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DEPARTMENT OF MANAGEMENT SCIENCE

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REPORT 3: IMPACT OF VARIOUS VACCINATION COVERAGES ON THE SPREAD OF COVID-19 AND DEATHS IN CARE HOMES

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Summary

In this report, we present the results of the modelling work that compares the effects of various COVID-19 vaccination coverages among residents and staff on the spread of COVID-19 and COVID-19 deaths in care homes. We also investigate the impacts of a reduction in the current weekly staff testing, which includes once RT-PCR test and two Lateral Flow SARS-CoV-2 Antigen tests (LFTs), for different scenarios of vaccination coverage and transmission in the community.

Our model results show that prioritising vaccination for residents is most effective for reducing the number of deaths due to COVID-19 among residents. After 12 weeks, vaccinating 90% of residents and 70% of staff with one dose results in a lower COVID-19 death toll than giving two doses spaced three weeks apart to 50% of residents and staff. This result occurs when either assuming that the vaccine efficacy after dose 1 does not wane and also when it decreases by 10 percent points per month. The median number of deaths averted are two (95% CI: one – three) and one (95%CI: one – two) per 1,000 residents after 90 days in the two scenarios of no waning and waning of dose 1 efficacy respectively. This result does not account for the potential increasing risk of new vaccine resistant.

When the vaccination coverage among residents and staff are ≥ 80% and ≥50% respectively, ceasing either the once-per-week RT-PCR test (sensitivity ≥ 90%, turnaround time less than two days) or twice-per-week LFTs one week after administering the second dose of the vaccine (three-week interval between doses) does not affect the death toll among residents due to COVID-19.

When the infection prevalence in the community equals half of the reported data for the second wave in Scotland and the vaccination coverage among both residents and staff are ≥ 90%, halting the current weekly staff testing intervention has a small impact on the number of infected residents and no impact on the death toll.

1. Introduction

A safe and effective vaccine against COVID-19 plays a critical role in alleviating the burden caused by the Covid-19 pandemic. Several candidate vaccines (17 as of December 2020) have undergone clinical trials and are at various trial phases. By the 8th of January 2021, the UK government approved the Pfizer/BioNTech COVID-19, Oxford University/AstraZeneca, and Moderna vaccines for use in the UK in response to the recommendation from the UK Medicines and Healthcare Products Regulatory Agency.[1-3] The vaccine trials suggest that vaccination is effective for reducing disease severity and deaths in vaccinated populations.[4,5] However, the vaccine efficacy in preventing infection remains unclear, and therefore, its effect on onward transmission is also unclear. The availability of vaccine supply and its potential level of uptake are uncertain, and we have no data on its efficacy beyond the trials' duration or for dosing schedules not trialed.

In the initial limited supply of COVID-19 vaccines, care home residents and staff in the UK who are most at risk from coronavirus are prioritized in the first phase of a mass vaccination program. There have not been studies that evaluate the potential impacts of different vaccination coverages in care home residents and staff which are critical under resource constraints. In this analysis, we used simulation modelling **to investigate the impacts of different vaccination coverage levels among residents and staff** on the spread of COVID-19 in care homes. We also **examined whether weekly testing of staff in care homes could be safely lifted** when vaccination coverage among residents and staff reach certain thresholds.

2. Methods

We adapted the agent-based model described in detail in Nguyen et al[6] to conduct this analysis. In brief, the base-case model simulated the transmission dynamics of COVID-19 in a representative care home of 80 residents and 72 staff members via contacts between individuals including residents, staff, and visitors. A time-series of COVID-19 infection prevalence in Scotland adjusted for undetected cases described prevalence in the community. We adopted the worst case that the undetected cases represent 80% of the total cases in the community in the base-case simulations.[6] As the global sensitivity analysis for all model parameters indicated that the infection prevalence in the community is the most impactful parameter, we further carried out a univariate sensitivity analysis for the model outcomes for this parameter.

NHS Scotland and Health and Social Care Partnership Lanarkshire advised that all residents and staff have received the Pfizer vaccine and very few will receive other vaccines going forward. Therefore, we assumed that residents and staff in our model receive the Pfizer vaccine. The vaccine efficacy against confirmed COVID-19 over time in different scenarios is described in Table 1. In the base-case simulations, the vaccine protects against confirmed COVID-19 cases, which are defined as having a positive virological test plus at least one COVID-19 symptom[5], but does not protect against asymptomatic infection. We assumed that the vaccine efficacy against confirmed COVID-19 in the resident population is 25% lower than for staff as it is known that response to vaccination is often less effective among older adults.[7,8]

We derived this level of reduction based on the evidence for other vaccines such as influenza vaccine[8] and from consulting with other researchers and professionals in the Scottish Government Care Home Data, Analysis and Research Group. We considered different scenarios where the vaccine has an efficacy of 0%, 20%, and 40% against infection and thus onward transmission.

