The impact of uptake and adherence on transmission and absences resulting from secondary school reopening strategies involving rapid testing

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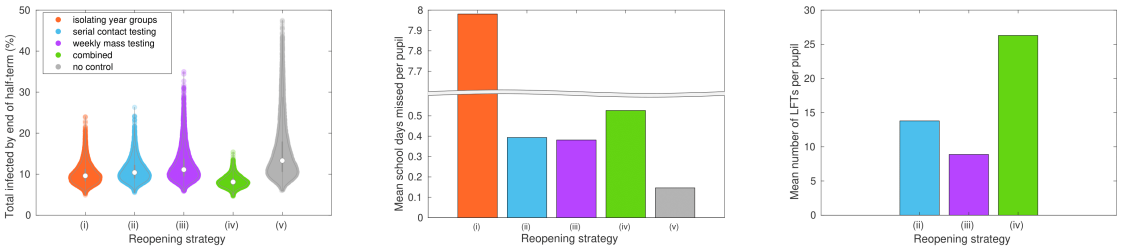
Aim: To assess the impact on transmission and absences resulting from school reopening strategies using lateral flow device tests (LFTs), and to understand the impact of uptake (pupils agreeing to participate in rapid testing), adherence (participating pupils actually taking tests at home), close contact group size, and transmission on within-school test days.

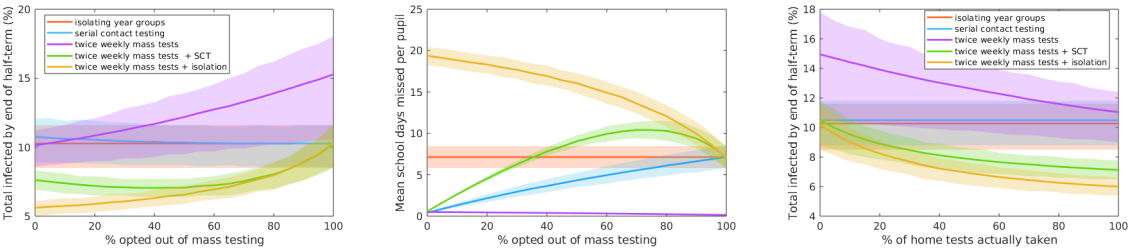
Method: An individual-based model of a secondary school formed of exclusive year-group bubbles.

Key results:

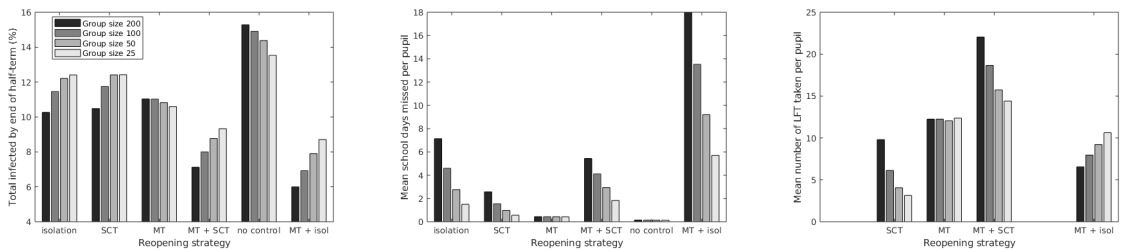
- Previously, we found that strategies involving **mass testing alone** or **serial contact testing alone** were less effective at reducing infections than isolating year-group bubbles, but were effective at reducing absences (Fig 1).
- Mass testing and serial contact testing **combined** were more effective at reducing infections than isolating year-group bubbles, but such a policy requires a high volume of tests (Fig 1).



- Lower uptake increases the number of infections for strategies not involving serial contact testing.
- Mass testing, with isolation or serial contact testing, can result in high levels of absences (Fig 2).
- Assuming 75% uptake, a **mass testing strategy alone was less effective at reducing infections across all levels of adherence** than year-group isolation. Combining mass testing with isolation was the most effective strategy considered for reducing infections, even at low levels of adherence, followed by mass testing with serial contact testing (Fig 3).



