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Methods: We developed a transmission model to evaluate the impact of self-imposed prevention measures (handwashing, mask-wearing, and social distancing) due to COVID-19 awareness and of short-term government-imposed social distancing on the peak number of diagnoses, attack rate and time until the peak number of diagnoses.

Findings: For fast awareness spread in the population, self-imposed measures can significantly reduce the attack rate, diminish and postpone the peak number of diagnoses. A large epidemic can be prevented if the efficacy of these measures exceeds 50%. For slow awareness spread, self-imposed measures reduce the peak number of diagnoses and attack rate but do not affect the timing of the peak. Early implementation of short-term government interventions can only delay the peak.

Interpretation: Handwashing, mask-wearing and social distancing as a reaction to information dissemination about COVID-19 can be effective strategies to mitigate and delay the epidemic. We stress the importance of a rapid spread of awareness on the use of self-imposed prevention measures in the population. Early-initiated short-term government-imposed social distancing can buy time for healthcare systems to prepare for an increasing COVID-19 burden.
Impact of self-imposed prevention measures and short-term government intervention on mitigating and delaying a COVID-19 epidemic

Alexandra Teslya∗†, Thi Mui Pham∗1, Noortje G. Godijk∗1, Mirjam E. Kretzschmar1,2, Martin C.J. Bootsma1,3, and Ganna Rozhnova1,2,4

1Julius Center for Health Sciences and Primary Care, University Medical Center Utrecht, Utrecht University, Utrecht, The Netherlands
2Center for Infectious Disease Control, National Institute of Public Health and the Environment, Bilthoven, The Netherlands
3Mathematical Institute, Utrecht University, Utrecht, The Netherlands
4BioISI—Biosystems & Integrative Sciences Institute, Faculdade de Ciências, Universidade de Lisboa, Lisboa, Portugal

∗Contributed equally
†Corresponding author:
Dr. Alexandra Teslya
Julius Center for Health Sciences and Primary Care
University Medical Center Utrecht
P.O. Box 85500 Utrecht
The Netherlands
Email: A.I.Teslya@umcutrecht.nl
Phone: +31 639315931

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Keywords: SARS-CoV-2, COVID-19, mathematical model, prevention measures, disease awareness, epidemic control, social distancing, handwashing, mask-wearing
Research in context

Evidence before this study

Evidence to date suggests that containment of SARS-CoV-2 using quarantine, travel restrictions, isolation of symptomatic cases, and contact tracing may need to be supplemented by other interventions. Given its rapid spread across the world and huge implications for public health, it is urgent to understand whether non-case-based interventions can mitigate, delay or even prevent a COVID-19 epidemic. One option is a broader-scale contact rate reduction enforced by governments that have been used during previous outbreaks, e.g., the 1918 influenza pandemic and the 2009 influenza A/H1N1 pandemic in Mexico. Alternatively, governments and media may stimulate self-imposed prevention measures (handwashing, mask-wearing, and social distancing) by generating awareness about COVID-19, especially when economic and societal consequences are taken into account. Both of these strategies may have a significant impact on the outbreak dynamics. Currently, there are no comparative studies that investigate their viability for controlling a COVID-19 epidemic.

Added value of this study

Using a transmission model parameterized with current best estimates of epidemiological parameters, we evaluated the impact of handwashing, mask-wearing, and social distancing due to COVID-19 awareness and of government-imposed social distancing on the peak number of diagnoses, attack rate, and time until the peak number of diagnoses. We show that a short-term (1-3 months) government intervention initiated early into the outbreak can only delay the peak number of diagnoses but neither alters its magnitude nor the attack rate. Our analyses also highlight the importance of spreading awareness about COVID-19 in the population, as the impact of self-imposed measures is strongly dependent on it. When awareness spreads fast, simple self-imposed measures such as handwashing are more effective than short-term government intervention. Self-imposed measures do not only diminish and postpone the peak number of diagnoses, but they can prevent a large epidemic altogether when their efficacy is sufficiently high (about 50%). Qualitatively, these results will allow public health professionals to compare interventions for designing effective outbreak control policies.