In the baseline simulations, the implemented interventions included the reference intervention and weekly staff testing consisting of one RT-PCR test and two LFTs.[9] The reference intervention comprised hand hygiene and using Personal Protective Equipment, social distancing, restricted visiting, isolation of symptomatic cases, and testing new admissions. The sensitivities of RT-PCR and LFT were 70% and 58% respectively.[10-13] The test return time for RT-PCR was 2-3 days based on discussion with the Lanarkshire Health and Social Care Partnership and Social Care Working Group. We assumed that asymptomatic and pre-symptomatic infected individuals transmit the virus 75% (95% CI 0.34 – 0.99) as effectively as symptomatic ones.[14,15] We began the simulations with a seeded infection in the care home and performed 1,000 runs for each scenario.

Table 1: Values of vaccine efficacy against confirmed COVID-19 over time under different scenarios[5]

Timeline	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**Week 6**	**Week 7 – 12**
Day	1 – 7	8 – 14	15 – 21	22 – 28	29 – 35	36 – 42	43 – 90
Scenario 1: One dose	**Dose 1**						
Scenario 1A	0		89 (52 – 97)	89 (52 - 97)			
Scenario 1B	0		89 (52 – 97)	Decrease of 10 percent points per month[16,17] (Assumption based on waning of influenza vaccine)			
Scenario 2: Two doses spaced 21 days	**Dose 1**			**Dose 2**			
	0		89 (52 – 97)	90.5 (61.0 – 98.9)	95 (90.3 – 97.6)	94.2 (88.7 – 97.2)	

Unit is % and values in brackets are 95%CI. Values in green cells are assumed as no evidence is available yet.

Experiment Designs:

For each vaccine dosing schedule and efficacy scenario described in Table 1, we tested the effects of different combinations of staff and resident coverages. We also examined the impacts of reducing the weekly staff testing strategy in different vaccination coverages. Table 2 describes the characteristics of the RT-PCR and Lateral Flow Antigen testing including their sensitivity, result return time, and frequency. In these scenarios of reducing weekly staff testing, vaccinated individuals received two doses of the vaccine spaced 21 days apart. The RT-PCR test and/or LFTs were lifted on day 29 (four weeks after Dose 1 and one week after Dose 2). Finally, we investigated the effects of lifting weekly staff testing in different scenarios of infection prevalence in the community.

Table 2: Characteristics of different types of testing in base case simulations [9-11]

Type of Test	Sensitivity	Test Result Return Time	Test Frequency
RT-PCR	0.7	2 – 3 days	Once per week
Lateral Flow SARS-CoV-2 Antigen	0.58	~ 30 mins	Twice per week

Measured Outcomes:

The cumulative number of infected residents and COVID-19 deaths per 1,000 residents after 90 days

Statistical Analysis:

We used the Wilcoxon signed-rank test at a significant level of $\alpha = 0.05$ to perform hypothesis testing for difference in the median cumulative numbers of infections and COVID-19 deaths per 1,000 residents after 90 between scenarios. We also adopted the Bonferroni correction method in which the *P* values were multiplied by the number of tests to counteract the potential type 1 error in multiple comparisons.

