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Predicting Individual level Public heath Interventions by Infectious diseases modelling to control COVID-19: A Review

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Abstract:

Objective: To review and critically appraise the published literature using infectious disease models to the benefits of Individual level public health interventions in COVID-19

Design: Rapid Systematic review and critical appraisal

Data Sources: Pubmed, Google Scholar, medRxiv and bioRxiv

Study Selection and Extraction: We retrieved 21 studies after 3 level of screening. We identified 17 studies that developed model to predict social distancing and4 studies to predict public health measures like use of face mask and hand washing. The data was extracted using extraction sheet by following the CHARMS Checklist. The quality and risk of bias of the predicting model were assessed using the framework used in the review by R. C. Harris et al consisting of 14 criteria's and the median score was 20/28.

Results: Included studies have predicted the benefit of social distancing on health care services and epidemic flattening. Individual level public health measures like wearing mask, hand washing consistently will reduce the infection. Few of the studies have also predicted no one measure can break the epidemic, along with social distancing other containment measures like closure of school, restriction of travel.

Conclusion: The public health interventions like social distancing and physical distancing, compulsory use of facial mask by all the people is the solution to bring down the epidemic and also to prevent further epidemic. Along with this early diagnosis, contact tracing and isolation will be the corner stone to get rid of this pandemic.

Keywords: Covid 19, Mathematical model, prediction, intervention.

Introduction:

The COVID19 pandemic has led to morbidity and devastating mortality worldwide. It has affected the populations of all regions of the world. The proportion of cases has increased significantly in most of the countries. The heroic actions taken against this pandemic by the health professionals are appreciative. The various Governments of the world, international organizations and policy makers have major responsibility to contain this pandemic. As there is no specific treatment and no effective vaccine is available as of now and in the near future, only the various control measures taken by the countries separately and in cooperation could contain this pandemic. The countries have implemented Public health measures like 'personal protection, environmental sanitation, social and physical distancing, and travel related interventions' as recommended by WHO.[1] This has also affected badly the unregistered or unorganized working class of people and also the economic development of the country and the globe.[2]

The epidemiological details of the new virus are slowly emerging from the data based and other epidemiological studies published in various regions. The consequences of COVID 19 virus

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pandemic are different in different countries. The major priority of Government is to keep the death rate to lower side and reduce the economic impact of the virus pandemic.[3] With lack of complete or sufficient information on the epidemic pattern of this virus, the countries are dependent on the disease progress predicting mathematical models. The Government rely on the disease prediction mathematical model for decision making of measures to control this pandemic.[3] Epidemic curve on number of cases with time interval can be predicted by various disease models. A mathematical model is derived using the collected statistics, some epidemiological assumptions and using a set of mathematical equations.[5] These models help in rapid assessments of the epidemiological process and calculate the future effects of epidemiological and other interventions like lockdown based social distancing, mass vaccination programs etc. Simulations of epidemic process based on mathematical models are also used, conditions when there are multiple approaches of interventions are available for a given problem and the data collection is expensive. These are classified into three categories, 1) Statistical methods used for outbreak surveillance like Spatial models, Regression techniques and time series auto-regressive models 2) Mathematical modelling applied to predict hypothetical or ongoing epidemic like Continuum deterministic SIR models, Stochastic models Markov Chain, Complex Networked Models and Agent-Based Simulations and (3) Machine learning for prediction of progression of an epidemic like Web-Based Data Mining and Surveillance Networks.[6] Based on existing evidence some of the important mathematical models describing dynamics of infectious diseases are:

SIR (Susceptible-Infected-Recovered): This model is for a closed population. In this model it is assumed that the population is fixed and all persons are susceptible. All will leave the susceptible group after getting infected will recover and gain immunity. No population specific factors affect the probability of getting infected and there is no inherited immunity.

- SIRS (Susceptible -Infected-Recovered- susceptible): It is similar to SIR but in exception to Recovered model it is assumed that the person is susceptible to infection after recovery when the immunity weans off.
- SEIR (Susceptible -Exposed-Infected-Recovered) In this model it is suggested that susceptible persons get exposed to infectious agents and for a period of time carries the infection but are not infectious themselves. Then they get infectious and recover but gain immunity.
- SEIRS (Susceptible -Exposed-Infected-Recovered) - It is similar to SEIR but in exception to Recovered model it is assumed that the person is susceptible to infection after recovery when the immunity weans off.[7]

Conversely the prediction models can be interpreted differently by different scientists and due to the varying assumption can lead to differences in prediction models.[8]

Why this review?