Implications of all available evidence

Our results highlight that dissemination of evidence-based information on effective prevention measures (handwashing, mask-wearing, and self-imposed social distancing) can be a key strategy for mitigating and postponing a COVID-19 epidemic. Government interventions (e.g., closing schools and prohibiting mass gatherings) implemented early into the epidemic and lasting for a short-time can only buy time for healthcare systems to prepare for the increasing COVID-19 burden.
Introduction

As of March 12, 2020, the novel coronavirus (SARS-CoV-2) has spread to more than 100 countries and has caused about 125,000 confirmed cases of COVID-19, starting with the detection of the outbreak in China on December 31, 2019. On March 11, the World Health Organization officially declared the COVID-19 outbreak a pandemic. Travel bans and airport screening likely had only a minor impact on SARS-CoV-2 containment because of a potentially large number of asymptomatic cases and the possibility of transmission before the onset of symptoms. Quarantine of fourteen days combined with fever surveillance was ineffective in containing the virus due to the high variability of the incubation period.

Now that SARS-CoV-2 has spread to Europe, it is evident that many European countries face a real possibility of a large COVID-19 epidemic. In the absence of a vaccine, the current policy regarding COVID-19 prevention is mainly limited to reporting cases, strict isolation of severe symptomatic cases, home isolation of mild cases, and contact tracing. However, unless highly effective, these case-based interventions are unlikely to have a significant impact on the transmission of SARS-CoV-2, due to potential asymptomatic spread. Other interventions in Europe included social-distancing measures aiming to reduce the contact rate in the population and with that transmission. Governments can impose social distancing by closing schools or public places, cancelling mass events, and promoting remote work. Previous studies showed that the timing and magnitude of such mandated interventions had a profound influence on the 1918 influenza pandemic. However, when poorly timed, the impact of short-term interventions might be limited, with a high risk of epidemic resurgence.

Self-imposed prevention measures such as handwashing, mask-wearing, and social distancing could also contribute to slowing down the epidemic. Alcohol-based sanitizers are effective in removing the SARS coronavirus and handwashing with soap may have a positive effect on reducing respiratory infections. Surgical masks, often worn for their perceived protection, are not designed nor certified to protect against respiratory hazards, but they can stop droplets from infectious individuals being spread. For individuals to adopt such prevention measures, they should be aware of the risks of COVID-19, e.g., due to information dissemination and official recommendations. Previous studies emphasized the importance of disease awareness for changing the course of an epidemic. Depending on the rate and mechanism of awareness spread, the awareness process can reduce the attack rate of an epidemic or prevent it completely, but it can also lead to undesirable outcomes such as the appearance of multiple epidemic peaks. It is essential to assess under which conditions, spread of disease awareness that instigates self-imposed measures can be a viable strategy for COVID-19 control.

The comparison of the effectiveness of short-term government-imposed social distancing and self-imposed prevention measures on reducing the transmission of SARS-CoV-2 are currently missing but are of crucial importance in the
attempt to stop its spread. Moreover, if a COVID-19 epidemic cannot be prevented, it is important to know how the epidemic peak can be diminished and postponed to give healthcare professionals more time to prepare and react effectively to the increasing health care burden. For affected areas like Europe, where the outbreak runs concurrently with the influenza season, the importance to identify such interventions is profound.

Using a transmission model we evaluate the impact of self-imposed measures (handwashing, mask-wearing, and social distancing) due to awareness about COVID-19 and of a short-term government-imposed social distancing intervention on the peak number of diagnoses, attack rate, and time until the peak number of diagnoses since the first case. We provide a head-to-head comparison of these interventions and assess for which efficacy of these interventions a large COVID-19 outbreak can be prevented.

Methods

Transmission model without disease-awareness

We developed a deterministic compartmental model describing SARS-CoV-2 transmission in a population stratified by disease status (Figure 1). In the baseline model, individuals are classified as susceptible (S), latently infected (E), infectious with mild or no symptoms (IM), infectious with severe symptoms (IS), diagnosed and isolated (ID), and recovered (RM and RS after an infection with mild and severe symptoms, respectively). Susceptible individuals (S) can become latently infected (E) through contact with infectious individuals (IM and IS) with the force of infection dependent on the fractions of the population in IM and IS. A proportion of the latently infected individuals (E) will go to the IM compartment, and the remaining E individuals will go to the IS compartment. We assume that infectious individuals with mild symptoms (IM) do not require medical attention, recover undiagnosed and are not conscious of having contracted the infection (RM). Individuals with severe symptoms (IS) are diagnosed and know their disease status when they are detected. After detection, they are kept in isolation (ID) until recovery (RS). Diagnosed individuals are assumed to be perfectly isolated, and, hence, neither contribute to transmission nor to the contact process. Recovered individuals (RM and RS) cannot be reinfected. The infectivity of individuals with mild symptoms is lower than the infectivity of individuals with severe symptoms. Natural birth and death processes are neglected as the time scale of the epidemic is short compared to the mean life span of individuals. However, severely symptomatic patients in isolation may be removed from the population due to disease-associated mortality.

