Empowering the crowd: Feasible strategies to minimize the spread of COVID-19 in high-density informal settlements

Authors names TBA

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Abstract

Background, Methods, Findings, Interpretation, and Funding. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetuer id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

Introduction

The COVID-19 pandemic is intensifying in the developing world [1]. In Africa, SARS-CoV-2 has been spreading from urban areas to informal settlements [2]. With more than 1 billion people living in informal settlements worldwide, urgent action is needed to contain the virus in these settings, a task which necessarily involves the engagement of the communities living in them [3].

The need for action is even more pressing in regions immersed in protracted armed conflicts, where large portions of their populations have become displaced. When the displaced population exceeds official resettlement and refugee camp capacity, Internally Displaced Persons (IDPs) must live in informal settlements (hereafter named "camps"). These regions must contend with the public health challenges resulting from violence [4], the deterioration of health-systems [5], especially of critical care [6], and the breakdown of essential public infrastructure such as water and sanitation systems [7].

This research focuses on the Northwest region of Syria (NWS): a relatively small geographical area with 4.2 million people, of which 1.15 million (27.4%) are IDPs living in camps [8]. The health status of households in camps in NWS is poor; 24% have a member with a chronic disease, of whom 41% have no access to medicines [9]. As in other conflict regions, the political instability in NWS hinders coordinated public health actions, and the ongoing movements of IDPs create ample opportunity for infectious disease transmission, while making contact tracing interventions infeasible.

To investigate feasible COVID-19 prevention interventions in the camps, we considered a Susceptible-Exposed-Infectious-Recovered model in which the camps' populations are divided into classes reflecting their estimated age-structures and comorbidity prevalence [SM Table 2]. We use this model to propose a number of interventions aimed at reducing the number of contacts within and between population classes in general, and with symptomatic individuals in particular. We paid special attention to how the living conditions in informal camps inform the assumptions underlying our proposed interventions. We modeled interventions previously proposed for African cities [10], such as self-distancing, isolation of symptomatic individuals and the creation of a 'safety zone' in which more vulnerable members of the population are protected from exposure to the virus.

Building upon the approach used to model the impact of these interventions in African cities, our model includes a parameterization of the contacts each individual has per day [10]. We further elaborate upon this approach by making a more explicit representation of contacts and other parameters in the model. We consider the micro-dynamics of contacts, the time that individuals take to recognize their symptoms before self-isolating, the effect of having care-givers to attend isolated individuals, and the existence of a buffering zone in which exposed and protected population classes can interact under certain rules, among other details. We examine a potential worst-case scenario in which there is no access to any healthcare facility. Since empowering local communities in conflict regions to understand how to control COVID-19 is possibly the most (and perhaps only) effective way to minimize its spread, our models are of utmost importance for informing the implementation of realistic interventions in these regions.

Methods

The model

We considered a discrete-time stochastic model, simulating a viral outbreak in a single camp over a 12 month period. The model is divided into compartments containing individuals at different possible stages along the disease's progression [SM Fig 1], and splits the population into classes by age and comorbidity status . The simulation starts with a completely susceptible population where one person is exposed to the virus. The disease in exposed individuals progresses through a preclinical infectious stage, followed by either a clinical (symptomatic) or subclinical (asymptomatic) infectious stage, resolving through recovery or death. Additional susceptible individuals become infected through contact with infectious individuals. We verified that a steady state was always reached before the end of each simulation. We did not consider migration, births, nor deaths due to other causes, since they are small enough in magnitude to not significantly impact the course of an outbreak, provided additional conflict does not erupt.

Population structure

We parameterized the model with data from IDPs in NWS [11]. The population size of informal camps is log-normally distributed, with a mean of 600 individuals. We simulated camps with 500, 1000 and 2000 individuals. Since interventions tend to be less effective in larger camps, the results presented refer to simulations with 2000 individuals, unless otherwise specified. We considered 3 age groups: age 1 (0-12 years old), age 2 (13-50 yrs.) and age 3 (>50 yrs). For ages 2 and 3, we considered two subclasses comprising healthy individuals and individuals with comorbidities. The fraction of a simulated camp's population in each of these 5 classes is shown in [SM Table 2].

Epidemiological severity assumptions

In NWS, there are 975 hospital and community-based treatment (CCTC) beds (1410 planned), 114 ICU beds (188 planned) and 86 ventilators available (159 planned) for 4.2 million people [12, 8]. Basic estimation predicted a collapse of the health facilities after 8 weeks of the outbreak [13]. Hence, we considered a worst-case scenario in which individuals will not have access to healthcare. We consequently assumed that all critical cases, those requiring ICU care, would die. However, there is greater uncertainty of the fate of severe cases, those requiring hospitalization but not ICU care. We therefore considered a compartment for severe cases to account for a longer infectious period if they stay in the camp. This compartment also helped us model some interventions more realistically, for example by noting that the symptoms of severe cases are incompatible with self-isolation. To estimate upper and lower bounds for the outcome variables of our model, we simulated two possible scenarios for the fate of this compartment: one in which all cases recover, and another in which all die. In the simulations presented in the Main Text, we consider the worst-case scenario in which all of these cases die.

