The effectiveness of eight nonpharmaceutical interventions against COVID-19 in 41 countries. Jan Markus Brauner, Sören Mindermann, Mrinank Sharma, AnnaB Stephenson, Tomáš Gavenčiak, David Johnston, Gavin Leech, John Salvatier, George Altman, Alexander John Norman, Joshua Teperowski Monrad, Tamay Besiroglu, Hong Ge, Vladimir Mikulik, Meghan A. Hartwick, Yee Whye Teh, Leonid Chindelevitch, Yarin Gal, Jan Kulveit
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This non peer-reviewed preprint article presents the results of a study evaluating the effectiveness of eight nonpharmaceutical interventions (NPIs) for reducing transmission of SARS-CoV-2 in 41 countries.

QUESTION The study PICO is as follows;
P – 34 European and 7 non-European countries
I – 8 Non-pharmaceutical interventions: (1) mandating mask-wearing in (some) public spaces, (2) limiting gatherings to ≤1000 people, (3) to ≤100 people, (4) to ≤10 people, (5) closing some high-risk businesses, (6) closing most non-essential businesses, (7) closing schools and universities and (8) issuing stay-at home orders
C – No non-pharmaceutical intervention
O – viral transmission

METHODS Data on NPI implementation for each country was obtained from internet searches by two independent authors with cross-checking against public datasets and comparison to the extraction of paid contractors. A Bayesian hierarchical model was used to estimate NPI effectiveness by linking NPI implementation dates to national case and death counts (when a country reached 100 confirmed cases and 10 deaths). Case and death data were used to infer the number of new infections at each point in time, which was then used to infer reproduction number (R). Data on generation interval (time between successive infections; Mean 6.67 days) and delay from infection to confirmation (mean 10.35 days) and to death (mean 22.9 days) were entered into the model.

RESULTS The largest percentage reductions in reproduction number (R) across countries, was for limiting gatherings to ≤10 people (36%; 95% credible interval 16%-53%), closing schools and universities (39%; 21%-55%) and closing most nonessential businesses (40%; 22%-55%). Percentage reductions in R for mandating mask-wearing was 2% (95% CI -14%-16%), limiting gatherings to ≤1000 people 2% (95% CI -20%-22%), to ≤100 people 21% (95%CI 1%-39%) closing some high-risk businesses 31% (95%CI 13%-46%) and issuing stay-at home orders 18% (95%CI 4%-31%). (Figure 1)

COMMENTS The following points were discussed:

–The method for ascertaining NPI implementation information was considered robust. Bias from attrition was difficult to judge – only countries from which sufficient detail of policy implementation could be obtained were included, but once a country was included, all NPIs within that country were evaluated.

- As a non-randomised study, there is potential for factors that may affect viral transmission (other than implementation of the NPIs assessed), to confound the results reported. For example, the estimates of the effect for the evaluated NPIs are not adjusted for the test/trace/quarantine/isolate policies of the country, a key factor affecting transmission.

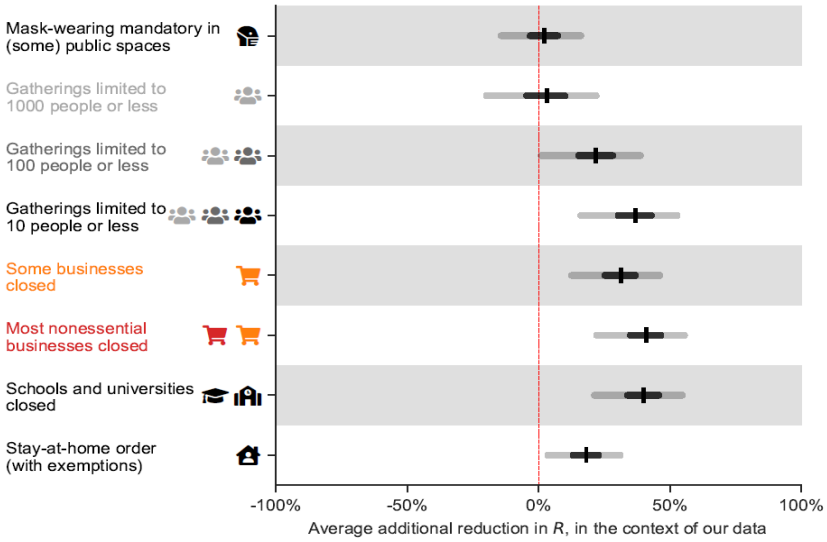
-The study is estimating the effect of policy decisions rather than actual behaviours.

