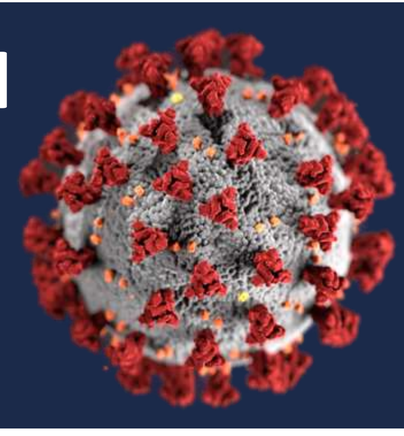
Evaluating the Effectiveness of COVID-19 Non-Pharmaceutical Interventions in the UK: Agent-Based Simulation of Wales



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Introduction and Objectives

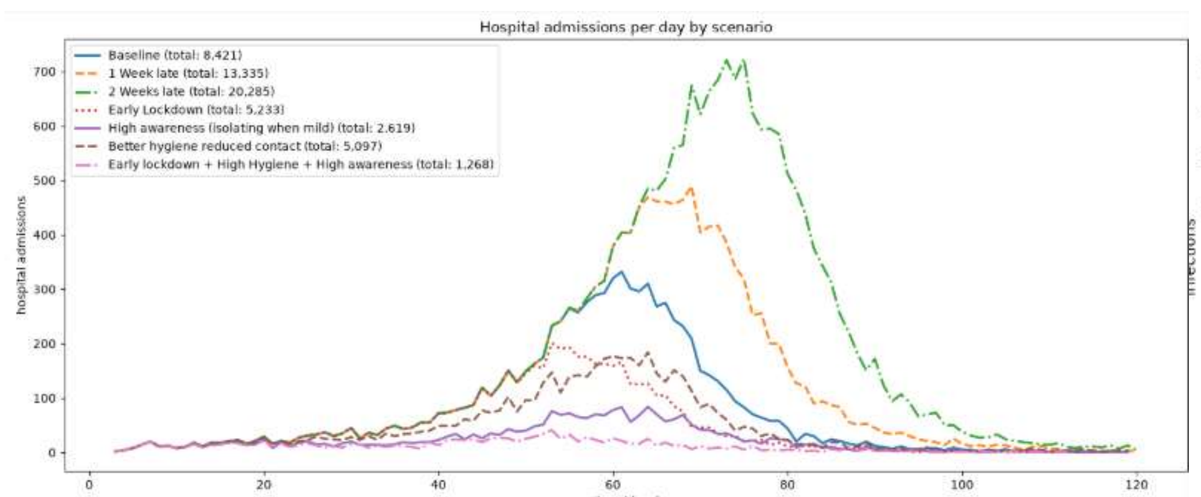
COVID-19 has been one of the deadliest diseases in recent years. Having caused over 7.1 million confirmed deaths worldwide and over 200,000 in just the UK alone, the pandemic had devastating effects on people; physically, socially, mentally and economically, which are felt even to this day. One of the main reasons for the scale of the UK's death toll, according to the UK COVID-19 Inquiry's own Module 2 findings, was the slowness and hesitancy of the government's early response (UK Covid-19 Inquiry (2025)). In particular, in the UK, the elderly and people from ethnic minorities were demographics affected the most disproportionately. (Buffel et al., 2023)