The lockdown of movement of people is a disagreeable event and has impaired the daily living of the majority of the population and especially those of low socio-economic status. The lock down will

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devastate the country's economy. The policy makers and country heads are trying hard to form strategies to come out of this lockdown. As most of countries have eased or are in the process of easing the lock down measures. The implementation of individual level public health measures like social or physical distancing, use of facial mask or hand washing practices are the primary measures to prevent the transmission of COVID19. Considering the significance of this information provided by these prediction models for taking key decisions on social distancing, lock down etc, a review of literature on such a topics a much needed one. This review wanted to find out the outcomes of various models which helped to predict the public health interventions. Our aim was to review and critically appraise the published literature using infectious disease progression models to the benefit of Individual level public health interventions.

Methods

Types of studies:

All studies published between December 2019 and May 2020 was included for the review. The studies that have used infectious disease model for predicting the public health interventions like social distancing and physical distancing, for prevention / control or have assessed the impact of COVID 19 were considered for the review.

Language: English was the language of choice and articles in other language which were translated into English was also considered for the rapid review

Search strategy

This review was conducted by following the guidelines of the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA).[9] The studies for this review was identified by the search strategy. We used the following combination of terms for searching public health interventions (Social distancing OR Physical distancing or mask or facial mask or hand washing), prediction models (Epidemic model OR Mathematical modeling OR Risk assessment modular concept OR Mathematical modeling OR random network OR small world network) and COVID (COVID 19 OR Corona virus OR sars-cov-2).The following electronic research databases were searched in PubMed, Google scholar and also among unpublished literature in Arxiv and MedRxiv. All the authors identified the key words for the search engine; first author conducted the search and extracted the articles. The second and third author extracted the data from the retrieved article. The articles which used mathematical model for predicting the individual level behavior public health interventions like, social distancing and physical distancing face mask and hand washing, were included in the review. The models used to predict other than the public health interventions and study using statistics were excluded from the review.

Study selection and extraction

The studies were retrieved and were uploaded in the electronic reference management database/software Zotero. The duplicates were removed, and all the titles and abstracts of retrieved

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articles were screened using predefined inclusion and exclusion criteria by two independent reviewers. After discussion all pre-selected citations were selected for full text review. In next step all the full text of included articles were obtained. Each study was read in full and was included as per criteria. The studies which fulfilled the exclusion criteria and studies eliminated by both reviewers were excluded. Any disagreement in inclusion by 1st and 2nd reviewers was solved by the third reviewer for final decisions. The data from the included studies were extracted by the second reviewer and was verified by the first author. The data was extracted using extraction sheet by following the CHARMS Checklist.[10] The references from the list of included articles were also hand searched and were extracted from the PubMed search engine.

Assessment of quality:

The quality and risk of bias of the predicting model were assessed using the framework used in the review by R. C. Harris et al and consisting of 14 criteria's. For the effective use of the tool each of the 14 criteria were rated by zero, one and two (in between 0-2), giving a maximum score of 28. [11] To avoid bias a minimum score of one was awarded for the irrelevant criterion. The included studies paper were graded as a quality as low (< 14), medium (14-18), high (19-22) and very high (> 22) based on the overall score. The assessment of quality was conducted by the third reviewer. In condition of low score and/ or doubt in scoring the process was intervened and facilitated by the first author. To increase the validity of the assessment one article from each grading was assessed by the first author.

Results:

Description of the studies:

In this review the models used to predict the individual level public health measures for control or prevention of COVID-19 were considered. We included 21 studies and by means of review and appraisal using CHARMS checklist we found that 9 different models were used to predict the public health interventions. Most of the models have mentioned the predictive performance as good but only few have clearly reported the methodology. All the studies have expressed their findings in the form of simulation curves and tables. Ten studies had reported the use of sensitivity analysis, numerical simulations, data validation using spatial and temporal correlations, verification and validation using independent data.[12-21]

Among the 21 included studies, 11 studies used dynamic, classic or deterministic Q SEIR modelsand 5studies used classic, modified or basic SIR models. The other models used MicroscopicMarkovChainApproach (MMCA), Stochastic transmission model and FluTE, 15 an agent-based epidemic simulation model. Seven studies were from China, six from USA, three from Spain, one each from India, Singapore, Switzerland, Korea and Italy, All the studies used the data from authenticated data base like country specific data base, WHO etc.