- Infection risk on test days for serial contact testing has a relatively small impact on transmission (Fig 4)
- Serial contact testing and isolation strategies have a larger impact if they target larger groups (Fig 5).



- **Interpretation:** Rapid testing should be used to **supplement rather than replace** existing measures.

Context

- Secondary schools in England are reopening on the 8th of March.
- The current reopening strategy advised to schools involves pupils taking three lateral flow device tests (LFTs) within school, and subsequently two LFTs per week at home. Participation in such rapid testing is not mandatory but strongly encouraged.
- Under current guidelines, upon identification of a positive case, close contacts of a pupil must isolate for 10 days - the rollout of serial contact testing of close contacts has currently been paused.

Methods

Model setup

- We used a discrete time individual-based model (with a daily time step) to simulate the spread of infection within a secondary school over a school half-term (7 weeks).

School Population

- In our simulations, schools consisted of five year groups of 200 pupils, equivalent to a secondary school without a sixth form.
- The inclusion of additional year groups corresponding to a sixth form does not qualitatively change findings.
- We assumed that the school implemented an effective year group bubble strategy, meaning that there was no risk of transmission between year groups. Within year group bubbles, we assumed that pupils mixed randomly.
- Teachers, siblings, and external contacts were not modelled explicitly. We assume that the impact that these have on transmission is captured by a constant external force of infection.

Reopening strategies considered

(i) isolation of year group bubbles
(ii) serial contact testing (with tests taken in school)
(iii) twice weekly mass testing (with tests taken at home)
(iv) a combination of twice weekly mass testing and serial contact testing
(v) no control strategy
(vi) a combination of twice weekly mass testing and isolation of year group bubbles.

Infection

- Infected pupils attending school (i.e. they are not isolating and it is not the weekend) transmit infection with a probability dependent on their day since infection. We assumed that the infectivity on each day since infection is given by a gamma distribution with shape 5.62 and scale 0.98 - see purple line in Fig 3A of [2]. This distribution was derived from data from known source-recipient pairs [2], with an assumed incubation period distribution under the assumption that the generation time and incubation period are independent. After 15 days, we assumed individuals were no longer infectious, and recover with immunity.
- We assumed that 12-31% of pupils would develop symptoms over the course of their infection, with the rest remaining asymptomatic throughout the course of their infection [3].
- We assumed that asymptomatic individuals were 30-70% as infectious as symptomatic individuals [4-5].
- The probability of transmission within school is likely to vary between schools, depending on the effectiveness of within-school social distancing policies, and may be influenced by the transmissibility of circulating strains. Accordingly, we considered a wide range of transmission assumptions, determined by a parameter K in the model.
- We assumed that, when not isolating, pupils had a constant probability of external infection each time step, capturing infection probability from teachers, other year groups, family, and the wider community.
- We assumed that isolating pupils adhered and effectively isolated, and so had no probability of infection while isolating.

- We assume 2% population prevalence and 20% population immunity at the beginning of the simulation [6-7].