The fractions of symptomatic cases that are severe or critical are class-specific (parameters h_i and g_i, see [SM Table 2]). We estimated these parameters using data from developed countries with superior population health [14, 15]. Following previous work [10], we reasoned that the case severity distributions of NW Syrian adult population classes would correspond with those of older age groups in developed countries.

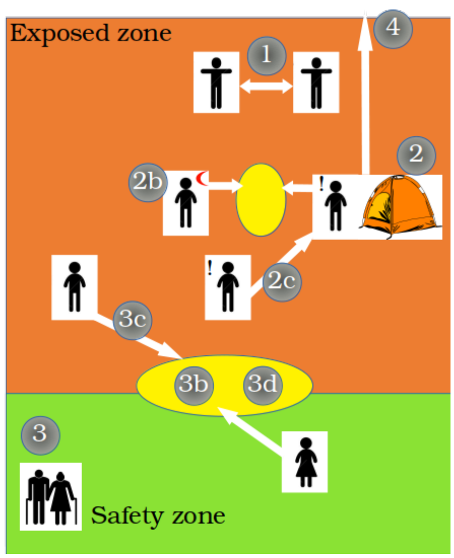
Transmissibility assumptions

Although asymptomatic individuals have been considered less infectious in previous models [10], our estimated 16% of cases being asymptomatic [16] may be an underestimate when considering recent findings that up to 49% of cases may be asymptomatic [Ref]. To compensate for this discrepancy, we consider asymptomatic and symptomatic cases, in addition to presymptomatic and hospitalized cases, to be equally infectious.We obtained the duration individuals spend in each compartment from the literature [SM Table 1].

Each individual's contact rate [SM Table 2] is class-specific, and was estimated from conversations with camp managers in NWS. The probability of random interaction with an individual from each class is proportional to this class' fraction of the population. The product of these two values is the contact rate between two respective classes.

The probability of infection from contact with an infectious individual, τ, was estimated from a Gaussian distribution of the basic reproduction number, R_0, with mean of 4 (99% CI:3–5). This distribution was a compromise between values reported in the literature from regions with high-density informal settlements: R_0=2.77 in Abuja, 3.44 in Lagos [17], 3.3 in Buenos Aires [18], and 5 in Rohingya refugee camps in Bangladesh [19]. The probability distribution of τ was estimated by randomly generating a value for R_0, and dividing this value by the real part of the main eigenvalue of the Next Generation Matrix (see Supplementary Material).

Interventions



	Intervention	Description	Levels
1	**Self-distancing**	Reduction of mean number of contacts per day and individual	20%, 50%
2	**Self-isolation**	Isolation of symptomatic (!) people in individual tents	Available tents: 10, 20, 50, 100, 250, 500, 1000, 2000
2b	Number of carers	Number of carers	1 per tent
2c	Self-isolation delay	Time from symptom onset to self-isolation	12h, 24h, 48h
3	**Safety zone**	Designated area for vulnerable population	Elderly only, elderly + adults with comorbidities, elderly + adults with comorbidities + kids, up to 20%, 25%, 30% of the population
3b	Number of contacts	In the buffering zone	2, 10 contacts per week and individual in the safety zone
3c	Health checks	Exclude symptomatic from buffering zone	
3d	Lockdown of buffering zone	Lockdown if one case is detected in the population	Reduces value of 3b by 50%, or 90%
4	**Evacuation of severely symptomatic**	Evacuated individuals cannot infect other people, but they do not receive healthcare	
	Buffering zones	Open space, 2m distancing, use of face cover	Reduces probability of infection by 80%

Figure 1: Diagram of interventions

Self-distancing

We considered a situation in which the whole population reduces their mean number of contacts per day by a certain magnitude (20% or 50%) (see Fig. 1-1) Since the mean number of people per tent in a camp is 7 [verify], we considered that the number of contacts per day cannot be reduced by more than a 50%. For an adult, this would mean 7.5 contacts per day.

Buffering zone

Since only moderate self-distancing can be reached, additional social distancing can be implemented by splitting the population in subgroups occupying different zones of the camp, and limiting the contact between individuals of different subgroups to specified locations named buffering zones. We envision these zones as open spaces, with guidelines in place to limit occupancy to 4 individuals wearing masks, with 2 meters separating individuals from the two separate zones. We assume that non-compliance will be such that the probability of transmission from contacts will be reduced by 80% compared to the baseline (see Fig. 1).

Self-isolation

Self-isolation is a challenge in informal settlements, where households consist of a single(often small) space, water is collected at designated locations, sanitation facilities are communal and food supplies are scarce. We considered the possibility of those showing symptoms self-isolating in individual tents in dedicated parts of the camps, or next to the tents of their relatives. We simulated this intervention with 10 isolation tents per camp, up to 2000 (see Fig. 1-2). In addition, we modeled the role of care-givers dedicated to supplying isolated individuals, who interact with them via a buffering zone (see Fig. 1-2b). In considering one care-giver per individual with one contact per day, we do not neglect the probability of infecting the rest of the camp. We further considered that severe cases, or those in the hospitalized compartment, are fully infectious since they require more intensive care that is not possible to deliver while adhering to the guidelines of the buffering zone. We also considered minimum time intervals for individuals to recognize their symptoms: with means of 12, 24 and 48 hours (see Fig. 1-2c).