3. Results

3.1. Impacts of Vaccination Coverages in Different Vaccine Dosing Schedule and Efficacy Scenarios

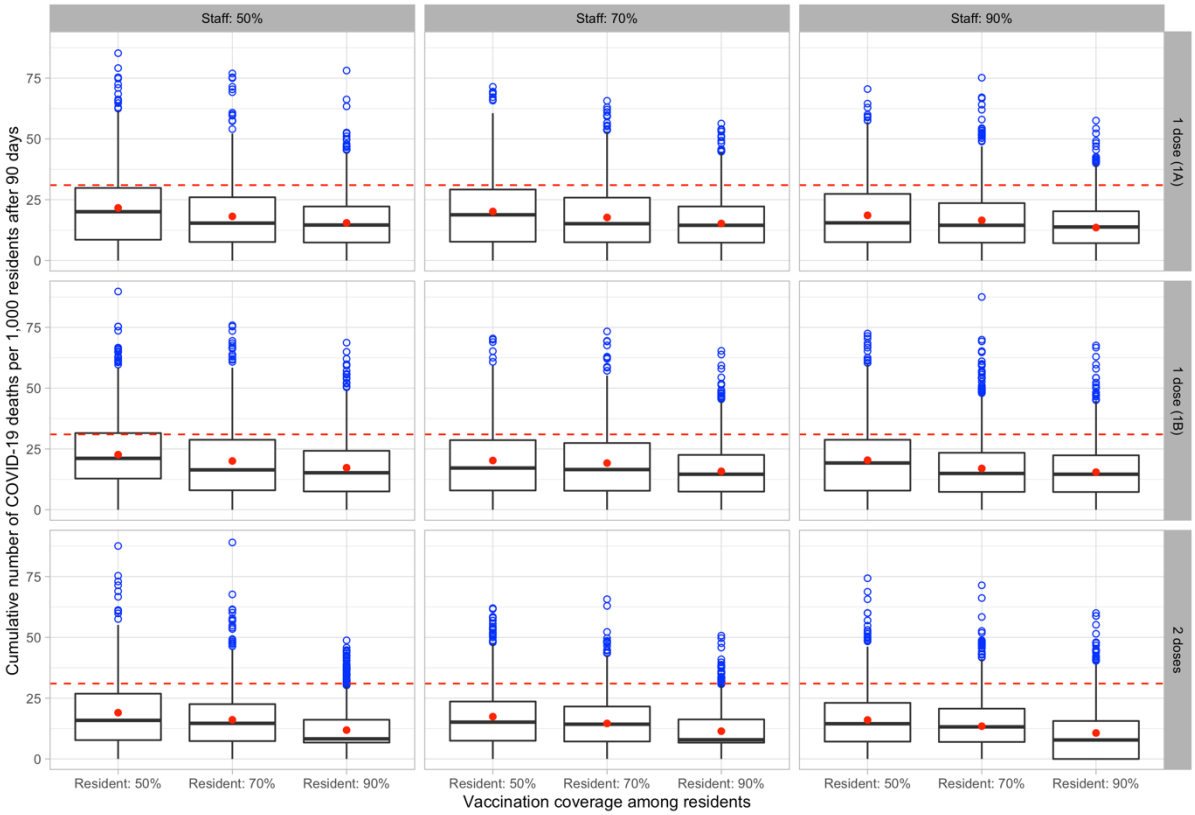

Figure 1: Impacts of vaccination coverage among residents and staff on the number of COVID-19 deaths per 1,000 residents in different vaccine dosing schedule and efficacy scenarios after 90 days

(The result is presented as a box plot – lower hinge: 25% quantile; lower whisker: smallest observation greater than or equal to lower hinge - 1.5 * IQR; middle: median; upper hinge: 75% quantile; upper whisker: largest observation less than or equal to upper hinge + 1.5 * IQR; red dot: mean; blue dot: outlier. Dashed red line denotes the median number of COVID-19 deaths in no vaccination scenario. Vaccine efficacy against infection is 20%. Other parameters have the base case values.)

Higher vaccination coverages among residents and staff reduced the number of COVID-19 deaths among residents (Figure 1 and Table S1). Vaccinating 50% of residents and staff with two doses of the vaccine spaced 21 days part averted 13 COVID-19 deaths (95%CI: 12 – 14) per 1,000 residents after 90 days. Increasing the coverages to 70% and 90% decreased the number of deaths further by approximately two and eight deaths per 1,000 residents respectively.

Increasing the vaccination coverage among residents had a greater impact on the death toll among residents than increasing the coverage among staff. This result was under the assumption that vaccine efficacy against infection and, therefore, onward transmission was low (0 – 40%). Covering 90% of residents (0% staff coverage) with two doses of the vaccine reduced the number of COVID-19 deaths among residents twice as much as the same coverage among staff (0% resident coverage). A 20% increase in resident coverage from 70%

to 90% reduced the number of COVID-19 deaths among residents by half whilst such increase in staff coverage did not lead to a statistically significant difference in the medians of this outcome ($p>0.5$).

Giving half of residents and staff two doses of the vaccine spaced 21 days apart resulted in a higher number of COVID-19 deaths among residents than covering 90% of residents and 70% of staff with one dose for 12 weeks ($p<0.0001$) (Table S1). In the most optimistic scenario where the vaccine efficacy of Dose 1 did not wane after day 21 without having Dose 2, covering 90% of residents and staff with one dose averted two deaths (95% CI: two – three) per 1,000 residents after 90 days compared to vaccinating 50% of residents and staff with the 21-day-interval two-dose regimen. When the vaccine efficacy linearly decreased at the rate of 10 percent points per month, the former strategy still lowered the death toll by one (95%CI: one – two) per 1,000 residents more than the latter strategy.

3.2. Effects of Reducing Weekly Staff Testing Strategy in No Vaccination Scenario

Figure 2 shows that removing the once-per-week RT-PCR test had a smaller impact on the model outcomes than removing the twice-per-week LFTs when vaccination was not implemented. Removing RT-PCR test increased the number of infections by 8 (95%CI: 7 – 9) – 13 (95%CI: 12 – 14) and the number of deaths by one (95%CI: one – two) – three (95%CI: two – three) per 1,000 residents across the values of RT-PCRT test sensitivity after 90 days (See Supplementary Material S2). Meanwhile, removing LFTs increased the number of infections by 22 (95%CI: 21 – 23) – 47 (95%CI: 46 – 48) and deaths by 4 (95%CI: 3 – 5) – 13 (95%CI: 12 – 15) per 1,000 residents over the same period.