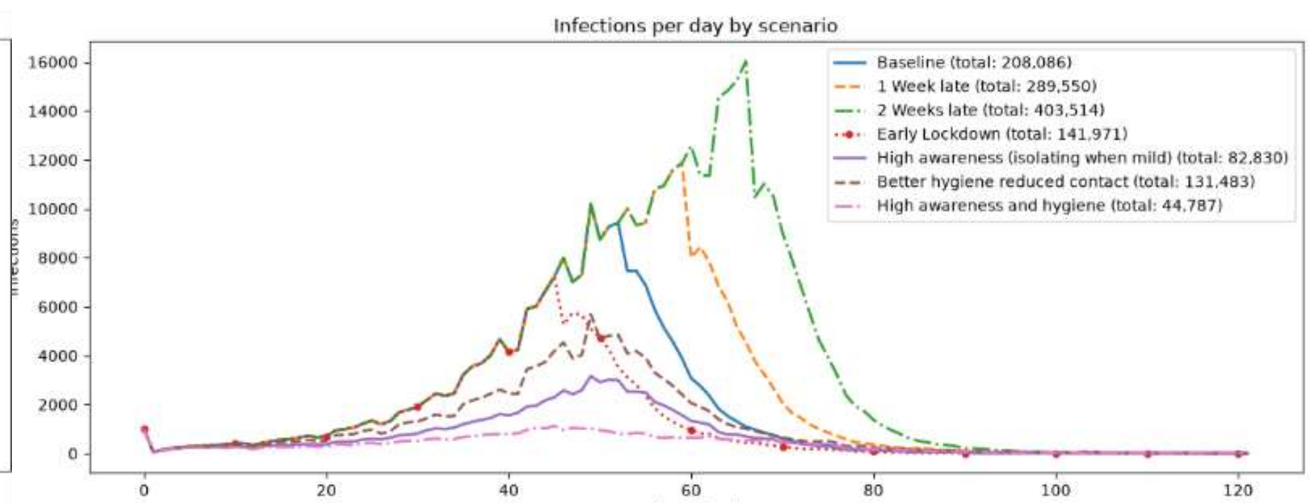
But could a faster response — or a different kind of response — have changed the outcome? Non-pharmaceutical interventions (NPIs) — lockdowns, hygiene measures, and behavioral awareness campaigns — were central to the UK's COVID-19 response, yet their effectiveness remains difficult to measure in isolation. This study tests different NPI's and the effects of earlier and later lockdown interventions on mortality, hospitalization and infection rates.