Safety zone

In this intervention, the camp is divided in two areas: a safety zone, in which more vulnerable people live (hereby referred to as a "green" zone following previous studies [10]), and an exposed (orange) zone with the remaining population. In the simulations, the first exposed individual always belongs to the orange zone. We avoided the use of the term "shielding" to describe this intervention, since it may erroneously suggest that the vulnerable population is isolated in a closed space, such as a separated building. Such an intervention would require additional assumptions on how contacts occur in a closed space. The living conditions within both zones remain the same so, the overall contact rate does not change unless self-distancing is also implemented. In practice, reducing the contact rate with individuals living in a different zone implies an increase in the contact rate with individuals in the same zone (see Supplementary Material). This allows us to investigate undesired side-effects of this intervention. Since proposals for partitioning the population may be received differently across camps, we considered several scenarios for allocating a camp's population to the two zones (see Fig. 1-3).

Interaction between the two zones is limited to a buffering zone. If individuals in the green zone cannot leave and thus need to be provided with supplies by individuals in the orange zone, any delivery of supplies will necessarily take place in the buffering zone. In our simulations, we considered limiting individuals in the green zone to 10 or 2 contacts with individuals from the orange zone per week (see Fig. 1-3b). Other variations on this intervention we explored include preventing symptomatic individuals from entering the buffering zone (see Fig. 1-3c) and "locking down" the green zone, where their number of weekly contacts in the buffering zone is reduced by 50% or 90% (see Fig. 1-3d).

Evacuation

The last intervention we simulated is the evacuation of individuals in the hospitalization compartment. We assume the evacuees will be taken to isolation centers, not hospitals, so this measure does not change their fate [12] ; The only effect this intervention has is reducing the infectivity of evacuees to zero (see Fig. 1-4).

Analysis of the interventions

For each implementation of the interventions, we ran 500 simulations, and compared results between them. The main variables considered are the fraction of simulations in which at least one death is observed, a proxy for the probability of an outbreak, the fraction ofthe population that dies and the time until the symptomatic population peaks, as well as the case fatality rate (CFR) and the fraction of population that recovers. For consistency, we only considered simulations in which there was an outbreak when comparing the outcome of a variable between interventions. For pairwise comparisons between interventions, we used Student's t-tests for variables with equal variance and Welch's t-tests for variables with unequal variance. For multiple comparisons across non-orthogonal variables, we used Tukey's tests.

Results

When interventions are absent, the CFR takes values around 2% when we consider that individuals that would require hospitalization (but not ICU) are recovered (Suppl. Fig.), raising up to ~11% when we considered that all would die . In the following and unless otherwise stated, we consider the latter scenario to evaluate the interventions. In such scenario, the probability of observing an outbreak is close to 0.85, having that 10% of the population in the camp would die, with the number of symptomatic cases peaking after 55 days.

Self-distancing has a notable effect in reducing the probability of outbreak, with a 10% decrease when just a reduction of a 20% in the number of contacts was considered (Fig. 2A). It was, however, needed a reduction of up to 50% to observe a more nuanced decrease in the fraction of population dying, that could be reduced as much as a 35% (Fig. 2B). The same occurs for the time to the peak of symptomatics (Fig. 2C), which increases up to 110 days, hence doubling the values when there are no interventions in place. As a counterpart, the proportion of population recovered is reduced a 35% (Suppl. Fig.)