Transmission model with disease-awareness

In the extended model with disease-awareness, the population is stratified not only by the disease status but also by the awareness status into disease-aware (S\(a\), E\(a\), IM\(a\), IS\(a\), ID\(a\), and RM\(a\)) and disease-unaware (S, E, IM, IS, and RM) (Figure 2 A). Disease-aware individuals are distinguished from unaware individuals in two essential ways. First,
Figure 1. Schematic of the transmission model without disease-awareness. Shown are epidemiological transitions in the baseline transmission model (black arrows). The red dashed arrows indicate the compartments contributing to the force of infection. Susceptible persons ($S$) become latently infected ($E$) with the force of infection $\lambda_{inf}$ via contact with infectious individuals in two infectious classes ($I_M$ and $I_S$). Individuals leave the $E$ compartment at rate $\alpha$. A proportion $p$ of the latently infected individuals ($E$) will go to the $I_M$ compartment, and the proportion $(1 - p)$ of $E$ individuals will go to the $I_S$ compartment. Infectious individuals with mild symptoms ($I_M$) recover undiagnosed ($R_M$) at rate $\gamma_M$. Individuals with severe symptoms ($I_S$) are diagnosed and kept in isolation ($I_D$) at rate $\nu$ until they recover ($R_S$) at rate $\gamma_S$ or die at rate $\eta$. Table 1 provides the description and values of all parameters.

Infectious individuals with severe symptoms who are disease-aware ($I_S^a$) get diagnosed faster ($I_D^a$), stay shorter in isolation and have lower disease-associated mortality than unaware individuals. Disease-aware individuals recognize the symptoms on average faster than disease-unaware individuals and receive treatment earlier which leads to a better prognosis of $R_S$-individuals. Second, disease-aware individuals are assumed to use self-imposed measures such as handwashing, mask-wearing and self-imposed social distancing that can lower their susceptibility, infectivity and/or contact rate. Individuals who know their disease status ($I_D$ and $R_S$) cannot change their awareness state. Individuals who are diagnosed ($I_D$) will be isolated and individuals recovered from a severe infection ($R_S$) know that they cannot contract the disease again. Hence we assume their behaviour in the contact process is identical to disease-unaware individuals.

Disease-unaware individuals acquire disease-awareness at a rate proportional to the rate of awareness spread and to the current number of diagnosed individuals ($I_D$ and $I_D^a$) in the population (Figure 2 B). We assume that awareness fades and individuals return to the unaware state at a constant rate. The latter means that they no longer use self-imposed measures. For simplicity, we assume that awareness acquisition and fading rates are the same for individuals of type $S$, $E$, $I_M$, and $R_M$. Also, the rate of awareness acquisition is faster and the fading rate is slower for infectious individuals with severe symptoms ($I_S$) than for the remaining disease-aware population.

Estimates of epidemiological parameters were obtained from most recent literature (Table 1). We used contact rates for the Netherlands, but the model is appropriate for other Western countries with similar contact rates. A
detailed mathematical description of the model with and without awareness can be found in the Appendix.

**Figure 2. Schematic of the transmission model with disease-awareness.** (A) shows epidemiological transitions in the transmission model with awareness (black arrows). The orange dashed lines indicate the compartments that participate in the awareness dynamics. The red dashed arrows indicate the compartments contributing to the force of infection. Disease-aware susceptible individuals ($S^a$) become latently infected ($E^a$) through contact with infectious individuals ($I_M$, $I_S$, $I_M^a$, and $I_S^a$) with the force of infection $\lambda_{inf}$. Infectious individuals with severe symptoms who are disease-aware ($I_S^a$) get diagnosed and are kept in isolation ($I_D^a$) at rate $\nu^a$, recover at rate $\gamma^a_S$ and die from disease at rate $\eta^a$. (B) shows awareness dynamics. Infectious individuals with severe symptoms ($I_S$) acquire disease-awareness ($I_S^a$) at rate $k\lambda_{aware}$ proportional to the rate of awareness spread and to the current number of diagnosed individuals ($I_D$ and $I_D^a$) in the population. As awareness fades, these individuals return to the unaware state at rate $\mu_S$. The acquisition rate of awareness ($k\lambda_{aware}$) and the rate of awareness fading ($\mu$) rates are the same for individuals of type $S$, $E$, $I_M$, and $R_M$, where $k$ is the reduction in susceptibility to the awareness acquisition compared to $I_S$ individuals. Table 1 provides the description and values of all parameters.

