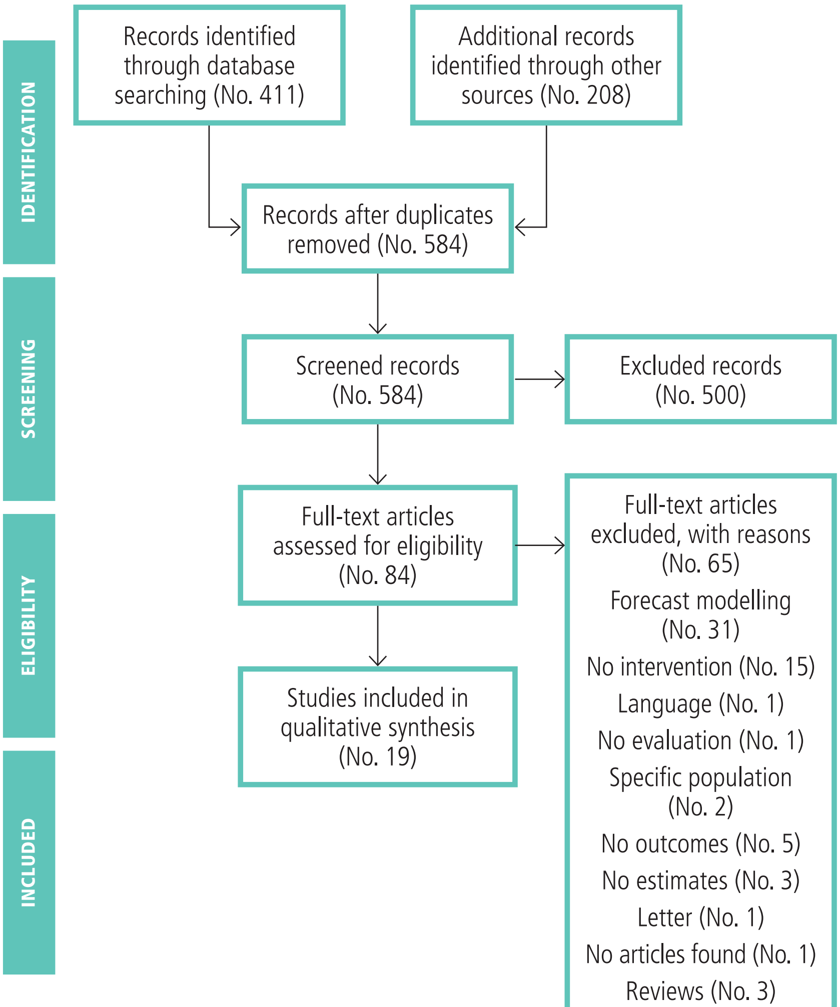

Figure 1. Flowchart of the selection process.
Figura 1. Flowchart del processo di selezione.