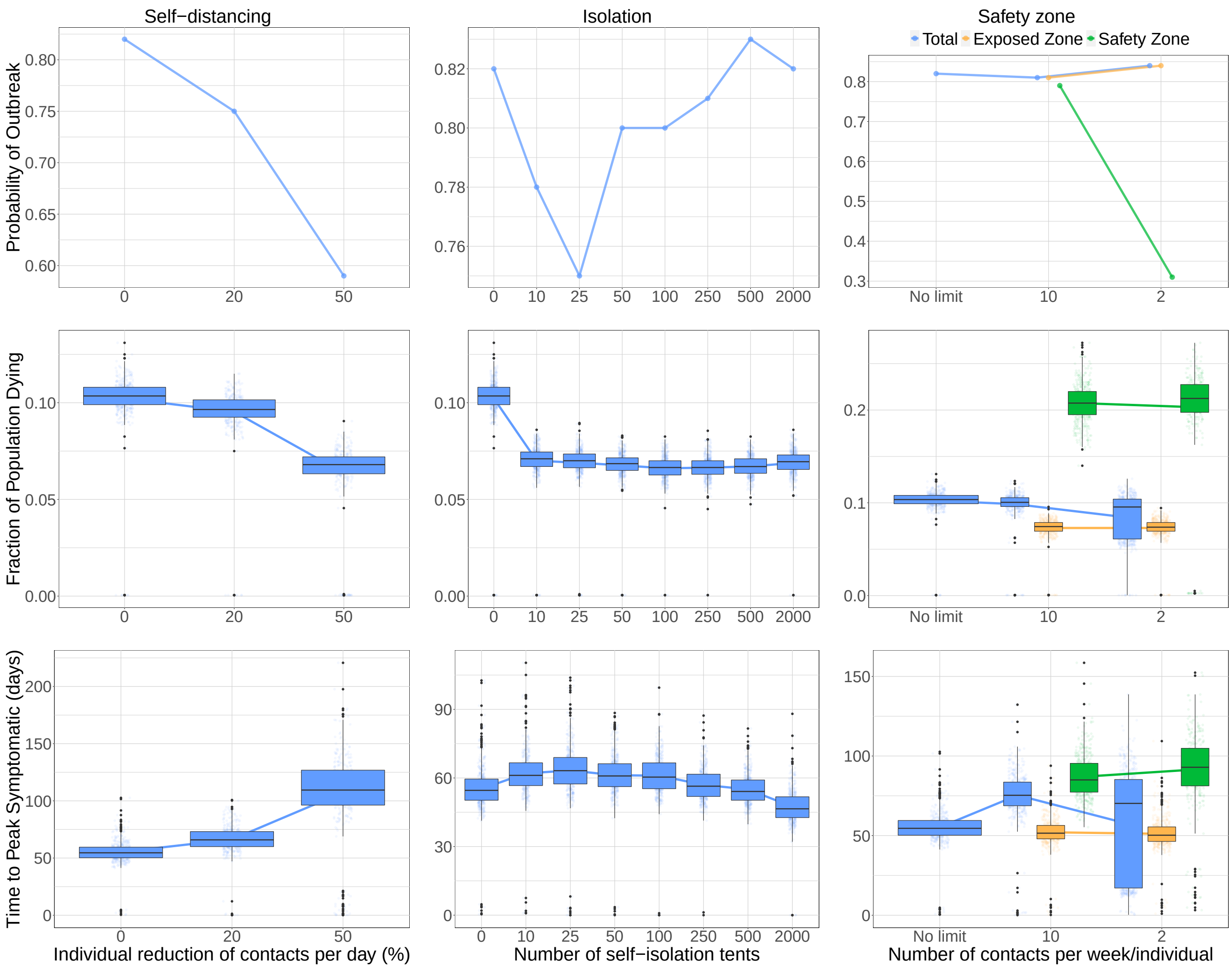


Figure 2: **Lower and upper bounds when interventions are absent.** Probability of outbreak (left-column), fraction of casualties (middle-column) and time in which the number of symptomatic cases peaks (right-column) for the interventions incorporating self-distancing (top-row) self-isolation (middle-row) and for the implementation of a safety-zone (bottom-row).

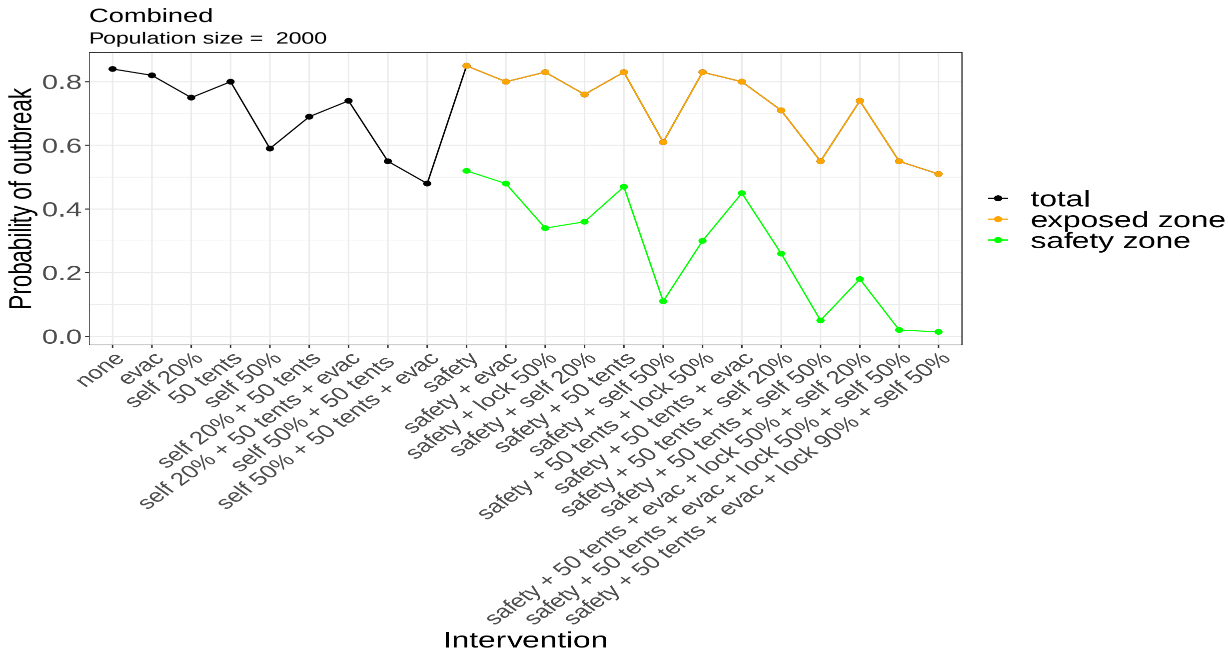
Self-isolation brings a modest decrease in the probability of observing an outbreak (Fig. 2D), but it provides a strong reduction in the fraction of population dying (~30%), when only 10 tents are available for a population of 2000 individuals, i.e. a 0.5% of the total population (Fig. 2E). Interestingly, increasing the number of tents does not significantly[?] enhance this reduction and, when the number of tents represent a 10% of the population, the fraction of deaths even increases. This effect is a consquence of having one carer per individual isolated (see Supplementary Material), whose side effect is that, when the number of isolated population increases, it also increases the number of adult healthy individuals in contact with the infected population. Still, the Case Fatality Rate experience a continuous, albeit small, reduction with an increasing number of tents (Supplementary Fig. XX).