We identified 17 studies that developed model to predict social distancing[12-20, 22-29]

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and4studiesto predict public health measures like use of face mask and hand washing.[21,30-32]

The overview of the screening of study articles is mentioned in PRISMAchecklist-based diagram in figure1, out of 664 articles, 410 articles were identified after removing the duplicates. Further after screening of the title and abstract, 37 articles fulfilling the inclusion could for full text review. During full text review 16 articles were excluded and 21 articles were considered for the review. Hence, finally 21articles were included for this review and the characteristics of the included studies are summarized in the table 1.

Effects of public health measures

Physical and social distancing

Studies mentioned here have simulated social distancing to predict epidemic peak. A study used reproduction number to predict the containment of high-risk people, social distancing or lockdown. With a R_0between 1.5–2.5 over 7days (recovery rate: $\gamma=1/7=0.14$), the noticeable part of the epidemic lasts about 45–90 days. [22] Another model demonstrated that interventions on sustained physical distancing has a strong potential to reduce the magnitude of the epidemic peak and the median (IQR) number of infections to more than 92% (66-97) and 24% (13-90) of otherwise expected by mid and end of year 2020 respectively.[27]One study predicted the effect of six strategies namely 'Social distancing', 'School closures', 'Self-distancing and teleworking', 'Self-distancing and teleworking plus School closure', 'Restaurants, nightlife and cultural closures' and 'Non-essential workplace closures' if implemented will reduce the probability of second peak of infections.[13]Another one also predicted the different duration to be recommended for social distancing. It predicted that, one-time social distancing will reduce the epidemic peak and will postpone the epidemic, intermittent social distancing will help in maintaining health care services. Hence a persistent and intermittent social distancing measure will contain the epidemic.[12]There were two studies that predicted the effect of mobility on the epidemic curve.[15,26] The concept that the expression R allowed to find the precise reduction of mobility (K_0or people at isolation0.7) was mentioned by one model, which helped to form the policy of total lockdown enforced by Spain.[15]Another study predicted that, if the values of K_0 is small, the epidemic curve becomes flat and promotes social distancing.[26] In a included study, 4 social distancing interventions were studied against different infectious periods, 1) adult age >65 years with contact reduced to 95%, 2) adult age >65 years with contact reduced to 95% and children contact reduced to 85 % , 3) adult age >65 years with contact reduced to 95% and adult < 65 years contact reduced to 25 %, 75 % or 95% and 4) adult age >65 years with contact reduced to 95%, children contact reduced to 85 % and adult < 65 years contact reduced to 25 %, 75 % or 95%. It was found that the fourth strategy delayed the epidemic by more than 50 days which was the longest and was not affected with the infectious period. Similarly, they also predicted 3 social distancing interventions of adults with timeframe (50and 80 days) after the first case were identified. It was found that the intervention was effective if started early in the epidemic curve.[19]

Two included studies predicted that physical isolation / social distancing will reduce the proportion of infections. The combined interventions along with quarantine, school closure; along with Isolation

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and workplace distancing was effective in decreasing the estimated number of infections by 99.3 % (IQR 92.6- 99.9) when Ro was 1.5. And further by 93 % (81.5-99.7) and 78.2 % (59.0 -94.4) when Ro was 2.0 and 2.5 respectively.[33] Whereas another study has found that physical distancing will reduce the proportion of infectious people and reduce the Ro, thereby delay the epidemic and can flatten the curve respectively.[29]

A disease modeling study assessed the impact of relaxing social distancing using the mobility pattern of the population using mobile phone data. The reduction of the Ro coincided with the mobility pattern. The reduction of infection was mainly due to the behavior change of the \population.[18] The Studywhich predicted that around 13,800 cases and 11,400 cases will occur in nationwide and in Daegu/ Gyeongbuk region by mid of June respectively, hence the advisory on behavior change like wearing mask and practicing social distancing was issued to reduce the transmission rate.[28]

Studydone in Lombardycan in its prediction model found that therate of hospitalizations depends on the contacts value. By fixing the contact value to 3.5 contacts/day and the containment for 90 days and 120 days respectively, they were able toavoid the surge in hospitalized cases. Whereas with 7.5 contacts/day in Emila-Romagna, the number of cases hospitalized could be practically controlled.[20] There was a study using dynamic cycle model where a “50-day suppression followed by 30 day relaxation” will reduce the transmission of the disease, case severity and death. This measure of strict social distancing and relaxation will ease the detrimental effects on the economy of the country.[24]