STUDY	COUNTRY	METHOD **	OBSERVATION TIME (DAY.MONTH)	CONSIDERED EVENTS	ESTIMATED VALUE (95%CI)
Allieta et al.[14]	Italy	Other	24.02-18.03 (b)	Cases	3.22 (3.14;3.29)
			18.04-24.04 (a)		0.84 na
Cowling et al.[31]	Hong Kong	Other	two weeks before the 22 January 2020 (b)	Cases	1.28 (1.26;1.30)
			two weeks after the 22 January 2020 (a)		0.72 (0.70;0.74)
			two weeks before the 22 January 2020 (b)	Hospital admissions	1.10 (1.06;1.12)
			two weeks after the 22 January 2020 (a)		0.73 (0.68;0.77)
De Brouwer et al.[15]	China	Compartmental model	10.01-22.01 (b)	Cases	3.36 (2.88;4.29)
			23.01-12.02 (a1)		1.15 (0.92;1.40)
			from 13.02 (a2)		0.19 (0.10;0.56)
	Belgium	Compartmental model	1.03-13.03 (b)	Cases	2.10 (1.94;2.12)
			23.03-17.03 (a1)		3.19 (2.43;4.14)
			from 18.03 (a2)		0.88 (0.39;1.21)
	Italy	Compartmental model	24.02-3.03 (b)	Cases	2.68 (2.42;3.08)
			10.03-19.03 (a1)		1.86 (1.36;2.37)
			from 20.03 (a2)		0.46 (0.08;0.85)
	Spain	Compartmental model	24.02-10.03 (b)	Cases	4.10 (3.70;4.49)
			from 11.03 (a)		1.11 (0.86;1.43)
Fang et al.[29]	Wuhan, China	Compartmental model	20.01-22.01 (b)	Cases	2.70 na
			23.01-29.01 (a)		3.20 na
			30.01-11.02 (a)		2.90 na
			12.02-20.02 (a)		2.60 na
			21.02-29.02 (a)		2.30 na
Flaxman et al.[24]	Europe (11 countries)	Compartmental model	27.01-28.03 (b)*	Deaths	3.80 (2.40;5.60)
			27.01-04.05 (a)*		0.66 na
Guzzetta et al.[18]	Italy (8 regions and 2 autonomous provinces)	Other	1.03-10.03 (b)		1.5-3.2* na
			11.03-25.03 (a)	Cases	0.70 na
Hyafil et al.[19]	Spain	Compartmental model	20.02-13.03 (b)	Hospital admissions	5.89 (5.46;7.09)
			20.02-13.03 (b)	Cases	6.91 (6.75;7.39)
			20.02-13.03 (b)	Deaths	6.48 (5.5;7.51)
			16-30.03 and 13-15.04 (a1)	Hospital admissions	1.86 (1.10;2.63)
			16-30.03 and 13-15.04 (a1)	Cases	2.22 (1.92;2.74)
			16.03-15.04 (a3)	Deaths	0.49 (0.16;1.57)
			31.03-12.04 (a2)	Hospital admissions	0.48 (0.15;1.17)
			31.03-12.04 (a2)	Cases	0.85 (0.50;1.05)
Lemaitre et al.[28]	Switzerland	Compartmental model	01.03-10.03 (b)	Cases	2.80 (2.50;3.10)
			29.03-05.04 (a)		0.40 (0.27;0.60)
Saberi et al.[22]	Iran	Compartmental model	01.03 (b)	Cases	1.73 (1.60;1.87)
			15.04 (a)		0.69 (0.68;0.70)
Tian et al.[21]	China	Compartmental mode	11.01-22.01 (b)	Cases	3.15 (3.04;3.26)
			23.01-19.02 (a)		0.04 (0.003;0.095)
Zhao et al.[30]	China, Wuhan	Compartmental model	20.01-30.01 (b)	Cases	4.70 na
			01.02-12.02 (a)		0.76 na
			13.02-21.02 (a)		0.50 na
	China, Hubei (no Wuhan)	Compartmental model	20.01-30.01 (b)	Cases	5.93 na
			01.02-12.02 (a)		0.61 na
	China (no Hubei)	Compartmental model	20.01-30.01 (b)	Cases	1.53 na
			01.02-12.02 (a)		0.58 na

(a) time after the start of the lockdown. 1, 2, and 3 means more than one period of evaluation after the lockdown/ *periodo successivo al lockdown. 1, 2 e 3 significano* più di un periodo di valutazione successivo al lockdown; (b) time before the start of the lockdown / *periodo precedente al lockdown*; **CI:** confidence interval / *intervallo di confidenza*; **na:** not available / *non disponibile*
* pre-intervention and post-intervention varied across the Countries analysed / il pre-intervento e il post-intervento differiscono a seconda del Paese considerato
** Regression models include regression analysis and interrupted time series. Compartmental models include SIR, SIER, SIERD and similar epidemic models. / *I modelli di regressione includono l'analisi e le serie temporali interrotte. I modelli compartimentali includono SIR, SIER, SIERD e modelli epidemici simili.*

Table 1. Before and after lockdown reproduction number estimated values (Rt; 95%CI). For each study included in this rapid review, the table presents observed country/ies, method to analyse data, time of observation, type of event considered to calculate Rt, estimated value of Rt, and its margin of errors (95%CI).
Tabella 1. Numero di riproduzione (Rt; IC95%) prima e dopo il lockdown. Per ogni studio incluso in questa rapid review, la tabella presenta la/e nazione/i osservata/e, il metodo usato per analizzare i dati, il periodo di osservazione, il tipo di evento considerato per stimare Rt, la stima di Rt e il relativo margine di errore (IC95%).