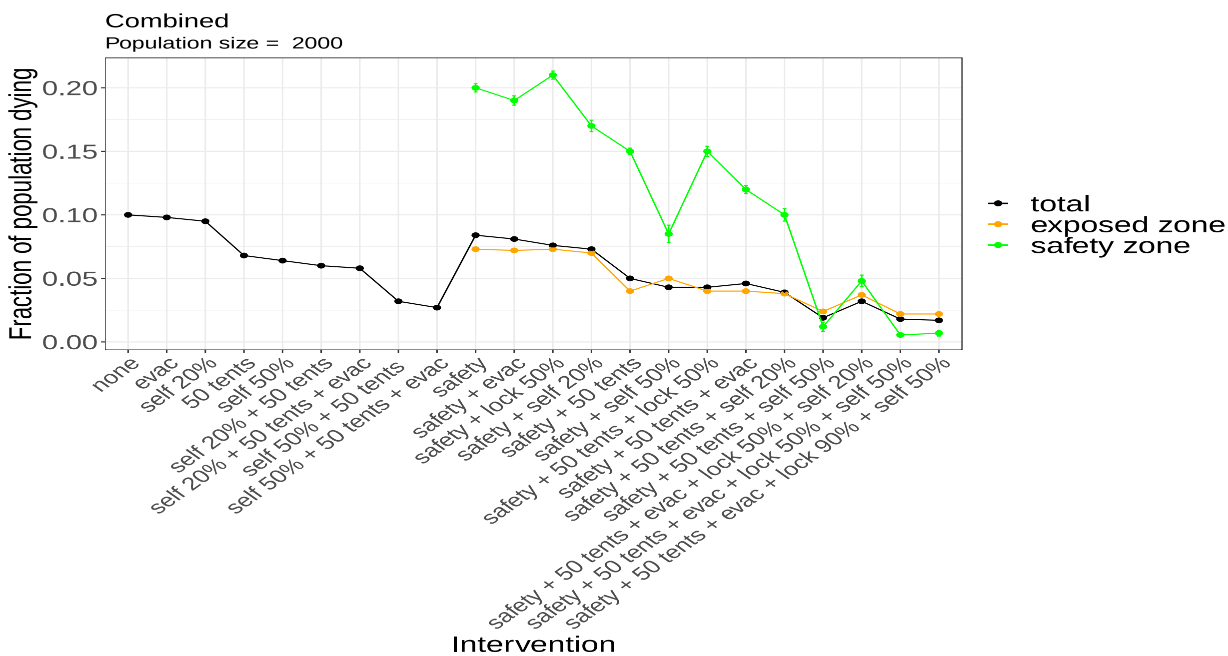
Importantly, these results hold when the time required for individuals to recognize their symptoms is of 24h on average, and the intervention becomes less effective when this time increases (Supplementary Fig. XX). On the other hand, reducing this time to 12h does not significantly reduce the fraction of people dying , but it does increase the time in which the number of symptomatic cases peak (Supplementary Figs. XX and XX). If we additionally consider that the symptomatic cases that would require hospitalization are evacuated, it is only observed a 2% reduction in the fraction of individuals dying (Supplementary Fig. XXX). Since we assumed that the evacuation does not change their fate, the intervention only affects their infectivity. Although the period between developing more important symptoms and dying is relatively long (~10 days), the number of individuals under these conditions is small, when compared to the rest of the infected population.