When the RT-PCR sensitivity was set at 90% and the test turnaround time was one day (or 95% and 1.5 days respectively), once weekly RT-PCR testing prevented the same amount of transmission compared to twice weekly LFT. The relative effectiveness of these two testing strategies was sensitive to the sensitivity of the tests and the turnaround time of RT-PCR testing. Other modelling studies suggested similar results.[a,18]

[a] Comparing sequential and alternative testing in care home staff; Ian Hall (on behalf of the modelling subgroup of the Social Care working group), November 2020

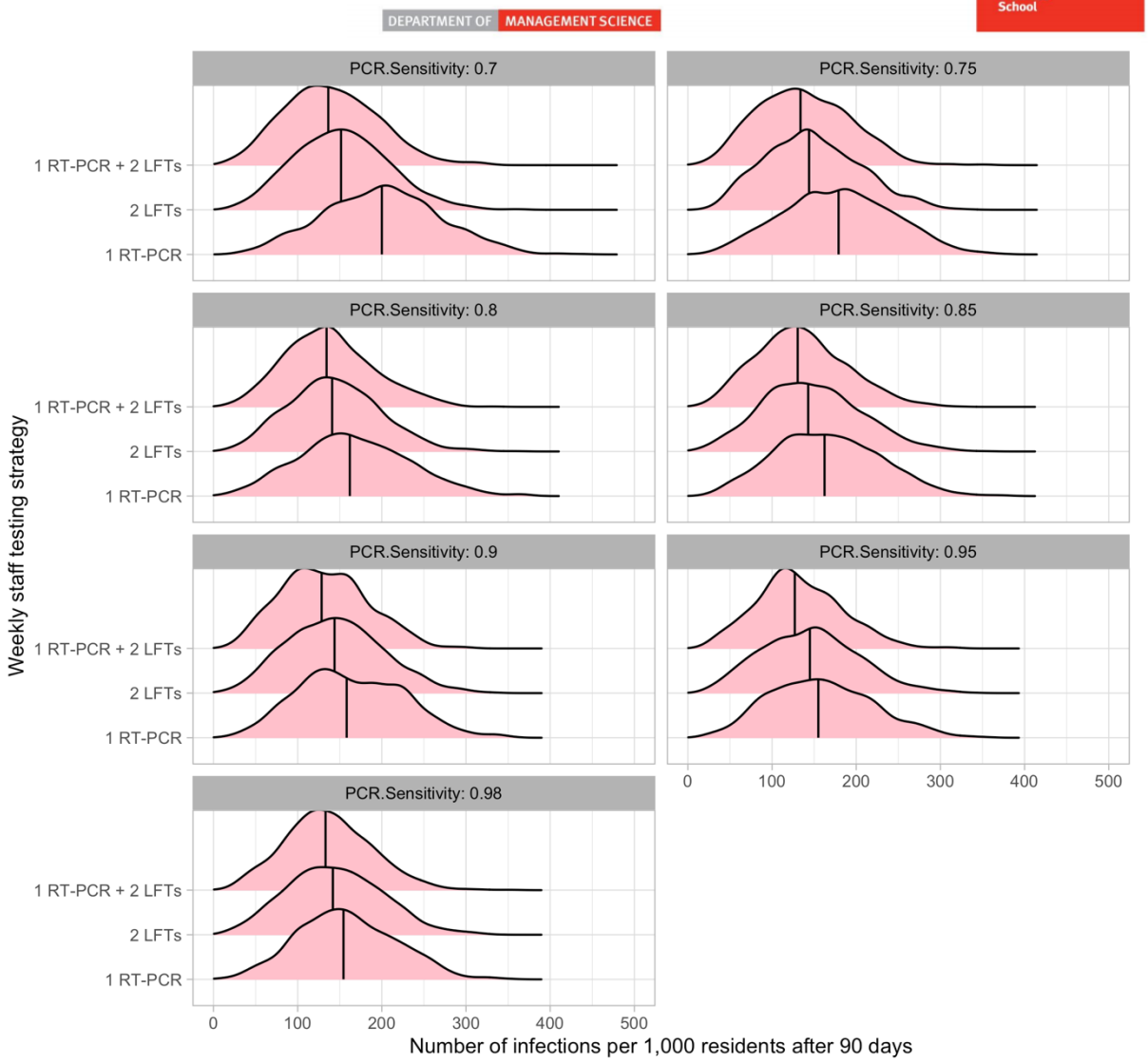

Figure 2: Impact of reducing weekly staff testing in no vaccination scenario

Distributions of the cumulative number of infections per 1,000 residents after 90 days in different weekly staff testing strategies and no vaccination. Panels show the results for different values of RT-PCR test sensitivity. Test return time is two to three days. Vertical lines denote the medians of distributions. Vaccinated individuals receive two doses of the vaccine spaced 21 days apart. RT-PCR and/or LFTs are lifted on day 29 – four weeks after Dose 1 and one week after Dose 2. Observed infection prevalence in the community reflects 20% of the actual prevalence. Vaccine efficacy against infection is 20%. Other parameters are set at base case values.