**Prevention measures**

We considered short-term government intervention aimed at fostering social distancing in the population and a suite of measures self-imposed by disease-aware individuals, i.e., mask-wearing, hand washing, and self-imposed social distancing.

**Mask-wearing**

Mask-wearing does not reduce the individual’s susceptibility because laypersons, i.e., not medical professionals, are unfamiliar with correct procedures for its use and may often engage in face-touching and mask adjustment. Therefore, we assume that masks only lower the infectivity of disease-aware infectious individuals ($I_S^a$ and $I_M^a$) with...
Table 1. Parameter values for the transmission model with and without awareness

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value*</th>
<th>Source</th>
</tr>
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<tbody>
<tr>
<td>Epidemiological parameters</td>
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<td></td>
</tr>
<tr>
<td>Basic reproduction number</td>
<td>$R_0$</td>
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<tr>
<td>Probability of transmission per contact with $I_S$</td>
<td>$\epsilon$</td>
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<tr>
<td>Transmission rate of infection via contact with $I_S$</td>
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<td>Average contact rate (unique persons)</td>
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<td>Relative infectivity of mildly infected ($I_M$)</td>
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<tr>
<td>Proportion of mildly infected ($I_M$)</td>
<td>$p$</td>
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<td>Latent period</td>
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<tr>
<td>Recovery period of mildly infected ($I_M$)</td>
<td>$1/\gamma_M$</td>
<td>7 days</td>
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<tr>
<td>Delay from diagnosis to recovery for diagnosed unaware ($I_D$)</td>
<td>$1/\gamma_S$</td>
<td>14 days</td>
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<tr>
<td>Relative infectivity of isolated ($I_D$)</td>
<td>0%</td>
<td>Assumed perfect isolation</td>
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<tr>
<td>Case fatality rate of unaware diagnosed ($I_D$)</td>
<td>$f$</td>
<td>1.6%</td>
</tr>
<tr>
<td>Disease-associated death rate of unaware diagnosed ($I_D$)</td>
<td>$\eta$</td>
<td>0.0011 per day</td>
</tr>
<tr>
<td>Awareness parameters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rate of awareness spread (slow, fast and range)</td>
<td>$\delta$</td>
<td>$5 \times 10^{-5}$, $1 \times 10^{-6}$–1 per year</td>
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<td>Relative susceptibility to awareness acquisition for $S$, $E$, $I_M$, and $R_M$</td>
<td>$k$</td>
<td>50% (0–100%)</td>
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<tr>
<td>Duration of awareness for $S^a$, $E^a$, $I_M^a$, and $R_M^a$</td>
<td>$1/\mu$</td>
<td>30 (7–365) days</td>
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<tr>
<td>Duration of awareness for $I_D^a$</td>
<td>$1/\mu_S$</td>
<td>60 (7–365) days</td>
</tr>
<tr>
<td>Delay from onset of infectiousness to diagnosis for $I_S^a$</td>
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<td>3 (1–5) days</td>
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<td>Delay from diagnosis to recovery of diagnosed aware ($I_D^a$)</td>
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<td>Case fatality rate of aware diagnosed ($I_D^a$)</td>
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<td>Disease-associated death rate of aware diagnosed ($I_D^a$)</td>
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<tr>
<td>Prevention measure parameters</td>
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<td>Efficacy of mask-wearing (reduction in infectivity)</td>
<td>0–100%</td>
<td>Varied</td>
</tr>
<tr>
<td>Efficacy of handwashing (reduction in susceptibility)</td>
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<td>Varied</td>
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<tr>
<td>Efficacy of self-imposed contact rate reduction</td>
<td>0–100%</td>
<td>Varied</td>
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<tr>
<td>Efficacy of government-imposed contact rate reduction</td>
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<td>Varied</td>
</tr>
<tr>
<td>Duration of government intervention</td>
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</tr>
<tr>
<td>Threshold for initiation of government intervention</td>
<td>10 (10–1000) diagnoses</td>
<td>Assumed¹</td>
</tr>
</tbody>
</table>