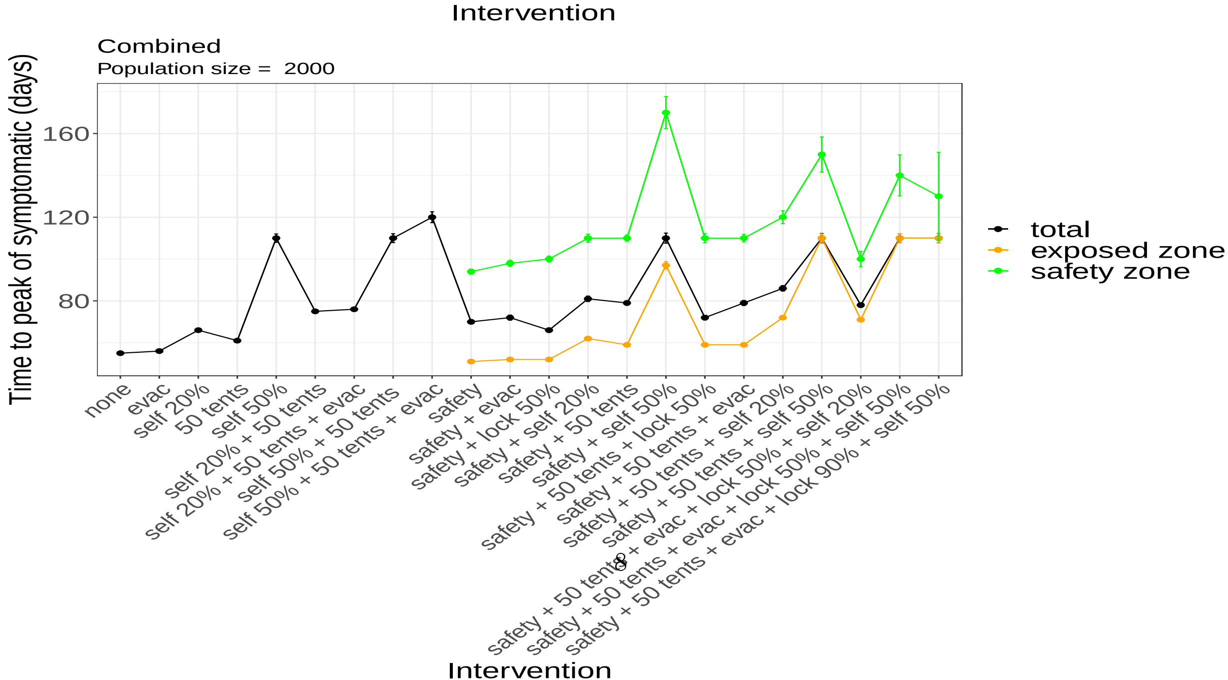
Creating a safety zone overall improves the effect of previous interventions, but sometimes with different outcomes for the exposed and protected populations. For instance, the probability of outbreak strongly decreases (almost 40%) for the protected population (see Fig. 2G). Notably, approximately 16% of this reduction is due to the health checks performed to get into the buffering zone, which exclude symptomatic individuals (Supplementary Fig. XX). On the other hand, the probability of outbreak may increase for the exposed population if the contacts per week and per individual occuring in the buffering zone are reduced to 2. This is a consequence of an increased number of contacts within subpopulations, which may also explain the increase in the CFR of the protected population (Supplementary Fig. XX), . Despite of this side-effect, the fraction of individuals dying for the protected subpopulation and, in turn, globally, is reduced (Fig. 2H). Another important outcome of this intervention is the notable increase of the time to peak of symptomatics, raising up to 35% globally, and to 70% for the protected population (Fig. 2I). Regarding the population moving to the safety zone, having only elderly or at most elderly and adults with comorbidities, guarantee a low probability of outbreak, which would otherwise increase the global fraction of population dying (Supplementary Fig. XX and XX). Positive effects of the safety zone are even more marked for smaller population sizes, except for the time to peak of symptomatic, which has a weaker effect for smaller populations (Supplementary Fig. XXX and XXX).

The incorporation of a lockdown again shows the side-effect in which, if there is an outbreak in the safety zone, it has a negative effect due to the increased number of contacts of individuals within the zone (Supplementary Fig. XXX). However, the probability of outbreak is very strongly reduced to a barely 10% and, consequently, when there is an outbreak in the camp (which in most of the cases will not reach the safe zone) the fraction of deaths decreases overall (Supplementary Fig. XXX).

Finally, the combination of interventions add their effects approximately behave as they were shown when incorporated individually (Fig. XXX and Supplementary Fig. XXX). In particular, the creation of a safety zone improves the benefits of the other interventions, and there are not noticeable side effects beyond those previously described.


Combined
Population size = 2000
Probability of outbreak
0.0
0.2
0.4
0.6
0.8
Intervention
none
evac
self 20%
50 tents
self 50%
self 20% + 50 tents
self 20% + 50 tents + evac
self 50% + 50 tents
self 50% + 50 tents + evac
safety
safety + evac
safety + lock 50%
safety + self 20%
safety + 50 tents
safety + self 50%
safety + 50 tents + lock 50%
safety + 50 tents + evac
safety + 50 tents + self 20%
safety + 50 tents + self 50%
safety + 50 tents + evac + lock 50% + self 20%
safety + 50 tents + evac + lock 50% + self 50%
safety + 50 tents + evac + lock 90% + self 50%
total
exposed zone
safety zone


Combined
Population size = 2000
Fraction of population dying
0.00
0.05
0.10
0.15
0.20
Intervention
none
evac
self 20%
50 tents
self 50%
self 20% + 50 tents
self 20% + 50 tents + evac
self 50% + 50 tents
self 50% + 50 tents + evac
safety
safety + evac
safety + lock 50%
safety + self 20%
safety + 50 tents
safety + self 50%
safety + 50 tents + lock 50%
safety + 50 tents + evac
safety + 50 tents + self 20%
safety + 50 tents + self 50%
safety + 50 tents + evac + lock 50% + self 20%
safety + 50 tents + evac + lock 50% + self 50%
safety + 50 tents + evac + lock 90% + self 50%
total
exposed zone
safety zone