3.3. Effects of Reducing Weekly Staff Testing Strategy in Vaccination Scenarios

In this section, we report the effect of reducing the current weekly testing of staff for various vaccination coverage scenarios in which at least 50% of both residents and staff were administered the vaccine.

Removing the once-per-week RT-PCR testing had a minimal impact on the cumulative number of infections and COVID-19 deaths among residents (Figure 3 and S1). For 50% coverage of both residents and staff, removing the once weekly RT-PCR testing increased the number of infections by 10 (95%CI: 9 – 11) per 1,000 residents over 90 days. For 90% coverage of both residents and staff, this strategy increased the number of infections by four (95%CI: three – five) per 1,000 residents. The impact on the model outcomes increased when removing the

twice-per-week LFTs. This resulted in an increase of approximately 40 (95%CI: 38 – 41) and 30 (95%CI: 29 – 31) infections per 1,000 residents for 50% and 90% coverage scenarios respectively. Lifting the current weekly staff testing completely had a significant effect. The median number of infected residents increased significantly by around 80 – 100 infections per 1,000 residents.

When the vaccination coverages among residents and staff were ≥80% and ≥50% respectively, the difference in the median numbers of COVID-19 deaths per 1,000 residents between the current weekly staff testing strategy and lifting RT-PCR testing was not statistically significant ($p>0.5$). For other coverage scenarios that we examined, lifting RT-PCR testing increased the median number of deaths by between one and two per 1,000 residents ($p<0.02$). Ceasing LFTs resulted in an increase of between two and six COVID-19 deaths per 1,000 residents across all the studied coverage scenarios ($p<0.0001$).