STUDY	COUNTRY	METHOD **	OBSERVATION PERIOD (DAY/MONTH)	PARAMETER	ESTIMATE VALUE	ESTIMATE UNCERTAINTY (95%CI)
Courtemanche et al.[23]	US	Regression model	1-5 days[(a)]	Daily infection rate variation (%)	-5.4	na
			6-10 days[(a)]		-6.8	na
			11-15 days[(a)]		-8.2	na
			16-20 days[(a)]		-9.1	na
Džiugys et al.[13]	Australia	Compartmental model	23.03-03.05*[(a)]	Daily infection rate variation (%)	-1.6	na
	Switzerland		13.03-19.04*[(a)]		-1.4	na
	New Zealand		21.03-20.05*[(a)]		-3.1	na
	Iceland		16.03-20.05*[(a)]		-1.6	na
	Austria		16.03-20.05*[(a)]		-2.4	na
	Poland		12.03-20.05*[(a)]		-1.0	na
	Italy		9.03-20.05*[(a)]		-1.1	na
	Germany		23.03-20.05*[(a)]		-0.7	na
	UK		24.03-20.05*[(a)]		-1.0	na
	Danmark		21.03-20.05*[(a)]		-1.2	na
	Sweden		10.03-20.05*[(a)]		-0.6	na
Gatto et al.[27]	Italy	Compartmental model	24.02-25.03*	Transmission rate variation during the period (%)	-45	(-49;-42)
Ghosal et al.[17]	India, Italy, UK, Spain, France, Germany, Austria, Belgium, Hungary, Poland, Malaysa, New Zeland	Regression model	na	Infection rate variation (%) from a week before to a week after lockdown	-61	na
Flaxman et al.[24]	Europe (11 countries)	Compartmental model	27.01-04.05 ***	Transmission rate variation during the period (%)	-81	(-87;-75)
Medeiros de Figueiredo et al.[16]	China (Hubei province)	Regression model	11.01-22.01[(b)]	Daily infection rate variation	reference	
			23.01-12.02[(a)]		-6.4	(-10;-2.3)
	China (Guangdong province)	Regression model	11.01-22.01 [(b)]	Daily infection rate variation	reference	
			23.01-02.02 [(a)]		-9.5	(-14;-4.4)
Reis et al.[32]	Brazil	Compartmental model	21.02-06.04***	Transmission rate variation compared to its initial value (%)	-40	na
	Italy				-77	na
	South Korea				-91	na
Saez et al.[25]	Spain	Regression model	11.03-13.03[(b)]		reference	
			14.03-05.04[(a)]	Daily infection rate variation (%) -1 day after lockdown	-3.1	(-0.9;5.4)
			14.03-05.04[(a)]	Daily infection rate variation (%) -3 weeks after lockdown	-5.2	na

(a) time after the start of the lockdown / *periodo successivo al lockdown*; (b) time before the start of the lock-down / *periodo precedente al lockdown*
CI: confidence interval / intervallo di confidenza; **na:** not available / non disponibile
* Time pre-interventions: 20-days before interventions started. / *Tempo di pre-intervento: 20 giorni prima dell'inizio dell'intervento.*
** Regression models include regression analysis and interrupted time series. Compartmental models include SIR, SIER, SIERD and similar epidemic models. / *I modelli di regressione includono l'analisi e le serie temporali interrotte. I modelli compartimentali includono SIR, SIER, SIERD e modelli epidemici simili.*
*** pre-intervention and post-intervention varied across the Countries analysed. / *Il pre-intervento e il post-intervento differiscono a seconda del Paese considerato.*

Table 2. Variation in infection rates and transmission rates from the selected studies before and after lockdown. For each included study, the table presents observed Country(ies), method to analyse data, time of observation, type of parameter presented, estimated value of parameter, and its margin of errors (95%CI).
Tabella 2 Variazione dei tassi di infezione e di trasmissione prima e dopo il lock-down degli studi inclusi. Per ogni studio incluso in questa rapid review, la tabella presenta la/e nazione/i osservata/e, il metodo usato per analizzare i dati, il periodo di osservazione, il tipo di parametro stimato, la stima e il relativo margine di errore (IC95%).