Testing

- Test positivity profiles of symptomatic pupils for both PCR tests and LFTs were obtained from a previous study [8]
- We inferred test positivity profiles of asymptomatic pupils by considering that the probability of testing positive to either test is likely a function of viral load, and that the viral load of asymptomatic pupils on average decreases quicker than symptomatic individuals (Appendix A) [9].
- We assumed that the specificity of PCR and LFTs to be 99.7%.
- Symptomatic pupils developed symptoms on a day drawn from a Gamma distribution with shape 5.807 and scale 0.948 [10], meaning the mean time to symptom onset was 5.5 days.
- We assumed that the infectivity of an individual and the time to symptom onset were independent, though in reality these factors likely influence one another [11-13].
- Under our assumptions, approximately 50% of infections would occur while individuals are presymptomatic (assuming no control measures are in place).
- We assume that all symptomatic pupils seek a PCR test upon symptom onset. Upon taking a PCR test, pupils self-isolate until they receive either a positive or negative test result. We assume that pupils receive a result 2 days after taking a test.
- If a pupil tests positive for a PCR test, under an isolation of year groups strategy, all individuals within a year group bubble self-isolate from the day after the test returns, for a period of 10 days from the day after the pupil undertook the test [14].
- If a pupil tests positive for a PCR test, under a strategy involving serial contact testing, all participating pupils within a year group bubble are tested from the day after the test returns, for a period of 7 days since the pupil was last in school. All pupils who are not participating must isolate for a period of 10 days.
- Under serial contact testing, the period of mass testing is reset if a pupil tests positive to an LFT taken through mass testing or to a PCR test they have sought, i.e. the school will test for the next 7 days whenever a positive test is returned.
- Lateral flow testing does not occur on weekends, and instead pupils isolate.
- We assume that, if an infectious pupil tests positive to an LFT, they also test positive to their confirmatory PCR test.
- For strategies involving mass testing, all pupils are also tested twice in the week before term starts, and once in the first week of term, in school using an LFT.
- Subsequently, for strategies involving regular mass testing, pupils take an LFT test at home twice a week and three days apart.
- It is assumed that participating pupils may not always adhere to taking these regular mass tests (considered in Figure 3).
- For the initial three tests, and for serial contact testing, it is assumed that pupils take tests within school. Our baseline assumption is that on within-school test days, positively identified individuals have no risk of onward transmission. We consider the impact of assuming that these pupils have the same transmission risk as for a full day at school in Figure 4.
- In practice, schools may target serial contact testing and isolation at groups smaller than year-group bubbles. We assess the impact this may have by considering the impact of strategies when these are targeted at smaller group sizes in Figure 5. We assume that these ‘close contact groups’ are exclusive and effective, i.e. within-school infection only happens within close contact groups.

