Title:
Phase-wise Impact Analysis of the Indian National Lockdown against COVID-19 Outcomes

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Conflicts of Interest:
None

Background:
India was one of the most vulnerable countries to COVID-19 pandemic considering the high transmissibility of the virus, exploding population, and fragile healthcare infrastructure. As an early counter, India implemented a country-wide lockdown in 4 phases starting from March 25 to May 31, 2020. While effectiveness of lockdowns at national level have been assessed, sub-national differences remain elusive. We aimed to study the impact of the 4 lockdown phases and the 2 unlock (re-opening) phases on four outcomes at the national and sub-national levels using two analytical methods.

Methods:
In order to assess the phase-wise impact, we used projected data for multiple outcomes for India available from the Institute for Health Metrics and Evaluation (IHME). We assessed the impact of 4 lockdown and 2 unlock phases on 1) case growth defined as $C(t) = \log (c(t)) - \log(c(t - 1))$ where c is confirmed infections on day t, 2) death rate in region s, D(t) defined as $D(t) = d(t)/\text{population in region s} * 100000$ where d(t) denotes the deaths observed on day t, 3) effective reproductive number R_t which was modeled using the EpiNow2 R package, and 4) composite mobility index (mobility). With the interrupted time series regression (ITR) model we assessed the impact using percentage changes in the coefficients representing slope and intercept in consecutive phases. In Bayesian causal impact analysis (BCIA) we assessed the impact using the absolute effect sizes.

Findings:
We observe that the effects are heterogeneous across outcomes and phases. For example, ITR, the national-level changes in intercept & slope for lockdown phase 3 for D(t) were 0.020 and 0.919, C(t) were -116 and - 400, R_t were -296 and -196.70, while those for mobility were -58.90 and -30.78. BCIA revealed effect sizes of 9.223 for phase 1, 38.156 for phase 2, 28.231 for phase 3, 24.975 for phase 4 of lockdown, 24.571 and -1.057 for unlock phase 1 & 2 for mobility. At the state-level, Maharashtra benefited from the lockdown in comparison to Tripura. Effects of lockdown phases 3 and 4 on D(t) were correlated (R=0.70, p<0.05) depicting 'extended impact' of phase-wise interventions.

Interpretation:
We observe the highest impact on mobility followed by effective reproduction number, case growth, and death rate. For optimal impact, lockdown needs to be implemented at the sub-national level. Furthermore, findings can be compared to countries that didn't have lockdowns during the same time period to understand causal effects.

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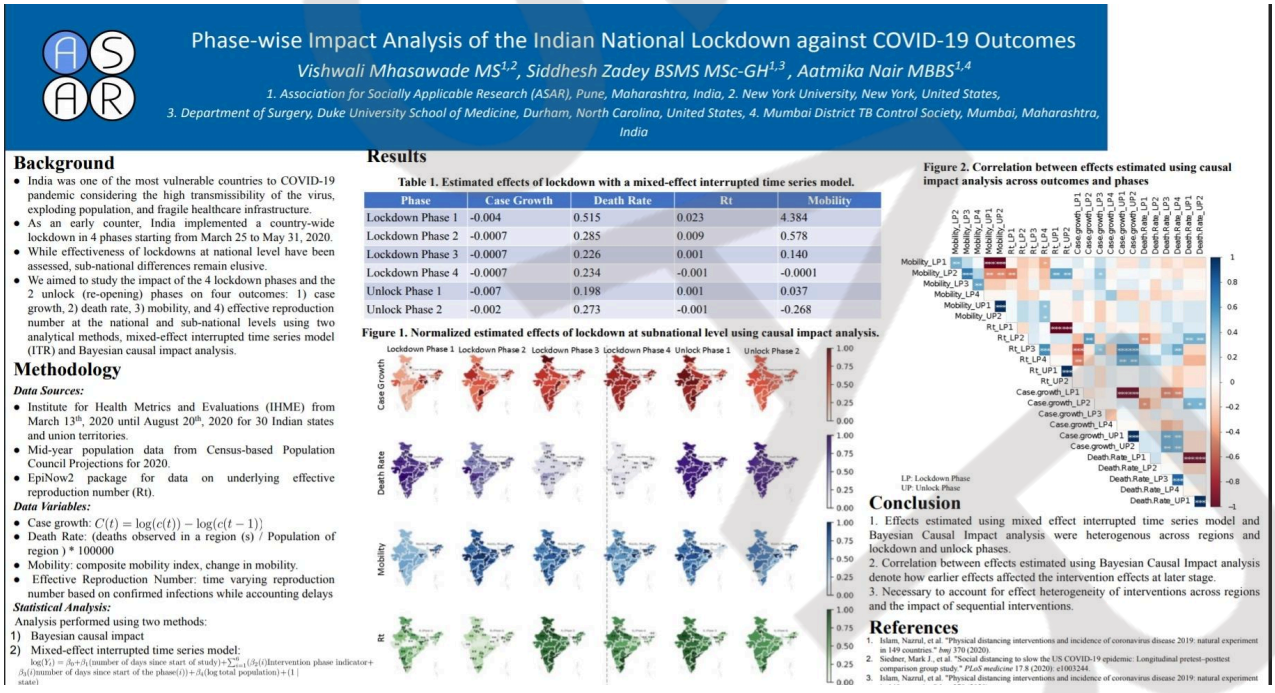