STUDY CHARACTERISTICS

Most of the studies included one or more European countries (No. 11), eight were referred to the Asian region, one to North America (US), two to Oceanian area, and one to the Middle East area (Iran). Among European countries, the most involved were Italy (No. 8), Spain (No. 6), UK, Switzerland, and Germany (No. 3), whereas China (No. 6) was most involved in Asia. Regarding China, two studies evaluated the effect of policies implemented in the whole country, two observed the Wuhan city, three the Hubei province, and one other regions of the country. Other Asian regions considered were Hong Kong (No. 1), Malaysia (No. 1), and India (No. 1).

As we have early reported, we defined lockdown as a set of different policies aimed to social distancing and simultaneously implemented to control COVID-19 spread involving several sectors of the society (e.g., travel limitation, mobility restriction, school closure, smart working or job interruption, public events bans, shop closure, and so on). These restrictive policies have been implemented in several ways, combinations, and intensity levels by the different countries considered by the studies included. While eight articles reported some definition of lockdown according to our eligibility criteria,[15-17,20,23-26] the other eleven did not explicit their definition. Nevertheless, considering the countries and periods observed by these last studies (Italy,[14,18,27] Spain,[19] Switzerland,[28] China and Wuhan city,[13,21,29,30] Hong Kong,[31] and Iran[22]), we assumed that analysed interventions fitted with our definition.

Considering the method used, seven studies used regression models (interrupted time series analyses and regression analyses), nine compartmental models (SIR, SIER, SIERD and similar), while the remaining three used other types of approaches. In relation to the measure used to evaluate the effect of lockdown or social distancing on the COVID-19 spread, most of the studies evaluated changes in the reproduction number (R_t) (No. 11) and infection rates or transmission rates (No. 8); other measures of effect were instead used in the remaining two studies. Some studies used more than one of the aforementioned measures.

ESTIMATES OF REPRODUCTION NUMBER (R_T) BEFORE AND AFTER THE IMPLEMENTATION OF LOCKDOWN

Eleven studies[14,15,18,19,21,22,24,28-31] evaluated the effect of lockdown on the reproduction number (R_t) of the COVID-19 (table 1). Almost all studies used COVID-19 cases to estimate R_t, except for Flaxman and colleagues, that used COVID-19 deaths. In addition, in the study of Hyafil and colleagues R_t was estimated using cases and deaths, while Cowling et al. and Hyafil et al. used also hospital admissions.[19,31] Observation time varied among the studies, even among those evaluating the same country. A substantial heterogeneity was also observed in the estimated values of R_t. Overall, pre-intervention values of R_t estimated on cases ranged from 1.28 (95%CI 1.26-1.30) in Hong Kong in early January 2020 to 6.91 (95%CI 6.75-7.39) in Spain, between February and March 2020. In all studies, a reduction of R_t at post-intervention was found. In particular, values decreased below 1 in all studies with the exception of two carried out in Spain and Wuhan. In the case of Spain,[15] this is probably due to the short observation time (up to the end of March), as another study carried out in the same country[19] found values of R_t below 1 in April. In the case of Wuhan, the two available studies were discordant about the effect of lockdown: Zhao and colleagues showed a reduction below 1 from the February 1st,[30] whereas Fang reported R_t values >2 until February 29th.[29] The implementation of lockdown in 11 European countries was associated with an average 82% reduction of Rt, ranging from a posterior R_t of 0.44 (95%CI 0.26-0.61) for Norway to a posterior R_t of 0.82 (95%CI 0.73-0.93) for Belgium..[24] Three studies provided estimates for Italy, with R_t decreasing from 1.5-3.2 to 0.46-0.84 after the introduction of the lockdown.[14,15,18]