* Mean or median values were used from literature; range was used in the sensitivity analyses.
† Expert at China’s National Health Commission
‡ Sensitivity analyses

an efficacy ranging from 0% (zero efficacy) to 100% (full efficacy).¹⁸

Handwashing

Since infectious individuals may transmit the virus to others without direct physical contact, we assume that handwashing only reduces one’s susceptibility. The efficacy of handwashing is described by the reduction in susceptibility (i.e., probability of transmission per single contact) of susceptible disease-aware individuals ($S^a$) which ranges from 0% (zero efficacy) to 100% (full efficacy).

Self-imposed social distancing

Disease-aware individuals may also practice social distancing, i.e., maintaining distance to others and avoid congregate settings.²⁷ As a consequence, this measure leads to a change in mixing patterns in the population. The efficacy of social distancing of disease-aware individuals is described by the reduction in their contact rate which is varied from 0% (no social distancing or zero efficacy) to 100% (full self-isolation or full efficacy).
Short-term government-imposed social distancing

Governments may decide to promote social distancing policies through interventions such as school and workplace closures or by issuing a ban on large gatherings. Such policies will cause a community-wide contact rate reduction, regardless of the awareness status. Here, government intervention is initiated if the number of diagnosed individuals exceeds a certain threshold (10–1000 persons) and terminates after a fixed period of time (1–3 months). As such, we assume that the intervention is implemented early in the epidemic. The efficacy of government-imposed social distancing is described by the reduction of the average contact rate in the population which ranges from 0% (no distancing) to 100% (complete quarantine of the population).

Model output

The model outputs are the peak number of diagnoses, attack rate (a proportion of the population that recovered or died after severe infection) and the time to the peak number of diagnoses. We compared the impact of different prevention measures on these outputs by varying the reduction in infectivity of disease-aware infectious individuals (mask-wearing), the reduction in susceptibility of disease-aware susceptible individuals (handwashing), the reduction in contact rate of disease-aware individuals only (self-imposed social distancing) and of all individuals (government-imposed social distancing). We refer to these quantities as the efficacy of a prevention measure and vary it from 0% (zero efficacy) to 100% (full efficacy) (Table 1). The main analyses were performed for two values of the rate of awareness spread that corresponded to scenarios of slow and fast spread of awareness in the population (Table 1). For these scenarios, the proportion of the aware population at the peak of the epidemic was 40% and 90%, respectively. In the main analyses, government-imposed social distancing was initiated when 10 individuals got diagnosed and was lifted after 3 months. Sensitivity analyses for parameters indicated in Table 1 are given in the Appendix.

Role of the funding source

The funders of the study had no role in study design, data collection, data analysis, data interpretation, writing of the manuscript, or the decision to submit for publication. All authors had full access to all the data in the study and were responsible for the decision to submit the manuscript for publication.

Results

Our analyses show that disease awareness has a significant effect on the model predictions. We first consider the epidemic dynamics in a disease-aware population where handwashing is promoted, as an example of self-imposed
measures (Figure 3). Further, we perform a systematic comparison of the impact of different prevention measures on the model output for slow (Figure 4) and fast (Figure 5) rate of awareness spread.

**Figure 3. Illustrative simulations of the transmission model.** (A) and (B) show the number of diagnoses and the attack rate during the first 12 months after the first case under three model scenarios. The red lines correspond to the baseline model without disease awareness. The orange lines correspond to the model with a fast rate of awareness spread and no interventions. The blue lines correspond to the latter model where disease awareness induces the uptake of handwashing with an efficacy of 30%.