A Chinese study estimated about 114325 cases in mainland China and that without Non-Pharmacological Interventions (NPI) the cases would have increased 67-fold (44-49 IPR) during a specified period. In the view of lifting the travel restrictions, if social distancing is followed increase in cases will not be there.[34]In an included study the model predicted the risk of transmission by use of data from USA, Australia, Canada and China in travel restriction.[23] One study predicted the optimal time for social distancing (For all simulations, 1=10; T = 30 days, r = 0:55; I(0) = 0:01%.).[14]

Individual level public heath interventions like wearing mask and hand washing:

One model demonstrates that if social distancing is relayed as the only measure, then the number of contacts per individuals should be reduced to 27%so as to reach Ro=1.0. Similarly, for the measures like contact tracing and quarantine, the reduction of Ro is greater if contact tracing and quarantining the individualshappens within 2-3 days after contact. The other individual level public health interventions like social-distancing, mask- wearing, frequent hand washing etc, may reduce the transmission of disease. The model predicted 96% of people wearing mask alone could flatten the epidemic growth at 0.3/day and by this Ro reduce from 3.68 to 1.[32]

There was a study which forecasted that thenumber of cases reduced if public health interventionswere implemented. If the public health intervention is followed to 70 % efficacy the number of cases reduced to 11,056 from 36,809. Among the public heath interventions use of facemask was the most effective.[30]

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With fixed transmission rate of 80%; the adoption of 20, 50 and 80 percentages effective use of face mask reduces mortality 1.8%, 17% and 55% respectively in New York. But with the same measures the reduction of mortality was 65%, 91% and 95% in Washington.[21]

In a model which performed long-term analysis with the Markovian process, predicted that wearing mask can help on reducing the infection rate.[31]

Quality assessment:

As mentioned in Table 2, based on the assessment tool, the scores of the studies were in the range of 10to 25. Among the studies, 1 study was considered as very high quality, 5 studies of high quality, 11 were medium quality and 4 were low quality. The issues identified in the quality assessment are the studies have not mentioned 'Aims and objective, assumption explicit and justified, quality of data and uncertainty, model validation, model fitting'. The studies with very high quality, have not mentioned 'model validation, assumptions explicit and justified, Quality of data and uncertainty'. As most of the studies have been conducted within short period and in spite of that the quality of most of the studies are not questionable.

Discussion:

The included studies have predicted various outcomes like reduction in the transmission of infection; effectson epidemic like delay, flattening and postponement of the epidemicprogression. These studies have also highlighted the benefits ofthese outcomes like reductioninthe proportion of infectious people which will help in breaking the infection chain, improve the health care services, will ease the economy of the country.

Few of the included studies have predicted the benefit of social distancing on health care services. Onestudy predicted that one time social distancing will push the peak in cases to further period even till 2022 and emphasizes the need to increase the critical care capacity so asto control the epidemic.[12]Another study recommends that social distancing should be strictly followed so as to avoid the collapse of health system.[13]As predicted the current health system is not equipped adequately with enough Intensive Care Unit (ICU) beds and other emergency care facilities to deal the rapid rise in number of cases and that public health measures will help in cope epidemic.[26] A study measured social distancing using Global positioning System GPS data and found that increase in social distancing was associated with reduction in COVID 19 incidence and mortality.[35]In a study it was highlighted that in countries where social distancing measures was promoted there was a decline in daily confirmed case numbers.Even though social distancing is an effective measure in limiting the spread of COVID - 19 till the vaccine or medicine available.[36]This study measured the benefit of implementing social distancing measures using interrupted time series analysis. And it mentioned that there was reduction in new cases and decrease in death due to COVID - 19 after implementing social distancing.[37]

Extreme control measures like lockdown will affect the psychological/mental status of the people and destroy economy, public health measures like social distancing, use of face mask and hand washing will help to get rid of the above crises, but at the same time aiding to control the pandemic.[38] As predicted China could contain the epidemic by implementing the all forms of public health intervention and by strictly following the use of Individual face mask by its population.[39]Two included studies[30-31] have also predicted the effect of wearing of 'universal face mask usage' will reduce the infection rate[30] and cause a drop in cases & ICU and Isolation ward beds.[31] A case-control study found that wearing mask all the time was associated with reduced infection of COVID-19. It also highlighted that individual level public health measures like wearing of masks and consistent hand washing will reduce the infection.[40]

Few of the studies have predicted that nosingle measure can break the epidemic,combination of social distancing, other containment measures like closure of school, restriction of travel, cclosure of restaurant/night life/cultural etc., if followed for longer duration will have better effect.[13,16,28]As complete lockdown and other containment measures will affect economy of the country the world hasto rely on the individual level behavior and practices based public health measures like social and physical distancing, hand washing and use of face masks. These interventions are well predicted by the infectious disease models. The report of WHO- China joint mission has also mentioned the role of non-pharmacological measures in controlling COVID- 19 in China.[39]

To conclude, as the vaccine or drug for COVID - 19 might take quite some time, following public health interventions like social and physical distancing; compulsory use of facial mask by all people seems to be the solution to bring down the dynamics of the epidemic and also to prevent further progression.