VARIATION IN INFECTION RATES AND TRANSMISSION RATES BEFORE AND AFTER THE IMPLEMENTATION OF LOCKDOWN

Eight studies[13,16,17,23-25,27,32] analysed the effect of lockdown on the variation of infection rates (estimated trough regression models) and transmission rates (estimated trough compartmental models) (table 2). All studies reported a decrease over time. In particular, a study evaluating the impact of the containment measures in China showed a daily reduction of the new diagnosed cases up to 8% (95%CI 2.31-10.31) in the whole country and up to 11.3% (95%CI 8.68-13.87) in the Hubei and Guangdong provinces.[16] A smaller effect was found in other countries. Daily changes in infection rates ranged between -0.6% in Sweden to -3.1% in the New Zealand[13] and -5.2% in Spain.[25] Infection rates dropped in few days after the lockdown also in US cities (from -5.4% 1-5 days after to -9.1% 16-20 days after).[23] Studies using compartmental models estimated a reduction of the transmission rates after the implementation of lockdown in different countries. The overall decrease of the transmission rate in 11 European countries was 81% (95%CI 75-87).[24] This decrease was found to be lower in Brazil (40%),[32] and Italy (ranging from 45% to 77%),[27,32] while it was substantially higher in South Korea (91%).[32]

OTHER MEASURES OF EFFECT

An effect of the lockdown was also found in studies using other measures of effect. Chinese cities that pre-emptively implemented control measures reported 33% (95%CI 11%-44%) fewer cases in the first week of their outbreaks compared with cities that started control later.[21] A change in the trend of hospitalizations was found in Italy and Spain as well.[26] Doubling time of cases increased about twice during the following three weeks after lockdown implementation in China (Hubei).[20]

HOW LONG DOES IT TAKE TO SEE AN EFFECT?

Some studies reported the elapsed time between the implementation of the control strategy and the start of the effects on COVID-19 outbreak (time lags). Different studies suggest a 14-15-day lag between the implementation of lockdown and a reduction of R_t.[14,22,24,29,31] Guzzetta et al.[18] reported an effect already evident 7 days after the start of the lockdown in Italy, whereas Lemaitre et al.[28] observed a lag of 10 days for Switzerland.

The evidence from studies considering infection and transmission rates is more scattered, with some authors suggesting a 2-4-week lag before seeing an effect,[17-24] and others reporting a substantially shorter time (from 1 to 7 days after the lockdown implementation).[16,23,25]

DISCUSSION

In this rapid review, we were able to identify 19 studies that evaluated the effect of the implementation of lockdowns on the spread of COVID-19 in different countries. Notably, all the selected studies reported a positive health effect of such interventions.

Among the strengths of the present study there is its timeliness. The COVID-19 epidemic is still on the rise worldwide and even the countries where the peak of the infections has been reached are now facing the threat of a new wave. For this reason, a thorough evaluation of the effects of the interventions of social distancing is currently of paramount importance to guide future decisions. On the other hand, as most of lockdowns have been implemented from March 2020 onwards, the evidence on their efficacy in flattening the curve of the epidemic has only become available very recently.

Adopting the largely used approach of rapid review,[9] we were able to quickly synthesize the available evidence, still maintaining an acceptable level of methodological rigor. Even if the results of the included studies consistently point in the same direction, there are some caveats deserving discussion.

First, the indicators used to evaluate the containment measures adopted – R_t or number of new cases – could be affected by completeness of available data. Official COVID-19 cases, in particular in the early phase of pandemic, underestimated the true frequency of the disease: they did not include asymptomatic carriers, those who were not ill enough to seek medical care, and those who were unable to obtain a test due to supply constraints. This underestimation is expected to translate into a bias toward the null of the effect of lockdown. Delay or incorrect information, occurring randomly or connected with high incidence areas, could lead to biased results not comparable among countries. Likewise, the lockdown effects measured using changes in the number of deaths and hospital admissions could be affected by a different hospital demand over time or changes in criteria for the attribution of the cause of death to COVID-19.

Second, it could be argued that other specific country-level factors may have impacted the spread of the infection in addition to the adoption of country-imposed social distancing measures. However, given the consistency of the direction of the results across countries, it seems unlikely that these factors have played a major role.

Third, studies included in this rapid review took into account only the first phase of lockdown. For this reason, it was not possible to thoroughly evaluate the possible effect of duration of lockdown. This is indeed a question with important public health implications, for which future research is warranted.