**Epidemic dynamics**

All self-imposed measures and government-imposed social distancing have an effect on the COVID-19 epidemic dynamics. The qualitative and quantitative impact, however, depends strongly on the prevention measure and the rate of awareness spread. The baseline model predicts 46 diagnoses per 1000 individuals at the peak of the epidemic, an attack rate of about 16% and the time to the peak of about 5.2 months (red line, Figure 3 A and B). In the absence of prevention measures, the spread of disease awareness reduces the peak number of diagnoses by 20% but has only a minor effect on the attack rate and peak timing (orange line, Figure 3 A and B). This is expected, as disease-aware individuals with severe symptoms seek health care sooner and therefore get diagnosed faster causing fewer new infections as compared to the baseline model. Awareness dynamics coupled with the use of self-imposed prevention measures has an even larger impact on the epidemic. The blue line in Figure 3 A shows the epidemic curve for the scenario when disease-aware individuals use handwashing as self-imposed prevention measure. Even if the efficacy of handwashing is modest (i.e., 30% as in Figure 3 A) the impact on the epidemic can be significant, namely we predict a 65% reduction in the peak number of diagnoses, a 29% decrease in the attack rate, and a delay in peak timing of 2.7 months (Figure 3 A and B).
The effect of awareness on the disease dynamics can also be observed in the probability of infection during the course of the epidemic. In the model with awareness and no measures, the probability of infection is reduced by 4% for all individuals. Handwashing with an efficacy of 30% reduces the respective probability by 14% for unaware individuals and by 29% for aware individuals. Note that the probability of infection is highly dependent on the type of prevention measure. The detailed analysis is given in the Appendix.

Figure 4. Impact of prevention measures on the epidemic for a slow rate of awareness spread. (A), (B) and (C) show the relative reduction in the peak number of diagnoses, the attack rate (proportion of the population that recovered or died after severe infection) and the time until the peak number of diagnoses. The efficacy of prevention measures was varied between 0% and 100%. In the context of this study, the efficacy of social distancing denotes the reduction in the contact rate. The efficacy of handwashing and mask-wearing are given by the reduction in susceptibility and infectivity, respectively. The simulations were started with one case. Government-imposed social distancing was initiated after 10 diagnoses and lifted after 3 months. For parameter values, see Table 1.
A comparison of prevention measures

Figure 4 shows the impact of all considered self-imposed measures as well as of the government-imposed social distancing on the peak number of diagnoses, attack rate, and the time to the peak for slow rate of awareness spread. In this scenario, the model predicts progressively larger reductions in the peak number of diagnoses and in the attack rate as the efficacy of the self-imposed measures increases. In the limit of 100% efficacy, the reduction in the peak number of diagnoses is 23% to 30% (Figure 4 A) and the attack rate decreases from 16% to 12-13% (Figure 4 B). The efficacy of the self-imposed measures has very little impact on the peak timing when compared to the baseline, i.e., no awareness in the population (Figure 4 C). Since the proportion of aware individuals who change their behavior is too small to make a significant impact on transmission, self-imposed measures can only
mitigate but not prevent an epidemic. When awareness spreads at a slow rate, a 3-month government intervention has a contrasting impact. The time to the peak number of diagnoses is longer for more stringent contact rate reductions. For example, at 100% efficacy (full quarantine) the government can postpone the peak by almost 7 months but its magnitude and attack rate are unaffected. Similar predictions are expected, as long as government-imposed social distancing starts early (e.g., after tens to hundreds cases) and is lifted few weeks to few months later (Appendix). This type of intervention halts the epidemic for the duration of intervention, but, because of a large pool of susceptible individuals, epidemic resurgence is expected as soon as social distancing measures are lifted.

Since the government intervention reduces the contact rate of all individuals irrespective of their awareness status, it has a comparable impact on transmission for scenarios with fast and slow rate of awareness spread (compare Figure 4 and Figure 5). However, the impact of self-imposed measures is drastically different. When awareness spreads fast, all self-imposed measures are more effective than short-term government intervention. These measures not only reduce the attack rate (Figure 5 B), diminish and postpone the peak number of diagnoses (Figure 5 A and C), but they can also prevent a large epidemic altogether when their efficacy is sufficiently high (about 50%). Note that when the rate of awareness is fast, as the number of diagnoses grows, the population becomes almost homogeneous, with most individuals being disease-aware. It can be shown that in such populations prevention measures yield comparable results if they have the same efficacy.

**Discussion**

For many countries around the world, the focus of public health officers on the COVID-19 epidemic has shifted from containment to mitigation and delay. Our study provides new evidence for designing effective outbreak control strategies. We show that hand-washing, mask-wearing, and social distancing adopted by disease-aware individuals are all viable strategies for delaying the epidemic peak, flattening the epidemic curve and reducing the attack rate. We show that the rate at which disease awareness spreads has a strong impact on how self-imposed measures affect the epidemic. For a slow rate of awareness spread, self-imposed measures have little impact on transmission, as not many individuals adopt them. However, for a fast rate of awareness spread, their impact on the magnitude and timing of the peak increases with increasing efficacy of the respective measure. For all measures, a large epidemic can be prevented when the efficacy exceeds 50%. In practical terms, it means that SARS-CoV-2 will not cause a large outbreak in a country where 90% of the population adopt handwashing that is 50% efficacious (i.e., reduces susceptibility by 50%).