Results

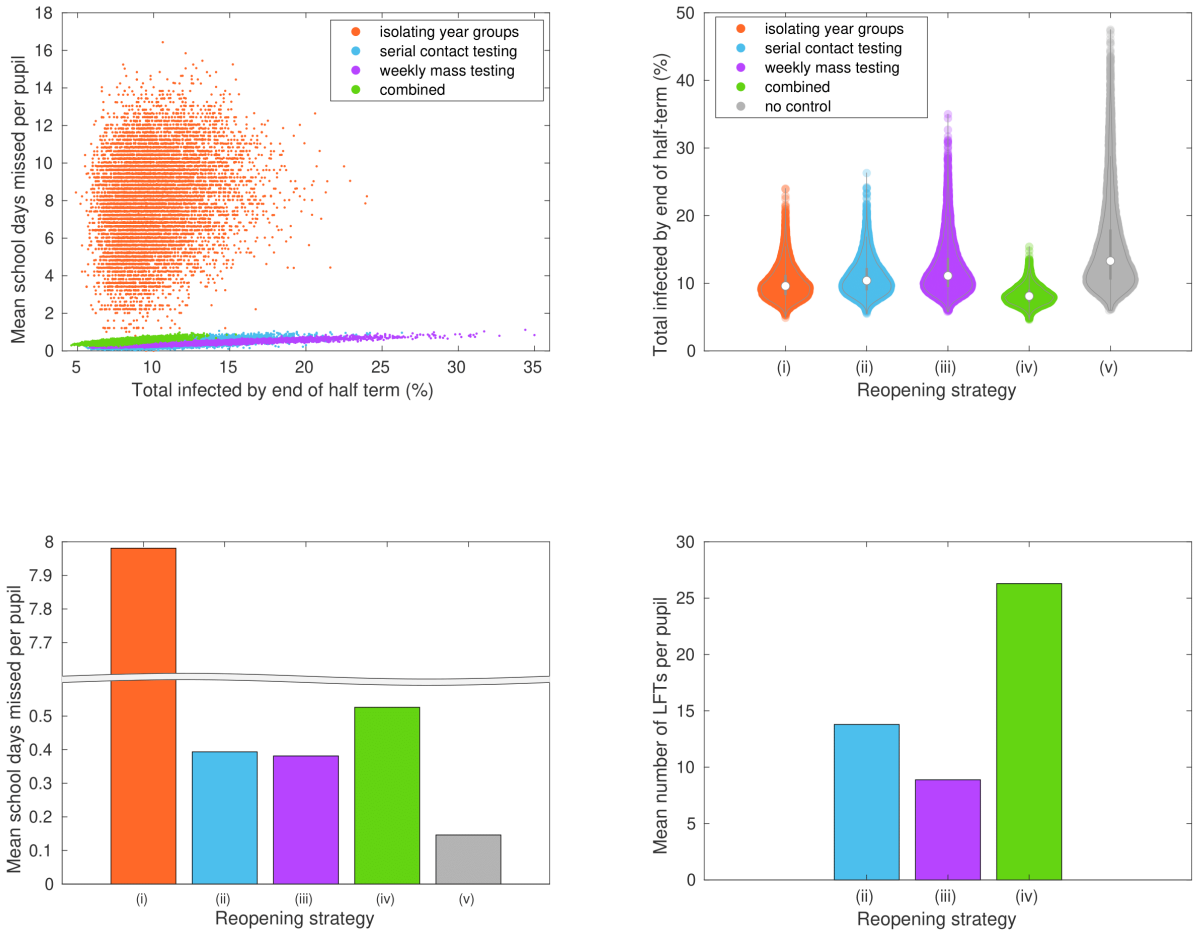


Figure 1: **The trade-off between transmission, absences, and testing volume (with 100% uptake and 100% adherence). (Top left)** Relationship between total infections and school days missed for an isolation of year group bubbles strategy (orange), serial contact testing (blue), weekly mass testing (purple), combined serial contact testing and mass testing (green). Strategies including rapid testing minimise the average number of school days missed per pupil, yet also correspond to a larger number of total infections. **(Top right)** Violin plots of percentage of school pupils infected during the course of the half-term. **(Bottom left)** The mean number of school days missed per pupil. **(Bottom right)** For strategies involving rapid testing, the mean number of LFTs taken per pupil. Results were obtained from 10,000 simulations. The above figures assume 100% uptake and 100% adherence to the current policies, N.B. These figures assume weekly, rather than twice weekly mass testing. The results are explained in greater detail in our preprint: https://www.medrxiv.org/content/10.1101/2021.02.11.21251587v1.full.pdf