The limitation of this review is that lackof funding restricted our search only to subscription free search engines, PubMed and Google Scholar. If the search would have done in Medline, Embase, etc., then the review would have been more complete. As the process of model evaluation and validation is not mentioned explicitly by name in many articles, we may have missed to identify the process.

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Fig.1: PRISMA (preferred reporting items for systematic reviews and meta-analyses) flowchart of included and excluded studies

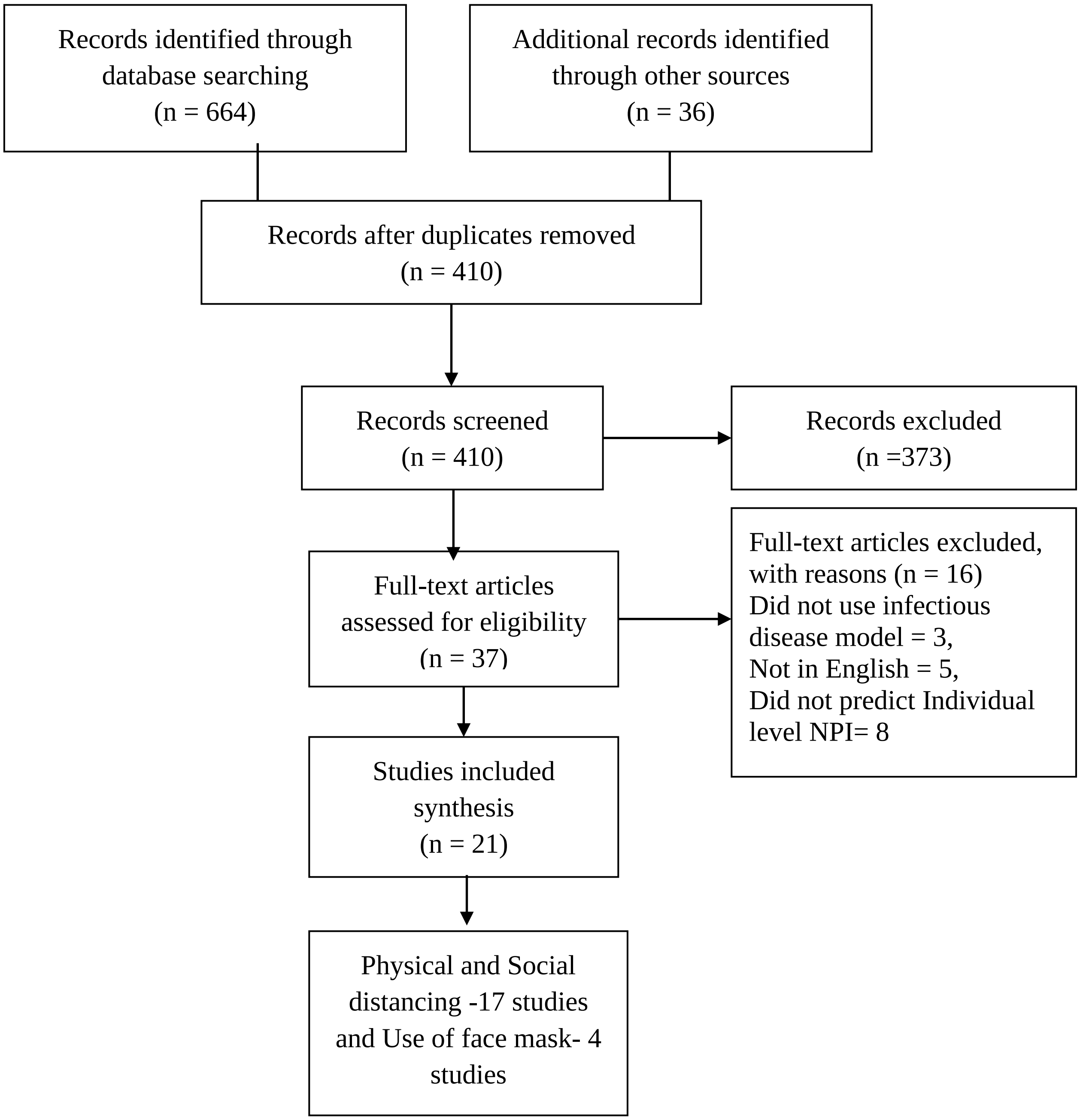

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Table 1: Overview of Included studies predicting Individual level Public health interventions