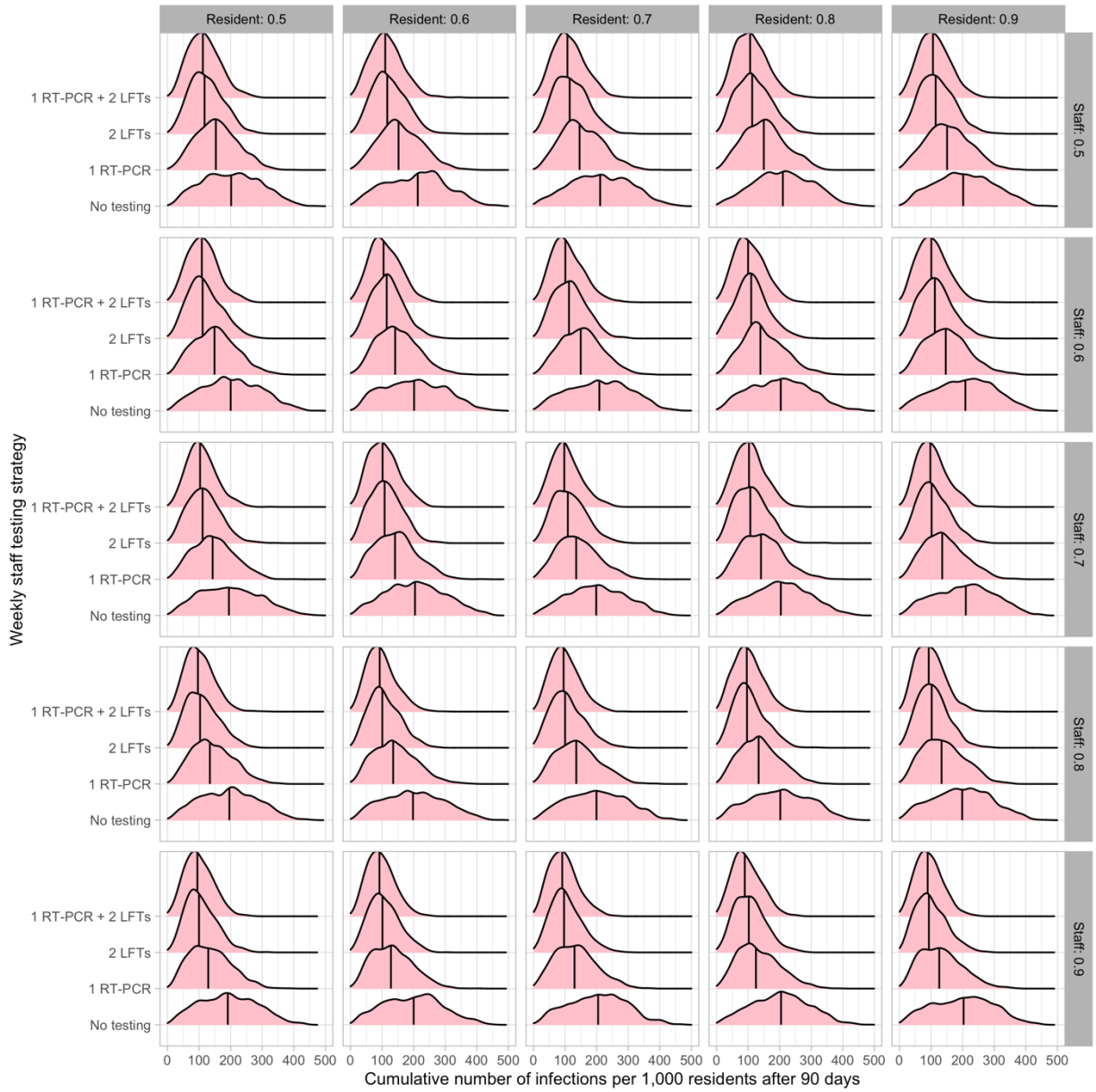

Figure 3: Impact of reducing weekly staff testing for different scenarios of vaccination coverage

Distributions of the cumulative number of infections per 1,000 residents after 90 days in different weekly staff testing strategies and vaccination coverages. Vertical lines denote the medians of distributions. Vaccinated individuals receive two doses of the vaccine spaced 21 days apart. RT-PCR and/or LFTs are lifted on day 29 – four weeks after Dose 1 and one week after Dose 2. Observed infection prevalence in the community reflects 20% of the actual prevalence. Other parameters are set at base case values.

3.4. Impact of Reducing Weekly Staff Testing under Different Scenarios of Community Prevalence

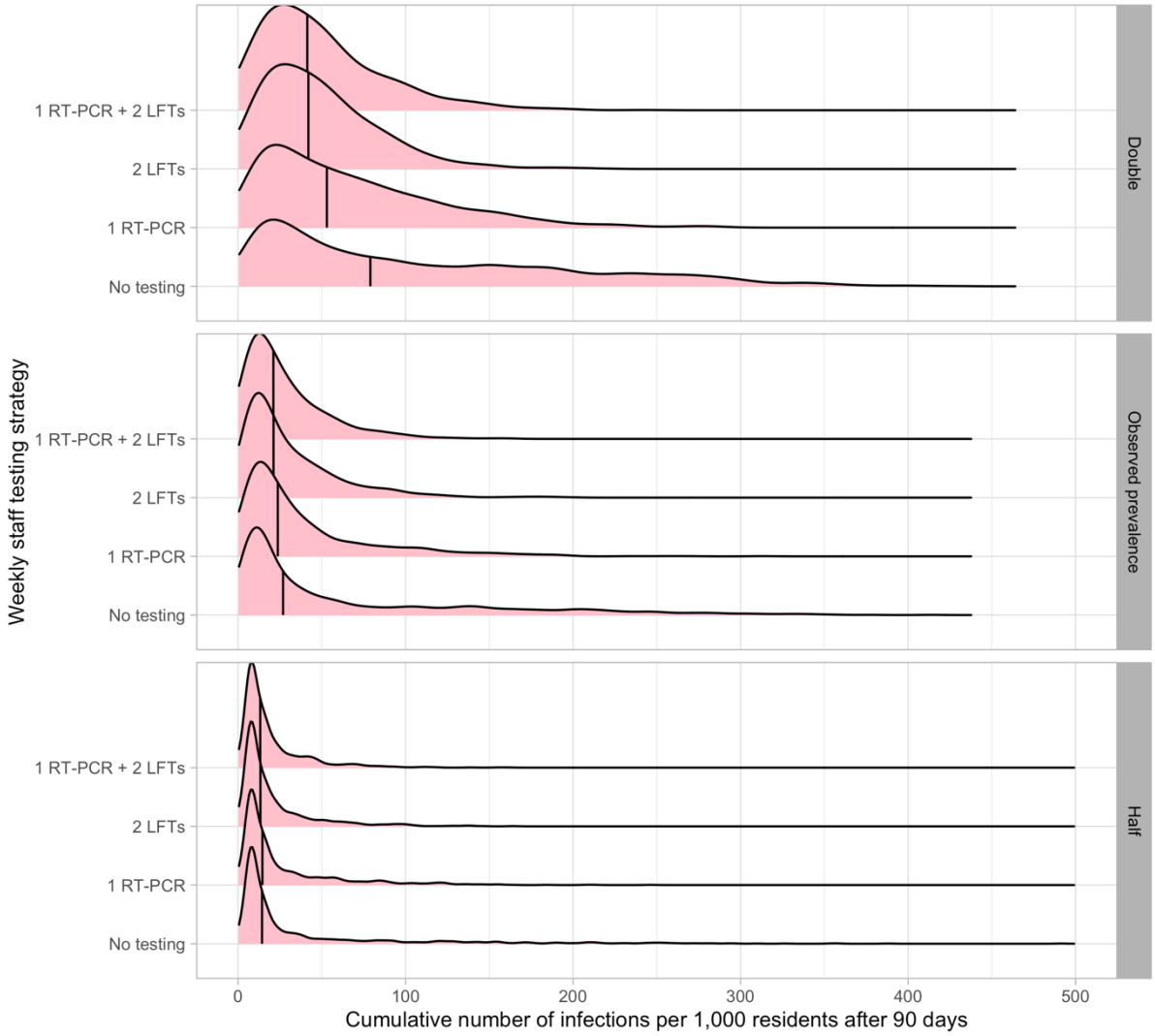

Figure 4: Impact of reducing weekly staff testing under different scenarios of community prevalence