Although the effects of self-imposed measures on mitigating and delaying the epidemic are similar (see Figure 4 and Figure 5), not all explored efficacy values may be achieved for each measure. For instance, handwashing with
soap or using alcohol-based sanitizers may remove the virus completely leading to 100% efficacy. For surgical masks, their filtration efficiency has a wide range (0%–84%) and thus their actual efficacy is difficult to quantify.

For this reason, the promotion of handwashing might become preferable. Thus, for a fair comparison between measures, realistic efficacy values of a specific measure should be taken into consideration.

We contrast self-imposed measures stimulated by disease awareness with mandated social distancing. Our analyses show that short-term government-imposed social distancing that is implemented early into the epidemic, can delay the epidemic peak but does not affect its magnitude nor the attack rate. For example, a 3-month government intervention imposing community-wide contact rate reduction that starts after tens to hundreds diagnoses in the country can postpone the peak by about 7 months. Such an intervention is desirable, when a vaccine is being developed or when healthcare systems require more time to treat cases or increase capacity.

Since the COVID-19 epidemic is still in its early stages, government-imposed social distancing was modeled as a short-term intervention initiated when the number of diagnosed individuals was relatively low. Previous studies suggested that the timing of mandated social distancing is crucial for its viability in controlling a large disease outbreak. As discussed by Anderson et al. and Hollingsworth et al., a late introduction of such interventions may have a significant impact on the epidemic peak and attack rate. However, the authors also show that the optimal strategy is highly dependent on the desired outcome. A detailed analysis of a combination of self-imposed measures and different government interventions that take into account the economic and societal damage, and the cost of SARS-CoV-2 transmission is a subject for future work.

Our study provides the first comparative analysis of a suite of self-imposed measures and of short-term government-imposed social distancing as strategies for mitigating and delaying a COVID-19 epidemic. In our analyses, we explored the full efficacy range for all prevention measures and different durations of early-initiated government intervention. Our results allow to draw conclusions on which prevention measure can be most effective in diminishing and postponing the epidemic peak when realistic values for the measure’s efficacy are taken into account. We show that spreading disease awareness such that highly efficacious preventive measures are quickly adopted by individuals can be crucial in reducing SARS-CoV-2 transmission and preventing large outbreaks of COVID-19.

Our model has several limitations. It does not account for stochasticity, demographics, heterogeneities in contact patterns, spatial effects, inhomogeneous mixing and imperfect isolation. Our conclusions can, therefore, be drawn on a qualitative level. Detailed models will have to be developed to design and tailor effective strategies in particular settings. To take into account the uncertainty in SARS-CoV-19 epidemiological parameters, we performed sensitivity analyses to test the robustness of the model predictions. As more data become available,
our model can be easily updated. In addition, our study assumes that individuals become disease-aware with a rate of awareness acquisition proportional to the number of currently diagnosed individuals. Other forms for the awareness acquisition rate that incorporate, e.g., the saturation of awareness, may be more realistic and would be interesting to explore in future studies.

In conclusion, we provide the first empirical basis of how stimulating the uptake of effective prevention measures, such as handwashing, can be pivotal to achieve control over a COVID-19 epidemic. While information on the rising number of COVID-19 diagnoses reported by the media may fuel anxiety in the population, wide and intensive promotion of self-imposed measures with proven efficacy by governments or public health institutions may be a key ingredient to tackle COVID-19.

**Contributors**

AT, TMP, NGG, MK, MCJB and GR developed the conceptual framework of the study. AT, TMP, NGG and GR developed the model. AT and GR performed the model analyses. GR produced the results for the main text and conducted sensitivity analyses. NGG conducted the literature search. NGG, AT, TMP and GR wrote the manuscript. AT wrote the appendix. MCJB and MK contributed to interpretation of the results and provided critical review of the manuscript. All authors approved its final version.

**Declaration of interests**

We declare that we have no conflicts of interest.

**References**


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