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Background

- India was one of the most vulnerable countries to COVID-19 pandemic considering the high transmissibility of the virus, exploding population, and fragile healthcare infrastructure.
- As an early counter, India implemented a country-wide lockdown in 4 phases starting from March 25 to May 31, 2020.
- While effectiveness of lockdowns at national level have been assessed, sub-national differences remain elusive.
- We aimed to study the impact of the 4 lockdown phases and the 2 unlock (re-opening) phases on four outcomes: 1) case growth, 2) death rate, 3) mobility, and 4) effective reproduction number at the national and sub-national levels using two analytical methods, mixed-effect interrupted time series model (ITR) and Bayesian causal impact analysis.

Methodology

Data Sources:

- Institute for Health Metrics and Evaluations (IHME) from March 13th, 2020 until August 20th, 2020 for 30 Indian states and union territories.
- Mid-year population data from Census-based Population Council Projections for 2020.
- EpiNow2 package for data on underlying effective reproduction number (Rt).

Data Variables:

- Case growth: $C(t) = \log(c(t)) - \log(c(t-1))$
- Death Rate: (deaths observed in a region (s) / Population of region) * 100000
- Mobility: composite mobility index, change in mobility.
- Effective Reproduction Number: time varying reproduction number based on confirmed infections while accounting delays

Statistical Analysis:

Analysis performed using two methods:

1) Bayesian causal impact
2) Mixed-effect interrupted time series model:

$\log(Y_i) = \beta_0 + \beta_1(\text{number of days since start of study}) + \sum_{j=1}^{m} (\beta_j(i)\text{Intervention phase indicator} + \beta_k(i)(\text{number of days since start of the phase}(i)) + \beta_l(\log \text{total population}) + (1 \mid \text{state})$

Results

Table 1. Estimated effects of lockdown with a mixed-effect interrupted time series model.

Phase	Case Growth	Death Rate	Rt	Mobility
Lockdown Phase 1	-0.004	0.515	0.023	4.384
Lockdown Phase 2	-0.0007	0.285	0.009	0.578
Lockdown Phase 3	-0.0007	0.226	0.001	0.140
Lockdown Phase 4	-0.0007	0.234	-0.001	-0.0001
Unlock Phase 1	-0.007	0.198	0.001	0.037
Unlock Phase 2	-0.002	0.273	-0.001	-0.268

Figure 1. Normalized estimated effects of lockdown at subnational level using causal impact analysis.

Figure 2. Correlation between effects estimated using causal impact analysis across outcomes and phases

LP: Lockdown Phase
UP: Unlock Phase

Conclusion

1. Effects estimated using mixed effect interrupted time series model and Bayesian Causal Impact analysis were heterogenous across regions and lockdown and unlock phases.
2. Correlation between effects estimated using Bayesian Causal Impact analysis denote how earlier effects affected the intervention effects at later stage.
3. Necessary to account for effect heterogeneity of interventions across regions and the impact of sequential interventions.

References

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