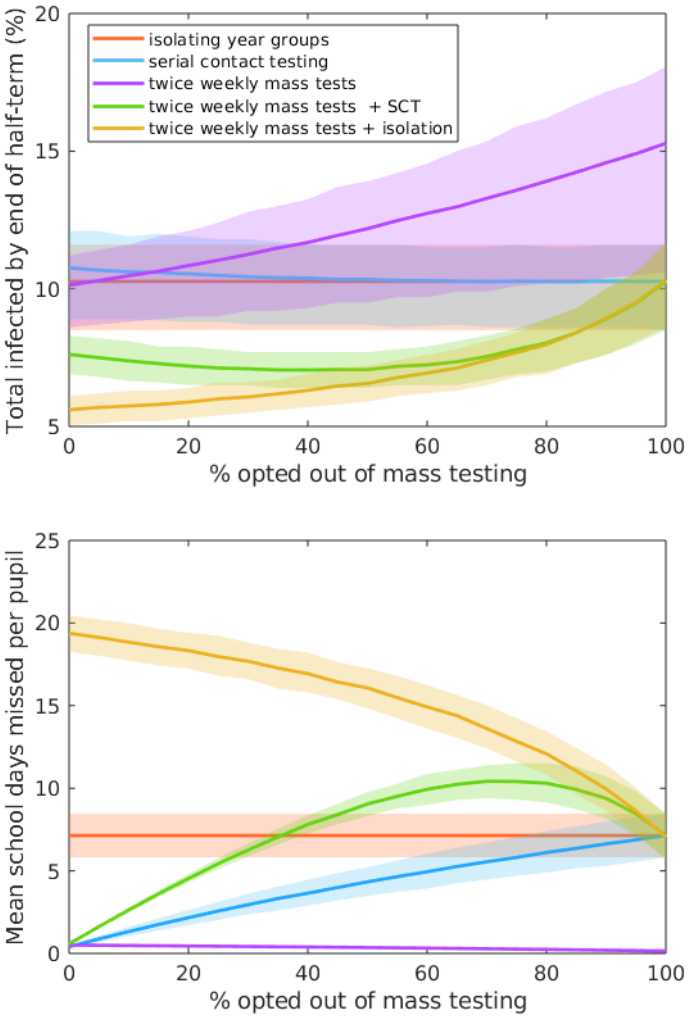


Figure 2: **The impact of uptake on transmission and absences. (Top)** The relationship between uptake of rapid testing and total infections for an isolation of year group bubbles strategy (orange), serial contact testing alone (blue), twice weekly mass testing (purple), combined serial contact testing and mass testing (green), and combined twice weekly mass testing and isolation of year-group bubbles (yellow). **(Bottom)** The relationship between uptake and absences. Results are averages of 1000 simulations.

- The effectiveness of mass testing against infection increases with uptake, with a very high uptake required to obtain comparable levels of infection to the levels that result from an isolation of year group bubbles strategy.
- For strategies involving serial contact testing, lower uptake can reduce the level of infection, because those who are not participating must isolate during serial contact testing periods.
- The effectiveness of the combination strategy using mass testing and serial contact tracing (green) against infection represents the balance of the two effects, resulting in reduced effectiveness at the highest and lowest uptakes.
- However, by the same token, the number of school days missed can increase with lower uptake for serial contact testing.
- Under a regular mass testing + serial contact testing strategy, this can lead to a higher number of school days missed than under an isolation of year groups strategy. This may exacerbate educational inequalities, as school days missed will be concentrated in those who have opted out.
- Regular mass testing + isolation of year group bubbles can lead to a very high number of absences.

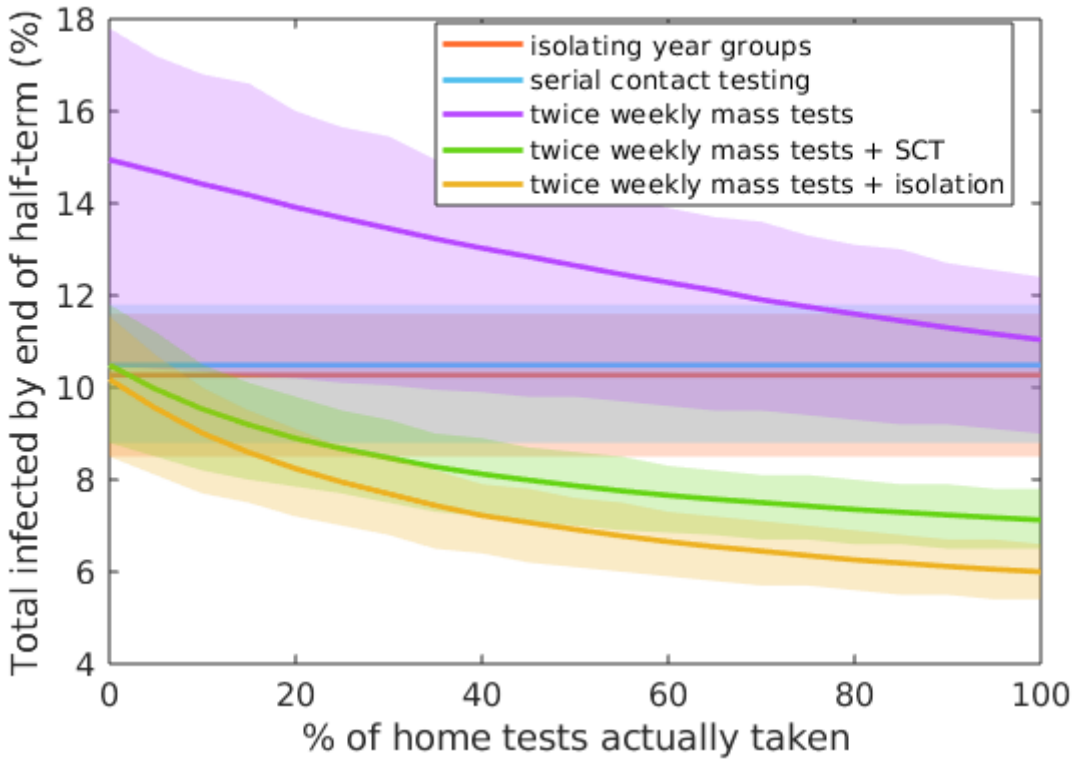


Figure 3: **The impact of adherence on transmission and absences.** Here, we assume that 75% of pupils are participating in rapid testing. Adherence is assumed to be random across participating pupils, i.e. all participating pupils take home tests with some probability p. Results are averages of 1000 simulations.