Distributions of the cumulative number of infections per 1,000 residents after 90 days in different weekly staff testing strategies and vaccination coverages. Vertical lines denote the medians of distributions. Vaccinated individuals receive two doses of the vaccine spaced 21 days apart. Vaccine efficacy against infection is 20%. RT-PCR and/or LFTs are lifted on day 29 – four weeks after Dose 1 and one week after Dose 2. Panels include the modelling results when the infection prevalence in the community is equal to, half and double of the observed data. Other parameters are set at base case values.

In this section, we examined whether lifting the weekly staff testing is safe when the vaccination coverages among residents and staff were both 90% and the infection prevalence in community declined. If the reported data reflected the true prevalence in the community, lifting the once-per-week RT-PCR testing did not affect the number of infected residents and deaths ($p>0.5$) while lifting the twice-per-week LFTs increased the number of infections and deaths by ten (95%CI 9 – 11) and one (95%CI 0 – 1) per 1,000 residents respectively . Stopping

both weekly RT-PCR and LFTs led to an increase of 27 infections (95%CI: 25 – 28) and two deaths (95%CI: one – three) per 1,000 residents after 90 days.

When the infection prevalence in the community was reduced in the model (Figure 4), the differences in outcomes between the current weekly staff testing intervention and halting this intervention declined. When the community prevalence was half of the observed prevalence, the cessation of weekly testing increased the number of infections by ten (95%CI: 9 – 11) per 1,000 residents and had no statistically significant impact on the death toll ($p>0.5$).

4. Implications for Policy

Our model results showed that prioritising vaccination for residents in care homes was most effective in reducing the risk of death due to COVID-19. Increasing the vaccination coverage among residents provided direct protection against COVID-19 death, and thus, effectively reduced the death toll. As we assumed low vaccine efficacy against infection, vaccinating staff has a limited role in providing indirect protection against COVID-19 to residents.

After 12 weeks, vaccinating 90% of residents and 70% of staff with one dose resulted in a lower risk of death than giving two doses spaced three weeks apart to half of residents and staff. The finding remained robust when assuming that the vaccine efficacy of the first dose waned. This prediction favoured the decision of extending the second dose of the Pfizer vaccine to 12 weeks instead of the three-week interval. However, this result did not account for the potential increasing risk of new vaccine resistant variants. Neither did the model consider scenarios in which delaying the second dose could affect the vaccine efficacy and protection duration.

When the vaccination coverages among residents and staff are ≥ 80% and ≥50% respectively, ceasing either the once-per-week RT-PCR testing (sensitivity ≥ 90%, test return time less than two days) or twice-per-week LFTs one week after giving the second dose of the vaccine did not affect the death toll among residents. When the infection prevalence in the community was low and the vaccination coverages among both residents and staff were ≥ 90%, halting the current weekly staff testing intervention slightly increased the number of infected residents but had no impact on the death toll. The analysis has not evaluated either the cost-effectiveness of these vaccination and de-escalation of testing strategies or their impacts on transmission in wider communities.

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Supplementary Materials

S1 – Plots of modelling results

Table S1: Impacts of vaccination coverages among residents and staff on the median number of infections and COVID-19 deaths per 1,000 residents (medians) in different vaccine dosing schedule and efficacy scenarios after 90 days

Vaccination Coverage		Vaccination Schedule and Waning of Vaccine Efficacy (VE)					
		2 Doses (3 weeks apart)		1 Dose (No VE waning)		1 Dose (VE decrease of 10 percent points per month)	
Residents	**Staff**	**Infections**	**COVID-19 Deaths**	**Infections**	**COVID-19 Deaths**	**Infections**	**COVID-19 Deaths**
0	**0**	132	29	132	29	132	29
0	**0.9**	102	21	101	21	107	22
0.5	**0.5**	109	16	109	20	111	21
0.5	**0.7**	101	15	106	19	106	17
0.5	**0.9**	95	14	96	16	100	19
0.7	**0.5**	109	15	103	15	108	17
0.7	**0.7**	102	14	100	15	103	16
0.7	**0.9**	91	13	93	14	94	15
0.9	**0**	123	13	124	16	115	17
0.9	**0.5**	108	8	104	15	104	16
0.9	**0.7**	98	8	98	14	93	15
0.9	**0.9**	87	8	88	14	92	15