Sl. No	Study: Setting and outcome	Modeling Methods	Model Predictor Methods:AI / Simulation methods	Intervention Stimulated	Epidemiologial parameters	Self reported limitations	Overall risk of bias	Inference
1	Kissler S; USA; One-time scoial distancing will reduce epidemic	(SEIR) model with three tracks	Sensitivity analysis	One time or intermittent social distancing	Maximum wintertime Ro is 2.5 and summer time Ro is 1.75. Social distancing results in 60 % reduction in Ro.	Not mentioned	14	Intermittent Social distancing will push the epidemic into 2022. Care for critically ill patients by increasing critical care capacity can reduce the duration of epidemic.
2	Calvo D M;USA; Six different social distancing strategies	SIR model	Contact network	Social distancing strategies: 1.School closures,2.Self-distancing and teleworking, 3.Self-distancing and teleworking plus School closure,4.Restaurants, nightlife and cultural closures 5.Non-essential workplace closures, 6.Total confinement	R(t) and the epidemic dynamic change.	1.Social mixing by age is not considered, 2. mobility data is biased, 3. Children are not present in community layer	15	1.Passive social distancing is not enough to contain the epidemic, other measures like school closure, resturant / cultural closure if implemented upto 90% for long duration will minmise the effect of epidemic. 2. If social distancing is lifted the epidemic wiil spread again and produce a second peak.
3	Lomba PA ; NA; Effect of time temporal social distancing	SIR model	Numerical simulations	Social distancing intervention (7, 14 and 30 days)	Optimal timing for social distancing (7, 14 and 30 days) vs pharmacological interventions was investigated corresponding to R0 = 2.	Not mentioned	23	The optimal timig of social distancing depends on the reproduction no of the disease .
4	Wittkowaki KM;USA; Containment of high-risk , people, Social distancing or lockdowns	SIR model	Not mentioned	Effect of Social distancing or lockdownor containment of high risk	Reducing the number of contacts will reduce Ro	Lack the sophistication and potential additional insights that could come from fitting	22	Social distancing is beneficail only during intial peak of incidence. Containment of low-risk people will prolong the epidemic.
5	Arenas A;Spain ; predict the incidence /total lockdown	Microscopic Markov Chain Approach(MMCA)	Not mentioned	Social distancing	IP- $\eta-1 + \alpha-1 = 5:2$ days / infection period is established as $\mu-1 =$ 3:2 days/period from ICU admission to death as $-1 = 7$ days]/and ICU stay to overcome the disease as $\chi-1 = 10$ days	Not mentioned	18	Application of scoial distancing measures are urgent so as to avoid the collapse of health system
6	Prem K;Wuhan, China;physical distancing measures	Deterministic age-structured SEIR mode	Not mentioned	Physical distancing	Physical distancing measures were most effective if the staggered return to work was at the beginning of April; this reduced the median number of infections by more than 92% (IQR 66–97) and 24% (13–90) in mid-2020 and end-	Did not capture individual-level heterogeneity in contacts, which could be important in super-spreading events,particularly early in an epidemic.	16	Interventions based on sustained intervention of physical distancing has the potential to reduce the magnitude of the epidemic peak.