Combined
Population size = 2000
Time to peak of symptomatic (days)
80
120
160
Intervention
none
evac
self 20%
50 tents
self 50%
self 20% + 50 tents
self 20% + 50 tents + evac
self 50% + 50 tents
self 50% + 50 tents + evac
safety
safety + evac
safety + lock 50%
safety + self 20%
safety + 50 tents
safety + self 50%
safety + 50 tents + lock 50%
safety + 50 tents + evac
safety + 50 tents + self 20%
safety + 50 tents + self 50%
safety + 50 tents + evac + lock 50% + self 20%
safety + 50 tents + evac + lock 50% + self 50%
safety + 50 tents + evac + lock 90% + self 50%
total
exposed zone
safety zone

Discussion

In this research, we proposed a number of feasible interventions of immediate applicability to informal settlements. We focused on IDP settlements in NW Syria, taking into account the interventions' feasibility, cultural acceptance and their need for low-cost. When confronted with different possible scenarios, we generally considered the worst-cases, highlighting the interventions most effective in the direst conditions but possibly resulting in an overestimate of the number of deaths. Our results are aligned with previous works XXX

Self-distancing proves to be an efficient measure, and reducing the number of contacts by 50% has the greatest effect among all the interventions. However, a reduction of this magnitude may be difficult to achieve, especially due to the large proportion of the population composed of children (0-12 years old), a group with a high contact rate, that is difficult to control [11].

We also propose self-isolation using individual tents which can be located in a dedicated zone or next to the tents of relatives, where contact with non-isolated individuals is mediated by a buffering zone ($\sim 2\ m^2$). This intervention is effective with even a small number of isolation tents, as low as 5-10 tents per 1000 camp residents. We found, after conversations with camp's managers that this interventionis more likely to be accepted in NW Syria than evacuation to community-based isolation centers. Community-based isolation not only poses cultural challenges; the capacity required to implement it has hardly been met [12].

One of the parameters that we assessed is the need for care-givers for individually isolated individuals. Altough, in many cases it will be impossible to discern Covid-19 from other affections by the community, an increase in the contacts between individually isolated individuals and their care-givers may increase the infectivity. We considered that there is one care-giver per individual isolated with a daily contact in a buffering zone, and this choice shows that increasing the number of isolated individuals over xx cases increases the infectivity, due to the consequent increase of exposed care-givers. This could be circumvented with a more organized group of care-givers, which would reduce the number of total contacts with infectious individuals. The intervention is effective even though we assumed that individuals requiring hospitalization should leave the tents due to their need of care, and hence they become fully infectious.

The division of a camp into a safety zone and an exposed zone does not modify its composition, nor change the number of people per tent or distance between tents. This would mitigate side-effects derived from an increase in the number of contacts between vulnerable population [20]. In our modelization, we considered that contacts between the individuals within the safety zone are not reduced as compared to the exposed zone, and we observed in some cases an increase in the fraction of deaths in the protected population. However, these side-effects are compensated by the strong reduction in the probability of outbreak in the safety zone that this intervention provides, which leads to an overall reduction in the fraction of deaths in the whole camp. Moreover, in NWS Syria there are about 1000 camps, which will statistically justify such an intervention. Most importantly, it is unrealistic to think that the level of contacts will be maintained in the safety zone if an outbreak occurs in the camp, which would lower the chances of such side-effects.

An important question for the success of this intervention comes from the efficacy of the buffering zone. The reduction in the number of contacts per week in the buffering zone between individuals living in the safety zone and individuals from the exposed zone, the implementation of basic health checks to identify symptomatic individuals, and the eventual lockdown, have notable effects. Also important is which population should be shielded. Protecting only elderly and at most adults with comorbidities have the most beneficial effects, and the intervention becomes less effective when healthy adults and kids are included. However, the elderly and individuals with comorbidities need care-givers, and leaving them alone might have more deleterious effects than allowing accompanying persons. This also allows to preserve the social cohesion of the population. Another relevant consideration is the fraction of population recovered, that may help to reach herd immunity. We observed that unless a self-distancing of 50% is considered, the fraction of population recovered is close to a 75%, which is quite promising to prevent future outbreaks.

Decisions on which population should be protected are one example of social challenges that may become more complex in practice. Another example we did not address is that it is unlikely that a kid under 13 is individually isolated. Altough the number of of exceptions to the cases proposed are possibly endless, our results demonstrate that a community-based approach can be effective, much more than health-based responses which may take years to reach the needed level of response. In this respect, this modelization research demonstrates that in an extreme environment like NW Syria alternative responses can be efficient if the dynamics of the virus are well understood by the local communities and if they can implement at least some of the interventions proposed in this research. Given the highly dynamic environment existing in the camps and the slow reaction of the local and international authorities, empowering the local population is possibly the best, if not the only way, to help these communities, not only for the IDP camps of NW Syria, but in many other cases: slums in India, Africa and South America, isolated rural villages in Africa, South America and east Asia and in areas with large numbers of IDPs such as South Sudan or Colombia.

References

[1] Total confirmed coronavirus cases in africa pass 1 million. http://web.archive.org/web/20080207010024/http://www.808m
Accessed: 2020-08-17.

[2] Africa marks six months of covid-19. https://www.afro.who.int/news/africa-marks-six-months-covid-19. Accessed: 2020-08-17.

[3] Annie Wilkinson. Local response in health emergencies: key considerations for addressing the COVID-19 pandemic in informal urban settlements. *Environment and Urbanization*, page 0956247820922843, May 2020.