Vaccine efficacy against infection: 20%

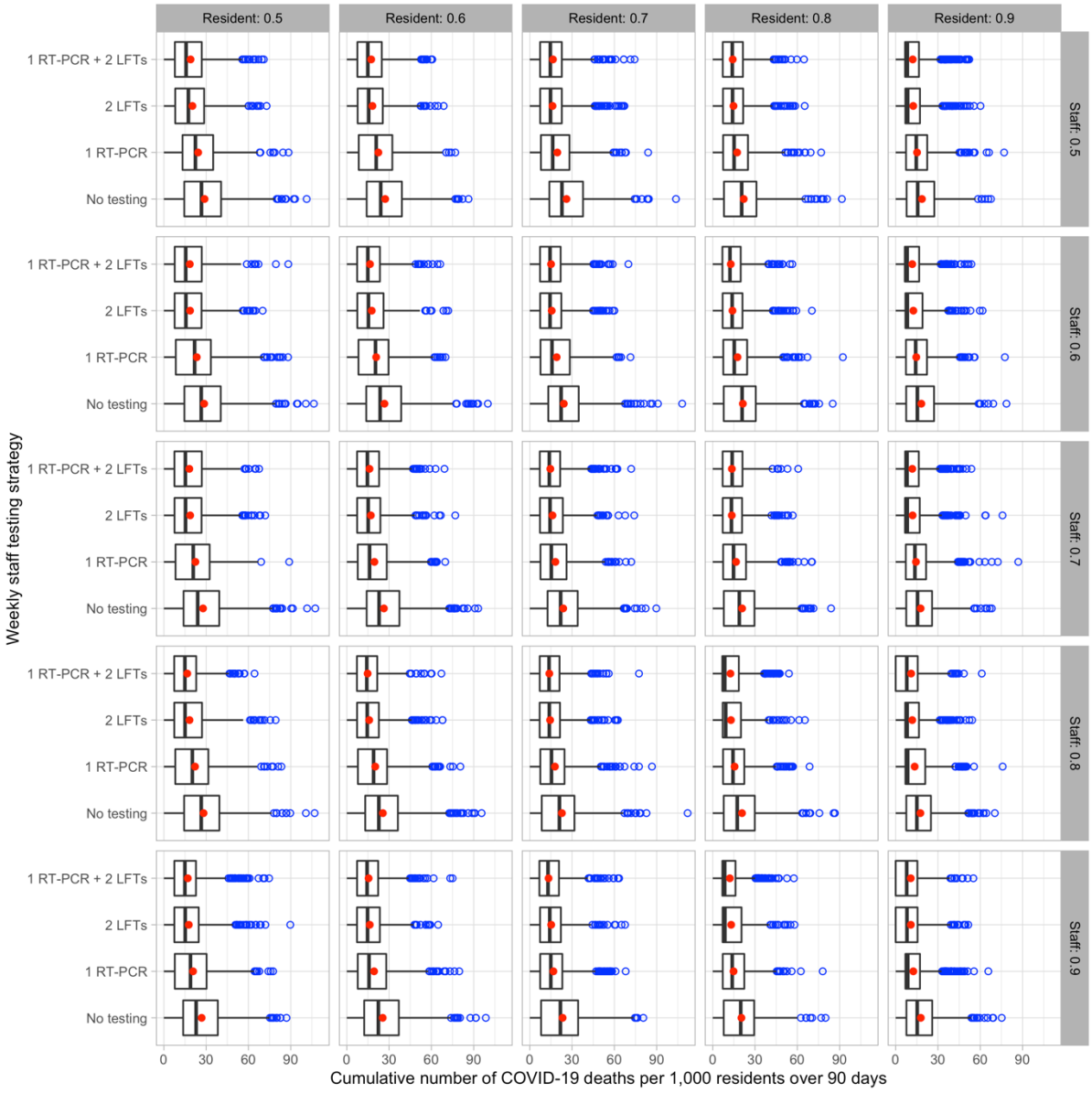

Figure S1: Impacts of reducing weekly staff testing on COVID-19 deaths among residents

(Panels present the results for different vaccination coverages among residents and staff. Vaccine efficacy against infection is 20%. Other parameters are set at base case values. The result is presented as a box plot – lower hinge: 25% quantile; lower whisker: smallest observation greater than or equal to lower hinge - 1.5 * IQR; middle: median; upper hinge: 75% quantile; upper whisker: largest observation less than or equal to upper hinge + 1.5 * IQR; red dot: mean; blue dot: outlier.)

S2 – Further Clarification on Analysis for RT-PCT and LFT Sensitivity

Our model used a lower sensitivity value of LFT (58% vs ~75% as reported in the evaluation study of the University of Oxford and Public Health England's Porton Down laboratory).[13] As we might have already underestimated the sensitivity of LFT, varying its value would still lead to the results that favour the strategy of lifting RT-PCR rather than lifting LFTs. By contrast, the base case scenarios used a lower value for RT-PCR sensitivity (0.7) compared to the reported sensitivity from manufacturers (92 – 98%). Thus, we varied it to assess whether higher sensitivity values of RT-PCR test alter the results.