Finally, several studies used complex modelling strategies, which rely on several and often untestable assumptions. For instance, assumptions on the length of incubation period, duration of infection, and prevalence of asymptomatic cases could have had some impact on the estimated effects of lockdowns.

From a public health perspective, there is a need of science-based information grounded on reliable, timely, accurate, complete, consistent and comparable data.[33] The negative impact of decisions made on poor quality data has been widely described,[34,35] providing examples in which the incomplete assessment or incorrect exposure, outcomes, confounding factors, eligibility criteria or other variables could lead to wrong conclusions. In particular, the current pandemic has highlighted challenges in data access related to data protection rights and linkage difficulties among data sources (i.e., non-interoperability and non-centralization). Future investment should focus on interoperability optimization among data sources and data sharing agreements involving public and private sectors.

Although we have not made any formal investigation, we also noted a low quality in reporting relevant information in many studies included in this rapid review. This phenomenon is probably connected both to the publication system promoted during COVID-19 pandemic, mostly in a quick, pre-print mode, skipping the formal reviewing process, and to the lack of standardized guidelines for reporting methods and results from compartmental models. Because of the importance that these models are assuming in the decision making during the COVID-19 pandemic, there is a need to improve their transparency and replicability.

Although the presence of sizeable evidence about effectiveness of lockdown on COVID-19 control, many pre-printed works appear scarcely judging for the quality of their reports. By contrast, some studies present more structured and rigorous published and unpublished reports giving elements to evaluate analysis as more valid and reliable. These studies showed an important reduction of R_t<1 in Hong

Kong,[31] Italy,[15] China,[15] Spain,[19] Switzerland,[28] Iran[22] after 15 days from the implementation of lockdowns, and a significant decrease in transmission/infection rates in Italy,[27] China,[16] and Spain.[25] Generally, a major effectiveness of this control strategy appears evident in more restrictive contexts and where lockdown started early.[21] Flaxman and colleagues reported a major impact of lockdown especially in South European countries (Italy, Spain, France),[24] whereas Tobias et al.[26] showed a significant reduction of hospitalization in Italy and Spain.

DIRECTIONS FOR FUTURE RESEARCH

Results of our rapid review highlight five main areas of uncertainty that should be addressed in future research.

- Results of available studies do not allow disentangling the effect of specific components of social distancing interventions (e.g., school closure) since most of them have been implemented almost at the same time. A thorough evaluation of the effectiveness of each component by itself and in combination with the others may help governments to make more rational decisions in the implementation of such complex interventions and be able to weigh the expected benefits of each strategy with its social and economic adverse effects.
- Another aspect that deserves further investigation is the impact of lockdowns and other social distancing measures among vulnerable groups and minorities. It is well known that COVID-19 pandemic has specifically affected care homes for elderly, accounting for 25-50% of the deaths in Western countries.[36] Furthermore, new outbreaks are developing among minorities,[37] raising questions on the role of socioeconomic differences and health inequalities in COVID-19 spreading and on whether recommendations issued from authorities effectively reach the whole population.
- Along with these public health strategy questions, there is uncertainty about the dynamics of the transmission of COVID-19. Detected cases include mainly moderate and severe hospitalized cases. Facing a reduction of total detected cases does not directly imply the absence of transmission in the general population. The hypothesis of an undetected transmission among children and young adults should be examined, especially in this second stage of the pandemic where young people meet up, and schools are reopening around the world.
- Although we focused our analysis only on indicators related to the virus outbreak, during the first six months of 2020 several contributions about the association of lockdown with other health outcomes (e.g., mental health outcomes), socioeconomic effects, and/or effects on climate (e.g., air pollution) were published. Further systematic reviews are needed to synthesize the evidence regarding these outcomes.
- Future research should also explore the use of other data such as mobility data, which capture the movements of personal electronic devices (e.g., smartphones) using mapping applications. These data represent an important proxy measure of social distancing that can be used to support decision-making and quantify the impact of containment policies on human mobility.
- Ultimately, the COVID-19 pandemic has also exposed the limitations of conducting research and implementing public health measures during a so rapidly evolving health emergency. Future studies are warranted to evaluate which approach is the most effective in a specific stage of the epidemic and in specific social contexts, in particular addressing if these approaches should be implemented on the whole population or target specific risk groups.