[4] Mohamed Abbas, Tammam Aloudat, Javier Bartolomei, Manuel Carballo, Sophie Durieux-Paillard, Laure Gabus, Alexandra Jablonka, Yves Jackson, Kanokporn Kaojaroen, Daniel Koch, Esperanza Martinez, Marc Mendelson, Roumyana Petrova-Benedict, Sotirios Tsiodras, Derek Christie, Mirko Saam, Sally Hargreaves, and Didier Pittet. Migrant and refugee populations: a public health and policy perspective on a continuing global crisis. *Antimicrobial Resistance and Infection Control*, 7, September 2018.

[5] Peter S. Hill, Ghulam Farooq Mansoor, and Fernanda Claudio. Conflict in least-developed countries: challenging the Millennium Development Goals. *Bulletin of the World Health Organization*, 88:562–562, August 2010.

[6] Mohammed Z. Sahloul, Jaber Monla-Hassan, Abdulghani Sankari, Mazen Kherallah, Bassel Atassi, Safwan Badr, Aula Abbara, and Annie Sparrow. War is the Enemy of Health. Pulmonary, Critical Care, and Sleep Medicine in War-Torn Syria. *Annals of the American Thoracic Society*, 13(2):147–155, January 2016.

[7] Mustafa Sikder, Umar Daraz, Daniele Lantagne, and Roberto Saltori. Water, sanitation, and hygiene access in southern Syria: analysis of survey data and recommendations for response. *Conflict and Health*, 12(1):17, April 2018.

[8] Health Information Central Unit and Health Directorates. Capacity of health sector in north of syria, March 2020. Accessed: 2020-08-18.

[9] Syria: Camps & Sites Needs Assessment - Northwest Syria Sub-district Profiles & Comparative Dashboard, January - February 2020 - Syrian Arab Republic.

[10] Kevin Van Zandvoort, Christopher I Jarvis, Carl Pearson, Nicholas G Davies, Timothy W Russell, Adam J Kucharski, Mark J Jit, Stefan Flasche, Rosalind M Eggo, Francesco Checchi, et al. Response strategies for covid-19 epidemics in african settings: a mathematical modelling study. *MedRxiv*, 2020.

[11] The Syrian IDP Camps Monitoring Study - Northern Syria Camps - Humanitarian Data Exchange.

[12] Health Cluster Turkey Hub and World Health Organization. Covid-19 response tracking dashboard | northwest syria. https://app.powerbi.com/view?r=eyJrIjoiNTRiMmZiMTAtNWYzZC00M2RmLWFkOTktZWZlMjQ4NmFhO
August 2020. Accessed: 2020-08-19.

[13] Mahmoud Hariri, Hazem Rihawi, Salah Safadi, Mary Ana McGlasson, and Wael Obaid. The covid-19 forecast in northwest syria the imperative of global action to avoid catastrophe. *medRxiv*, 2020.

[14] Yuanyuan Dong, Xi Mo, Yabin Hu, Xin Qi, Fang Jiang, Zhongyi Jiang, and Shilu Tong. Epidemiological characteristics of 2143 pediatric patients with 2019 coronavirus disease in china. *Pediatrics*, 2020.

[15] CDC Covid, CDC COVID, CDC COVID, Nancy Chow, Katherine Fleming-Dutra, Ryan Gierke, Aron Hall, Michelle Hughes, Tamara Pilishvili, Matthew Ritchey, et al. Preliminary estimates of the prevalence of selected underlying health conditions among patients with coronavirus disease 2019âunited states, february 12–march 28, 2020. *Morbidity and Mortality Weekly Report*, 69(13):382, 2020.

[16] Oyungerel Byambasuren, Magnolia Cardona, Katy Bell, Justin Clark, Mary-Louise McLaws, and Paul Glasziou. Estimating the extent of true asymptomatic covid-19 and its potential for community transmission: systematic review and meta-analysis. *Available at SSRN 3586675*, 2020.

[17] Mutiu Abimbola Oyinlola, Tolulope Osayomi, and Oluwatosin Adeniyi. Empirical Modelling of Confirmed COVID-19 Cases in Nigeria: Forecasts and Implications. SSRN Scholarly Paper ID 3596095, Social Science Research Network, Rochester, NY, May 2020.

[18] Jose' M. Carcione, Juan E. Santos, Claudio Bagaini, and Jing Ba. A simulation of a COVID-19 epidemic based on a deterministic SEIR model. *arXiv:2004.03575 [physics, q-bio]*, May 2020. arXiv: 2004.03575.

[19] Shaun A. Truelove, Orit Abrahim, Chiara Altare, Stephen A. Lauer, Andrew Azman, and Paul B. Spiegel. The Potential Impact of COVID-19 in Refugee Camps in Bangladesh and Beyond: a modeling study. *medRxiv*, page 2020.03.27.20045500, May 2020.

[20] Maysoon Dahab, Kevin van Zandvoort, Stefan Flasche, Abdihamid Warsame, Ruwan Ratnayake, Caroline Favas, Paul B Spiegel, Ronald J Waldman, and Francesco Checchi. Covid-19 control in low-income settings and displaced populations: what can realistically be done? *Conflict and Health*, 14(1):1–6, 2020.