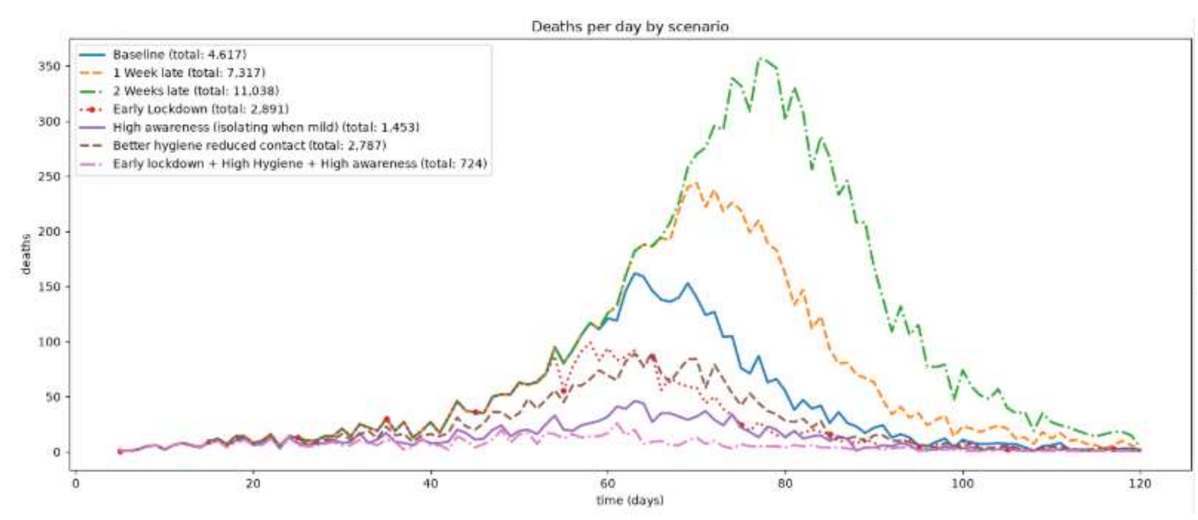
Key Results

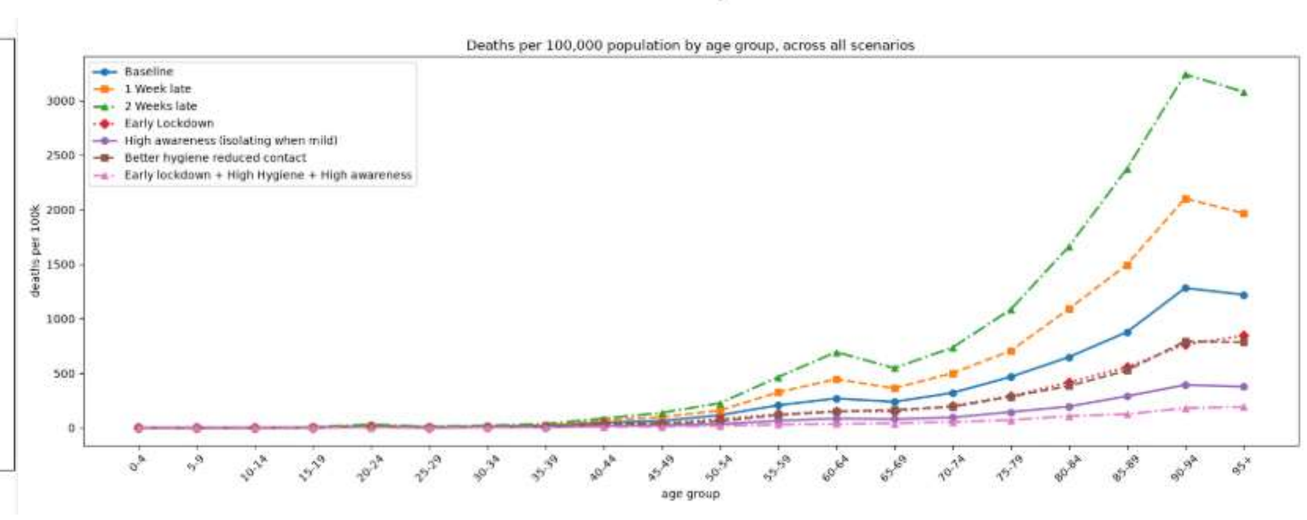
Using an agent-based simulation of Wales calibrated to the second COVID-19 lockdown, this study found that:

- Lockdown delay compounds exponentially, not linearly: each week of delay → ~41% more infections, ~57% more deaths and hospitalisations ($R^2 > 0.998$)
- Sustained behavioural change had a greater impact than timing alone: high awareness (a 90% compliance rate of isolating with mild symptoms) cut deaths/hospitalisations by ~69% — roughly double early lockdown (~37%) or improved hygiene (~40%) alone.
- Combining all three NPIs achieved the largest effect: 78–85% reduction across infections, deaths, and hospitalisations compared to the baseline scenario
- More effective interventions also reduced severity, not just case counts — hospitalisation rate and the ratio of deaths to infections (CFR) both fell as intervention effectiveness increased.
- Mortality risk varied sharply by ethnicity (Other/Asian highest, Mixed groups lowest per capita), substantially explained by age-structure differences (much younger population of mixed ethnicities in Wales led to lower risk).









Methodology

MAY Population synthesis
▼
Agent-Based Simulation in JUNE2
▼
Collection of data through Jupyter Notebook
▼
Analysis of data through Jupyter Notebook

Agent-based epidemic simulation of a synthetic Welsh population (using the 2021 UK Census), built and run through an end-to-end computational pipeline.

Conclusion

- Every week a decision is delayed, the outbreak grows exponentially harder to control and contain than it was the week before – so rapid action is crucial.
- Sustained behavioural measures (isolation support, testing access) may beat lockdown timing alone — so it is vital to invest into programs which educate people quickly and effectively to maximize public safety
- Combining interventions works best, but expect diminishing returns — a portfolio approach beats relying on one strong measure, though benefits are simply not additive.
- Population-wide NPIs shrink absolute inequality far more than relative inequality — targeted support for higher-risk groups is still needed alongside general measures
- Mortality alone is an incomplete success metric — future policy evaluation should pair aggregate outcomes with distributional/demographic breakdowns (e.g. QALYs/DALYs), not hide disparities behind a single national figure

References

- UK Covid-19 Inquiry (2025) *Modules 2, 2A, 2B, 2C report: core decision-making and political governance.*
- Buffel, T., Yarker, S., Phillipson, C., Lang, L., Lewis, C., Doran, P. and Goff, M. (2023) 'Locked down by inequality: older people and the COVID-19 pandemic', *Urban Studies*, 60(8), pp. 1465–1482.
- IDAS-Durham (2026a) MAY. GitHub repository.
- IDAS-Durham (2026b) JUNE2. GitHub repository.
- gavdoubleu (2026a) MAY World Visualiser. GitHub repository.

Acknowledgments

With thanks to Dr Gavin Woolman and Laidlaw Foundation for guidance and support throughout this project, and making it possible for me to conduct.

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