- Twice weekly testing at home, implemented on its own, is likely to be less effective at controlling the spread of infection than isolation.
- Acting together with serial contact testing, regular mass testing can result in lower levels of infection, even if tests are taken inconsistently.

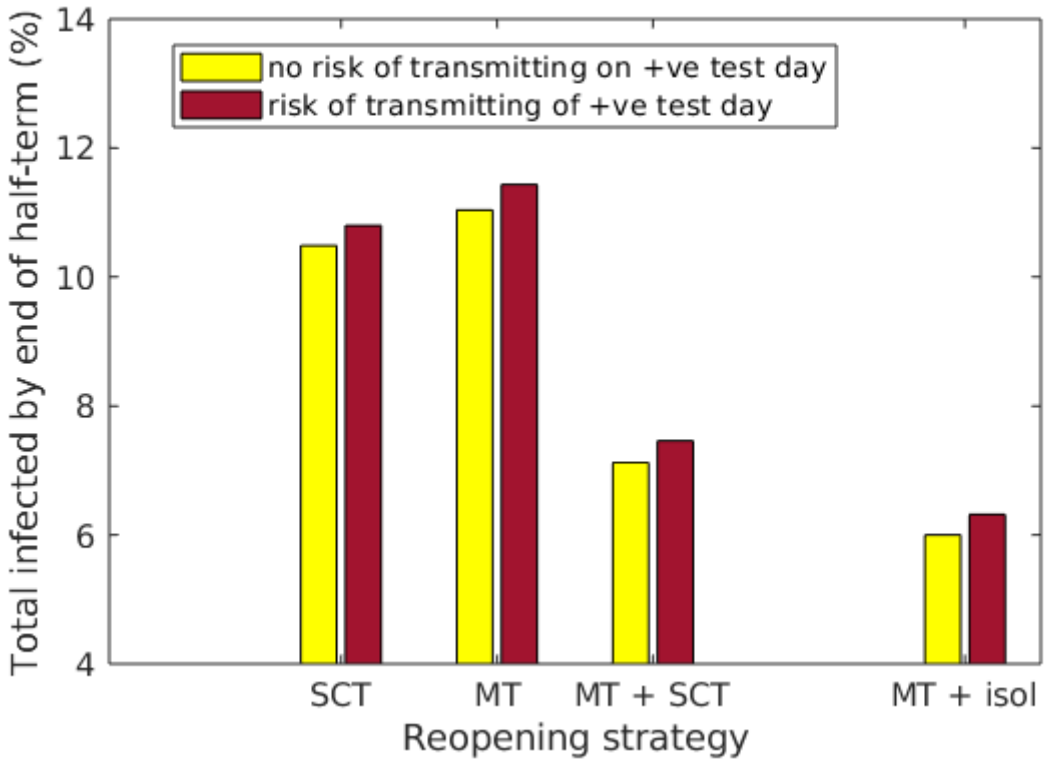


Figure 4: **The impact of transmission occurring on test days, for strategies involving serial contact testing**. Here, we compare a situation where there is no risk of transmission from positively identified individuals tested within school on the day they return a positive test result (yellow), against a situation where there is an equal risk of transmission from such individuals as if they had attended school normally that day (burgundy). Results are averages of 1000 simulations. (ii) - serial contact testing (SCT) (iii)* - twice weekly mass testing (MT) , (iv)* - twice weekly mass testing + serial contact testing (MT + SCT), (vi) twice weekly mass testing + isolation of year groups (MT + isol).

* (iii) and (iv) from our preprint refer to weekly mass testing. Here, they refer to twice weekly mass testing, in line with the government's current reopening strategy.