Conflicts of interest: none declared.

Funding: the present study was conducted with the support and in collaboration with the Italian Epidemiological Association.

Acknowledgements: the study was conducted within the activities of the Working group of the Italian Epidemiological Association (AIE) on the evaluation of the effectiveness of lockdowns: Carla Ancona, Chiara Badaloni, Francesco Barone-Adesi, Valeria, Belleudi, Silvia Caristia, Flavia Carle, Manuela De Sario, Andrea Faragalli, Luigi Ferrante, Margherita Ferranti, Rosaria Gesuita, Enrica Lapucci, Raffaele Palladino, Daniela Pierannunzio, Elena Raffetti, Rodolfo Saracci, Edlira Skrami, Simona Vecchi.

Submission date: 26.07.2020
Accepted on: 26.09.2020

REFERENCES

1. World health organization. Rolling updates on coronavirus disease (Covid-19).
2. World health organization. WHO director-general's opening remarks at the media briefing on Covid-19 -11 march 2020. Geneva: WHO; 2020. Avaiable from: https://www.who.int/dg/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19---11-march-2020
3. World health organization. Coronavirus disease (Covid-19) pandemic 2020.
4. Guan WJ, Zhen, Ni ZY, Hu Y, et al. Clinical Characteristics of Coronavirus Disease 2019 in China. N Engl J Med 2020;382(18)1708-20.
5. Paudel S, Dangal G, Chalise A, Bhandari TR, Dangal O. The Coronavirus pandemic: what does the evidence show? J Nepal Health Res Counc 2020;18(1):1-9.
6. U.S. national library of medicine. Listed clinical studies related to the coronavirus disease (Covid-19). Clinicaltrials.gov 2020. Available from: https://clinicaltrials.gov/ct2/results?cond=COVID-19
7. Qualls N, Levitt A, Kanad N, et al. Community Mitigation guidelines to prevent pandemic influenza – United States, 2017. MMWR Recomm Rep 2017;66(1):1-34.
8. Güner H, Hasanoglu I, Akta F. Covid-19: prevention and control measures in community. Turk J Med Sci 2020;50(SI-1):571-77.
9. Tricco AC, Langlois EV, Straus SE, et al. Rapid reviews to strengthen health policy and systems: a practical guide. Geneva: WHO; 2017.
10. Knobloch K, Yoon U, Vogt PM. Preferred reporting items for systematic reviews and meta-analyses (PRISMA) statement and publication bias. J Craniomaxillofacial Surg 2011;39(2):91-92.
11. Nussbaumer-Streit B, Mayr V, Dobrescu AI, et al. Quarantine alone or in combination with other public health measures to control Covid-19: a rapid review. Cochrane Database Syst Rev. 2020;4(4):CD013574.
12. Park M, Cook, AR, Lim JT, Sun Y, Dickens BL. A Systematic Review of Covid-19 Epidemiology Based on Current Evidence. J Clin Med 2020;9(4):967.
13. Džiugys A, Bieliūnas M, Skarbalius G, Misiulis E, Navakas R. Simplified model of Covid-19 epidemic prognosis under quarantine and estimation of quarantine effectiveness. Chaos Solitons Fractals 2020;140:110162.