					2020, respectively.			
7	IslamM M; China ; Risk Index, travel specific risk, Area specific risk	SEIR	Not mentioned	Physical distancing and air travel	RI is 0.00691484	Not mentioned	12	Avoiding mass gathering, maintaining physical distances and restricting air travel will help in tackling COVID 19 transmission.
8	Ming WK; China, Burden of healthcare system lockdown of city, Efficacy of public health intervention	Modified SIR model	Not mentioned	Public health interventions	1.70 % efficacy of public health intervention the number of cases dropped to 11,056 when compared to 36,809 without public health interventions, 2. With 80 % to 90% efficacy the cases would drop further.	Not reported	13	Among the public health preventive measure wearing facemask is feasible and to be operationalised.
9	Yang Q;China; Effectiveness of non-pharmaceutical interventions on daily cases and the epidemic peak	SIR model with ensemble Kalman filter (EnKF) / Long-term analysis: (SEIR) compartmenta l mode with GEMF	Not mentioned	Non-pharmaceutical interventions .	1. Infection rate 'β' is 0.12 for 0-7 days and drops to 0.027 for 8-10 days. From day 19 the 'β' drops to 0.02 indicating the effect of public health intervention. 2.When 'β' was reduced by 25 % the number of infections cases would peak by day 22 (median:24; IQR: 19-27) and fade by day 250, 3. Reducing the 'β' further will reduce the number of infectious case.	1.infectious period and incubation period do not follow exponential distributions, 2.Simulations suggest that future works need to consider distributions of epidemiological characteristics to better capture the COVID-19 spreading trajectory	20	1.Implementation of protective measures and social distancing measures epidemic would peak.2.Preventive measures such as wearing masks can help reduce the infection rate.
10	Tian L; China; Effect of basic reproduction number under specific disease control practices	Semi-quantitative model- SEIR	Not metioned	Contact tracing, testing,social distancing, wearing masks and staying at home	Wearing mask at 96 % will flatten the epidemic growth at rate of 0.3/ day by decreasing the Ro to 0 from 3.68. The effects mutilies is combained with contact tracing.	1. The role played by asymptomatic carriers of the virus was not considered, 2. Assumption that the reproduction rate function for this group of infected individuals is weaker or the same	9	The epidemic growth can be faltted in 4 day if 70% of the public could wear mask and if the efficacy contact tracing is at 60 %.
11	Arenas A;Spain; Mobility restrictions and confinement measure	Epidemic spreading model, Microscopic Markov Chain Approach (MMCA)	Sensitivity analysis	Mobility restriction and social distancing	If the confinement measrures increased (Ko-0:6 − 0:8) there is a dramatic in the behavior of the epidemic curve.	Not mentioned	22	COVID-19 pandemic will overload the critical capacity of health systems. The implementation of restriction of mobility and social distancing reduce the impact on health systems.

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12	Koo JR ;Singapore; Effects of quarantine, school closure, and workplace distancing	FluTE,15 an agent-based epidemic simulation model	Sensitivity analyses	Social distancing	Median cumulative number of infections at day 80 was 279 000 (IQR 245 000–320 000), corresponding to 7·4% (IQR 6.5–8.5) of the resident population of Singapore	1. Migrant workers, tourists and long-term visa owners were considered not accounted. 2. Uncertinity on avoiding mass gathering, maintaining physical distance and restriction on aflight services, 3. Heterogeneous of Contact pattern is heterogeneous.	21	Combined approach of quarantine, school closures, and workplace distancing can prevent a outbreak when the infectivity is low and reduce the total infections when the infectivity is high.
13	KathyC : China; Transmissibility and sverity after pubic health intervention	SIR	Markov chain Monte Carlo	Social distancing measures and behavioural measures	The region were control measures was implementes, Rt was <1. The cCFRwas -0.98% (0.82-1.16) to when compared to other regions 1.76%(1.11-2.65).	1.The number of confirmed cases might have under reported. 2. No of imported cases varied arcoss the regions	19	Non-pharmaceutical interventions like scoial distancing and behavioural changes has reduced transmissibility.
14	Lemaitre CJ: Switzerland: Assess the impact of these NPIs	Stochastic transmission model	Stochastic compartmental model	Mobility changes for catgories: grocery & pharmacy, parks, transit stations, retail & recreation,residential and workplace	Ro was 3.15 (95% CI: 2.13-3.76) at the start of the epidemic.	1.Time distribution of in- and out-of hospital patients is biased towards shorter duration,2.limited data 3. Not possible to disentangle the individual contribution of each NPI on Ro	18	These results warrant a cautious relaxation of social distance practices and close monitoring of changes in both the basic and effective reproduction numbers.
15	Peirlinck M ; China and the United States: effect of relaxing political measures including total lockdown, shelter inplace, and travel restrictions	Integrate a global network model with a local epidemic SEIR model	mentioned	Isolation and social distancing	China: latent period of 2.56 ± 0.72 days, a contact period of 1.47 ± 0.32 days, and an infectious period of 17.82 ± 2.95 days. USA: contact period: 3.38 ± 0.69 days, basic reproduction number of 5.30 ± 0.95	Initial exposed group E0 is really unknown	14	This mathematical modeling can help estimate outbreak dynamics and provide decision guidelines for successful outbreak control.
16	Chowdhury R;16 countries from Europe, South and North America, Africa , South and West Asia and Pasific; Effect of de COVID-19 transmission under various NPIs.	SEIR compartmental model	Mentioned	NPI including Social distancing	Assuming Ro of 2.2 for no intervention, effective Ro of 0.8 for dynamic mitigation and 0.5 for suppression interventions. The dynamic cycle of 50 days of mitigation and 30 days of relaxation decreased the transmission, but could not reduce ICU demands. But in dyanmic cycle of 50 days of supperesion and 30 day of	Absence of country-specific, real-time, reproduction numbers for the epidemic, we assumed a constant transmission rate during each modeled cycle	16	The strategy of intermittent reductions of R below 1 through a combination of suppression interventions and relaxation can be effective for control of this pandemic. But in low income countries social distancing measures will be of more feasible where sustained suppression intervention is not pratical.