-The percentage reductions in R presented in Figure 1 are for individual NPIs independent of the other implemented NPIs. However, it is likely the effectiveness of an NPI depends on the context of implementation, including the presence of other NPIs and the order in which they are implemented, and country-specific factors. For example, in all countries in this study, masks were mandated only at a later stage of intervention implementation, when strategies such as limiting gatherings and closing businesses has already occurred. The effects of masks in this context are likely to be minimal. However, when worn in other contexts mask effectiveness may vary from what is seen in this study. As such, the estimates for all of the NPIs reported should be understood to represent the average effectiveness over the contexts in which the NPI is used across the 41 (predominantly European) countries included in the study.

-The NPIs evaluated frequently co-occur (they are collinear). When collinearity is high and the dataset is small, effectiveness estimates are highly sensitive to variations in the data and the model parameters. The study investigators state that while collinearity in this dataset is manageable, it should be taken into consideration when evaluating the combined effects of the NPIs (e.g. when two NPIs are usually implemented together, there may be more certainty about the combined effect than about the effect of the two NPIs individually). Figure 2 shows the combined effectiveness of sets of NPIs. Using a reproduction number of 3.8 (the mean R without any NPIs across the countries included in this study), R maybe reduced to below 1 by closing schools and universities, high-risk businesses and limiting gathering sizes.

OVERALL SUMMARY This review addresses an issue of critical importance for informing policy decisions during second waves of SARS-CoV-2 infection and future pandemics. The study contributes useful information on the independent and combined effect of NPIs, but the estimates represent an 'average' effect over the contexts in which the NPI was implemented in the dataset and as such, effectiveness is likely to vary according to the context in which an NPI is implemented.

Figure 1: Effectiveness of individual NPIs on reproduction number (R), with description of each NPI



NPI	Description
Mask-wearing mandatory in (some) public spaces	A country has mandated mask usage in the public, sometimes limited to just some public spaces (which the government deems to have a high risk of infection). For example, some countries mandated mask-wearing in most or all indoor public spaces but not outdoors.
Gatherings limited to 1000 people or less	A country has set a size limit on gatherings. The limit is at most 1000 people (often less), and gatherings above the maximum size are disallowed. For example, a ban on gatherings of 500 people or more would be classified as "gatherings limited to 1000 or less", but a ban on gatherings of 2000 people or more would not.
Gatherings limited to 100 people or less	A country has set a size limit on gatherings. The limit is at most 100 people (often less).
Gatherings limited to 10 people or less	A country has set a size limit on gatherings. The limit is at most 10 people (often less).
Some businesses closed	A country has specified a few kinds of customer-facing businesses that are considered "high risk" and need to suspend operations (blacklist). Common examples are restaurants, bars, nightclubs, cinemas, and gyms. By default, businesses are not suspended.
Most nonessential businesses closed	A country has suspended the operations of many customer-facing businesses. By default, customer-facing businesses are suspended unless they are designated as essential (whitelist).
Schools closed	A country has closed most or all schools.
Universities closed	A country has closed most or all universities and higher education facilities.
Stay-at-home order (with exemptions)	An order for the general public to stay at home has been issued. This is mandatory, not just a recommendation. Exemptions are usually granted for certain purposes (such as shopping, exercise, or going to work), or, more rarely, for certain times of the day. In practice, a stay-at-home order was often accompanied by other NPIs such as businesses closures. However, a stay-at-home order does not in principle entail these other NPIs, but only the (additional) order to generally stay at home except for exemptions.

Figure 2: Combined NPI effectiveness for the most common sets of NPIs in the dataset, by size of the NPI set. Shaded areas are 50% and 95% credible intervals. The left panel shows the maximum R_0 that can be reduced to below 1 for each set of NPIs. The right panel shows the predicted R after implementation of each set of NPIs (from an R_0 of 3.8)