14. Allieta M, Allieta A, Rossi Sebastiano D. Covid-19 outbreak in Italy estimation of reproduction numbers over two months toward the phase 2. Medrxiv 2020. doi:10.1101/2020.05.12.20076794.
15. De Brouwer E, Raimondi D, Moreau Y. Modeling the Covid-19 outbreaks and the effectiveness of the containment measures adopted across countries. Medrxiv 2020. doi:10.1101/2020.04.02.20046375.
16. Medeiros de Figueiredo A, Daponte Codina A, Moreira Marculino Figueiredo DC, Saez M, Cabrera León A. Impact of lockdown on Covid-19 incidence and mortality in China: an interrupted time series study. Bull World Heal Organ, 06.04.2020. Available from: https://www.who.int/bulletin/online_first/20-256701.pdf
17. Ghosal S, Bhattacharyya R, Majumder M. Impact of complete lockdown on total infection and death rates: a hierarchical cluster analysis. Diabetes Metab Syndr 2020;14(4)707-11.
18. Guzzetta G, Riccardo F, Marziano V, et al. The impact of a nation-wide lockdown on Covid-19 transmissibility in Italy. ArXiv 2020. Available from: https://arxiv.org/abs/2004.12338
19. Hyafil A, Morina D. Analysis of the impact of lockdown on the evolution Covid-19 epidemics in Spain. Gaceta Sanitaria 2020;04.18.20070862. doi:10.1101/2020.04.18.20070862.
20. Lau H, Khosrawipour V, Kocbach P, et al. The positive impact of lockdown in Wuhan on containing the Covid-19 outbreak in China. J. Travel Med 2020;27(3)taaa037.
21. Tian H, Liu Y, Li Y, et al. An investigation of transmission control measures during the first 50 days of the Covid-19 epidemic in China. Science 2020;368(6491):638-42.
22. Saberi M, Hamedmoghadam H, Madani K, et al. Accounting for underreporting in mathematical modelling of transmission and control of Covid-19 in Iran. Medrxiv 2020; 2020.05.02.20087270. doi:10.1101/2020.05.02.20087270.
23. Courtemanche C, Garuccio J, Le A, Pinkston J, Yelowitz A. Strong social distancing measures in the united states reduced the Covid-19 growth rate. Health Aff (Millwood) 2020;39(7):1237-46.
24. Flaxman S, Swapnil M, Gandy A, et al. Estimating the number of infections and the impact of non-pharmaceutical interventions on Covid-19 in European countries: technical description update. Arxiv 2020. Available from: https://arxiv.org/abs/2004.11342
25. Saez M, Tobias A, Varga D, Barceló MA. Effectiveness of the measures to flatten the epidemic curve of Covid-19. The case of Spain. Sci Total Environ 2020;727:138761.
26. Tobías A. Evaluation of the lockdowns for the SARS-CoV-2 epidemic in Italy and Spain after one month follow up. Sci Total Environ 2020;725:138539.
27. Gatto M, Bertuzzo E, Mari L, et al. Spread and dynamics of the Covid-19 epidemic in Italy: Effects of emergency containment measures. Proc Natl Acad Sci U S A 2020;117(19):10484-91.
28. Lemaitre JC, Perez-Saez J, Azman AS, Rinaldo A, Fellay J. Assessing the impact of non-pharmaceutical interventions on SARS-CoV-2 transmission in Switzerland. Swiss Med Wkly 2020;150:w20295.
29. Fang Y, Nie Y, Penny M. Transmission dynamics of the Covid-19 outbreak and effectiveness of government interventions: A data-driven analysis. J Med Virol 2020; 92(6):645-59.
30. Zhao S, Chen H. Modeling the epidemic dynamics and control of Covid-19 outbreak in China. Quant Biol 2020;1-9. Online ahead of print.
31. Cowling BJ, Ali ST, Ng TWJ, et al. Impact assessment of non-pharmaceutical interventions against coronavirus disease 2019 and influenza in Hong Kong: an observational study. Lancet Public Heal 2020;5(5):e279-88.
32. Reis RF, de Melo Quintela B, de Oliveira Campos J, et al. Characterization of the Covid-19 pandemic and the impact of uncertainties, mitigation strategies, and underreporting of cases in South Korea, Italy, and Brazil. Chaos Solitons Fractals 2020;136:109888
33. Belleudi V, Rosa A. Riscoprire la necessità di investire sulla qualità del dato. Epidemiol Prev 2020;43(1):102-03.
34. Weiss NS. The New World of Data Linkages in Clinical Epidemiology. Epidemiology 2011;22(3)292-94.
35. Cheng, P, Gilchrist A, Robinson KM, Paul L. The risk and consequences of clinical miscoding due to inadequate medical documentation: a case study of the impact on health services funding. Heal Inf Manag J 2009;38:35-46.
36. Grabowski DC, Mor V. Nursing home care in crisis in the wake of Covid-19. JAMA 2020;324(1):23-24.
37. Khunti K, Singh AK, Pareek M, Hanif W. Is ethnicity linked to incidence or outcomes of Covid-19? BMJ 2020;369:m1548.