Quantifying Norovirus Intervention Impact in Restaurant-Associated Outbreaks

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INTRODUCTION

Restaurants are high-contact environments where norovirus spreads rapidly through staff–patron interactions, contaminated food, and poor hygiene.

This study evaluates the impact of:

- **Symptomatic worker exclusion**
- **Enhanced hygiene (handwashing + glove use)**

Using a **stochastic, discrete-time norovirus transmission model** calibrated to CDC NORS outbreak data.

METHODS

Data (CDC NORS, 2011–2023)

1,980 restaurant-associated, foodborne norovirus outbreaks

Model Overview

- Stochastic, discrete-time SEIR-type simulation
- Agents: staff (S, E, I_a, I_s, R)
- Flow population: patrons per shift
- Disease spread pathways:
  staff–staff spread → staff–patron spread → contamination events

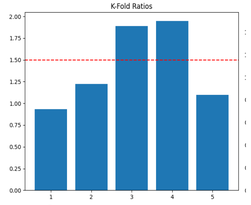
$$S_s \xrightarrow{\text{infection}} E_s \xrightarrow{1\text{ day}} \begin{cases} I_{a,s} \\ I_{s,s} \end{cases} \xrightarrow{3\text{ days}} R_s.$$

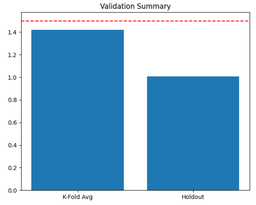
Transmission Pathways

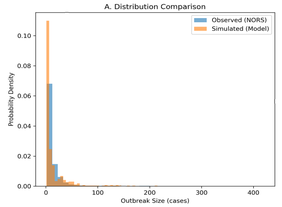
- Staff → Staff (β_{ss})
- Handler → Patron (β_{hp})
- Non-handler → Patron (β_{other})
- Food contamination: Bernoulli event + lognormal superspreading

Calibration

- K-fold CV → 80/20 holdout → full grid search
- Objective: match NORS outbreak-size percentiles (10th–99th)
- Final calibrated parameters reproduce observed distribution, including tail







Policies

- **Symptomatic worker exclusion:** compliance = 0.3, 0.6, 1.0
- **Hygiene improvements:** moderate (30% reduction) or strict (60% reduction)
- Policies modify β values and contamination probability

Scenario Structure

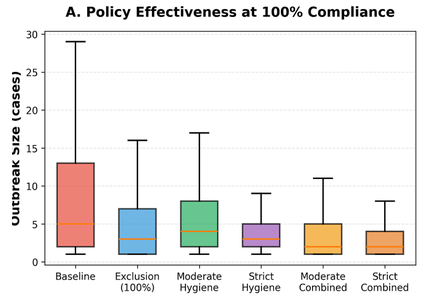
- **16 total scenarios:** baseline + exclusion-only + hygiene-only + combined
- **1,500 simulations** per scenario
- Outputs: outbreak-size distribution, percentiles, tail probabilities, cases averted

RESULTS

Policy Effectiveness at 100% Compliance

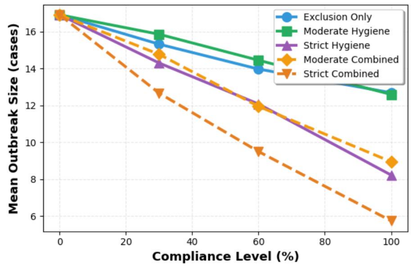
Policy scenarios evaluated in the stochastic norovirus model

Scenario Group	Hygiene Level	Exclusion	Compliance
Baseline	None	None	–
Exclusion Only	None	Yes	0.30
	None	Yes	0.60
	None	Yes	1.00
Moderate Hygiene	Moderate	No	0.30
	Moderate	No	0.60
	Moderate	No	1.00
Strict Hygiene	Strict	No	0.30
	Strict	No	0.60
	Strict	No	1.00
Moderate + Exclusion	Moderate	Yes	0.30
	Moderate	Yes	0.60
	Moderate	Yes	1.00
Strict + Exclusion	Strict	Yes	0.30
	Strict	Yes	0.60
	Strict	Yes	1.00



Strict hygiene + exclusion produced the largest reduction in outbreak size, followed by strict hygiene alone. All interventions outperformed exclusion-only or moderate hygiene.