					relaxation could lower the ICU hospitaliztion.			
17	Matraj L;USA; Effectiveness of Social Distancing Interventions to Delay or Flatten the Epidemic Curve of Coronavirus Disease	SEIR model	Not mentioned	Social Distancing	Interventions reduced contacts of adults >60 years of age, adults 20–59 years of age, and children <19 years of age for 6 weeks. Social distancing can provide crucial time to increase healthcare capacity but must occur in conjunction with testing and contact tracing of all suspected cases to mitigate virus transmission.	1. Overestimate the final size of an epidemic 2. Predict a rebound in the epidemic once the intervention is lifted if the number of exposed or infectious persons is >0.	16	Social distancing interventions should be followed along with testing and contact tracing to reduce the pandemic.
18	Kim S;South Korea; To predict epidemic size and the time to end of the spread	SEIR model	Not mentioned	Social distancing and Delayed school opening	Final size of epidemic = 13,830 Final incidence rate per 100,000 = 26.49, End of outbreak = Jun 14, 2020	Not mentioned	14	By considering behaviour changes in the prediction contributed to decrease in total number of confirmed cases and duration of outbreak.So, Even after schools opens it is necessary to suggest public health measures like mask wearing, hand washing and avoid close contact.
19	Reno C; Italy; Burden on hospitalizations under different conditions of social distancing	Eextended susceptible-infected-removed (eSIR) model	Sensitivity Analysis	Different conditions of social distancing	Minimum contact rate (cb) is set from 1.0 to 2.4 contacts/day and final contacts achieved have been set to 3.0. By following strict containment (cb = 1.0) it is possible in reducing the severity of the outbreak.	Not mentioned	16	Daily contact should be reduced to to half daily in Emilia Romagna(contact rate= 7.4) and to more than two thirds in Lombardy (c = 3)
20	EikenberryES;USA; Impact of mask use	SEIR model	Not mentioned	Face mask use by the general public	Considering a fixed transmission rate (b0) 80% adoption of 20%, 50%, and 80% effective masks reduces cumulative relative(absolute) mortality by 1.8% (4,419), 17% (41,317), and 55% (134,920), respectively	Theoretical results should be interpreded with caution beacuse of i.high rate of non-compliance with face mask usage. ii. the efficacy of the mask in blocking the droplets and aerosols	13	Our results suggest use of face masks by the general public is potentially of high value in curtailing community transmission and the burden of the pandemic.
21	Shengjie Lai S;China;Effect of non-pharmaceutical interventions (NPI) in containing the outbreak	SEIR model	Sensitivity analyses	Travel restricttion and contact distancing	Total cases of Covid-19 is 114,325 (interquartilerange 76,776 - 164,576) in mainland China as of February 29, 2020. Without NPIs, the cases would likely have shown a 67-fold increase (interquartile	1.As the Simulations were based on symptomatic cases , asymptomatic and mild infections could have missed 2. Confounded by	14	Early detection and isolation of cases have prevented more infections than travel restrictions and contact reduction. But when combined with NPI the effect was rapid and stronger. It will effective even if the Social distancing interventions is maintained, at 25%.

					range 44 - 94) by February 29, 2020.	other factors that changed during the outbreak.		

Ro / Rt =Reproduction number, cCFR= confirmed case-fatality rate, IP=Incubation period, K0= confinement measures, RI

Table 2: Assessment of quality: Score and items not mentioned in the included studies

Quality assessment	Number	Items not mentioned
< 14	4	Aims and objective, parameters, ranges and data sources, assumption explicit and justified, Quality of data and uncertainty, model validation, methods of fitting, structure and time horizon, Interpretation and discussion of results, Funding sources and conflict of interest
14 – 18	11	Aims and objective, assumption explicit and justified, Quality of data and uncertainty, model validation, structure and time horizon, methods of fitting, Intervention/comparators, parameters, ranges and data sources, Funding sources and conflict of interest.
19 – 22	5	Aims and objective, assumption explicit and justified, Quality of data and uncertainty, model validation, model fitting,
>22	1	Model validation, assumptions explicit and justified