- If we assume that transmission can occur on testing days, we observe only a marginal impact on the success of testing measures, even when the transmission risk is assumed to be the same as for a full day at school.

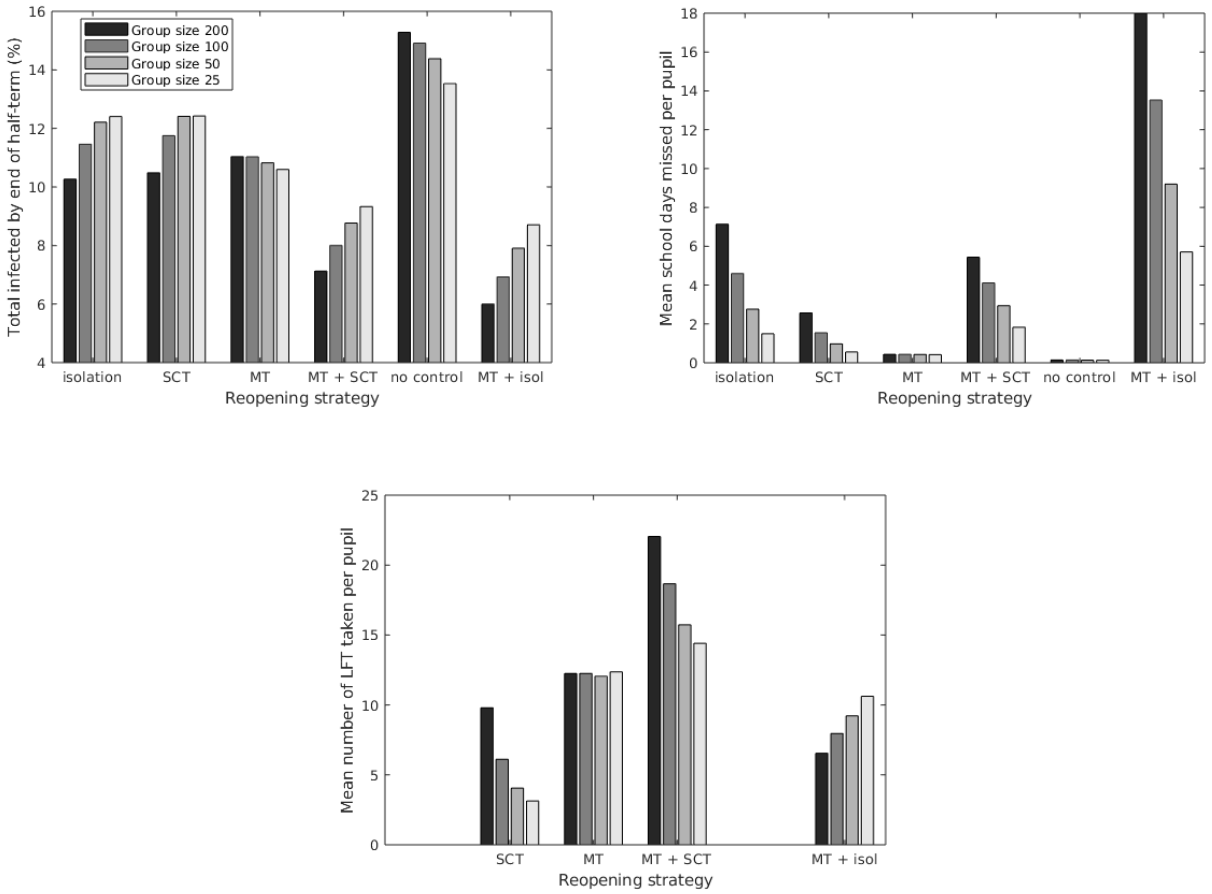


Figure 5: **The impact of size of group targeted for isolation or serial contact testing.** Here, we compare the effectiveness of interventions involving isolating groups of pupils, or serial contact groups of pupils, for different group sizes, on **(top left)** infections, (**top right)** absences, and **(bottom)** tests. It is assumed infection only occurs within close contact groups. Strategies involving serial contact testing are more effective at larger group sizes. (i) isolation of close contacts groups, (ii) - serial contact testing within close contact groups (SCT) (iii)* - twice weekly mass testing (MT), (iv)* - twice weekly mass testing + serial contact testing (MT + SCT), (v) - no control, (vi) - twice weekly mass testing + isolation of close contact groups (MT + isol).