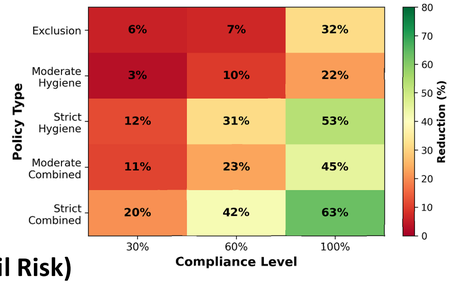
Compliance Dose–Response Curves



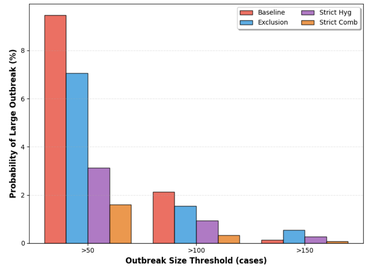
- **Higher compliance consistently reduces outbreak size across all policy types.**
- Strict hygiene and combined policies show the strongest dose–response effect.

- **Interventions prevent 6–66% of cases depending on compliance.**
- Strict hygiene + exclusion achieves the greatest reductions at every compliance level.

Outbreak Reduction Heatmap (%)



Large Outbreak Prevention (Tail Risk)

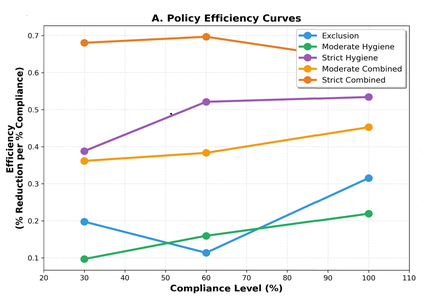


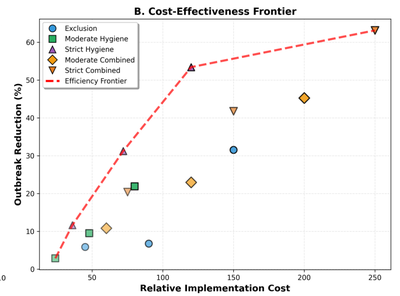
- **Strong hygiene measures cut the risk of large outbreaks (>50–150 cases) by up to 80–95%.**
- Combined policies have the greatest impact on preventing superspreading events.

IMPACT & DISCUSSION

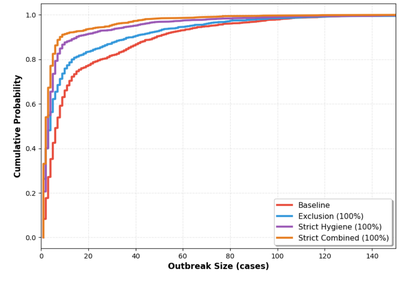
Cost-Effectiveness

- **Strict hygiene = highest efficiency (best reduction per cost).**
- Moderate combined = strongest mid-cost performer.
- Exclusion-only = lowest cost but lowest effect.





- Hygiene interventions are the most effective, consistently outperforming exclusion alone.
- Strict hygiene compresses the upper tail, substantially reducing the risk of superspreading outbreaks.
- Exclusion-only has modest impact, since symptomatic workers account for only part of overall transmission.



Combined hygiene + exclusion provides the strongest reductions, often outperforming what would be expected from adding the two effects separately (functional synergy).

FUTURE WORKS

- **Include environmental persistence modeling**
  - Add environmental compartments like surface and restroom contamination to capture norovirus survival outside hosts.
- **Add direct time-series data**
  - If temporal outbreak data becomes available, calibrate not only to outbreak size but also to daily case curves.
- **Extend model to other foodborne pathogens**
  - Adapt the two-population SEIR system to handle pathogens with different incubation periods and shedding profiles (e.g., Salmonella, Shigella, Campylobacter).
- **Incorporate uncertainty quantification and sensitivity analysis**