* (iii) and (iv) from our preprint refer to weekly mass testing. Here, they refer to twice weekly mass testing, in line with the government's current reopening strategy.

- Serial contact testing and isolation strategies, which require the identification of a positive case before they are initiated, are more effective for larger group sizes at reducing infections.
- Because of this, strategies involving regular mass testing become comparatively more beneficial for smaller group sizes.
- The strategy combining regular mass testing with isolating close contacts remains the most effective way of controlling infections across the range of bubble sizes considered, followed by regular mass testing with serial contact testing.
- If schools are implementing such serial contact testing or isolation policies at small group sizes, then rapid testing becomes more important for controlling within-school transmission.

Appendix A - Identifying asymptomatic individuals

- Whether mass testing strategies are successful in controlling infections will depend, in part, on the ability of tests to correctly identify infectious asymptomatic individuals.
- The probability of symptomatic individuals testing positive through time has been detailed for both PCR and lateral flow tests [7].
- The probability of testing positive is likely a function of viral load; while symptomatic and asymptomatic individuals have similar average peak viral loads and proliferation stage durations, their average duration of clearance stages has been observed to differ [8].
- We assume that the probability of asymptomatic individuals testing positive is equal to that of symptomatic individuals until the peak of infection, but then decays more rapidly, such that the probability of an asymptomatic individual testing positive at 6.7 days after the peak should equal the probability of a symptomatic individual testing positive at 10.5 days after the peak (corresponding with findings from [8], who estimated an average duration of clearance of 10.5 days in symptomatic cases versus 6.7 days in asymptomatic cases).
- Throughout this study we use the baseline profiles.
- We highlight that this is an area of considerable uncertainty. Future studies detailing the testing probability of asymptomatic individuals, and the specific relationship between viral load and testing probability, would be a valuable contribution to this area.

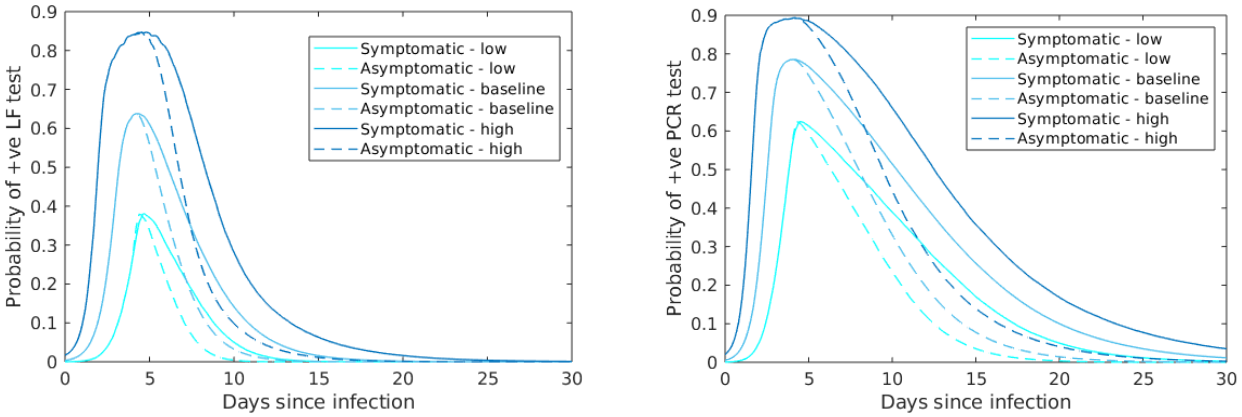


Figure 6 - Probabilities of testing positive through time for symptomatic and asymptomatic individuals. We assume that the probability of positive lateral flow tests (left) and PCR tests (right) in symptomatic and asymptomatic individuals are equal during the proliferation stage of the virus, but that the probability of asymptomatic individuals testing positive decays faster in the clearance stage, owing to a shorter mean clearance duration of 6.7 days [8].

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