Report on modelling the impact of preventive measures on SARS-CoV-2 transmission in secondary schools in the Netherlands

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Abstract

Background: In many countries secondary schools were closed to curtail transmission of SARS-CoV-2. On 22 May 2021, the Dutch government announced that all secondary schools can open at full occupancy from 31 May 2021 and that physical distancing measures between students under 18 years old can be lifted. Therefore, it is important to estimate the expected effect of these measures on the number of infections in students and teachers and the relative impact of preventive testing and adult vaccination hereon.

Methods: We developed an agent-based model for SARS-CoV-2 transmission in a secondary school parameterized using observational data from a pilot study including contact patterns and test results collected in February-April 2021. In the base case scenario schools were open at half occupancy with baseline mitigation measures (i.e., isolation of symptomatic cases and quarantine of their close contacts) and with risk-based testing of classmates and other contacts of symptomatic cases (with 50% adherence to testing). We estimated the effect of reopening secondary schools to full occupancy with baseline mitigation measures and with various preventive testing and vaccination strategies on the number of infections in students and teachers within the first month. The rate of introductions from the community was based on the prevailing population incidence in March 2021 in the Netherlands. We used the model-based estimates to extrapolate the number of school-related infections at the country level.

Results: Reopening secondary schools at full occupancy with baseline mitigation measures in place leads to approx. 47,500 school-related infections in the first month (44,000 in students, 3,500 in teachers). Twice weekly screening of students and teachers reduces infection rates by 57% (compared to full occupancy) with 50% adherence (i.e., 50% adherence to being tested and 100% compliance to isolation and quarantine measures when positive). With lower adherence, advancing vaccination of teachers may further reduce school-related infection rates.

Conclusions: Reopening secondary schools at full occupancy will unavoidably lead to additional school-related infections. Screening twice weekly represents an effective strategy to reduce the infection rates. Protecting students and teachers requires screening adherence of at least 50%. If screening adherence is as low as 30%, vaccination of teachers may further reduce infection rates.

1 Introduction

In many countries periods of secondary schools closure were implemented to curtail transmission of SARS-CoV-2 [1]. In the Netherlands, secondary schools (ages 12-17 years) were closed from mid-December 2020 to mid-January 2021. Thereafter, schools gradually reopened up to half-occupancy in April 2021. In May 2021, vaccination coverage among older age-groups was steadily increasing and COVID-19 hospital admissions were decreasing in parallel [2, 3]. The Dutch government, therefore, considered returning to full in-person learning for all secondary schools as of 1 June 2021 and lifting all physical distancing measures between students under 18 years old, which would no longer be feasible at full occupancy levels. It is important to estimate the expected effect of these changes on the number of infections in students and teachers and the relative impact of preventive testing and vaccination strategies hereon. The following report serves as the basis for the presentation delivered by the authors on 20 May 2021 for the Ministry of OCW (Ministry of Education, Culture and Science) and the OMT (Outbreak Management Team).

2 Methods

2.1 Data

Following the period of national lockdown and school closure in December 2020 and early January 2021 caused by high SARS-CoV-2 community incidence, in-person learning was first restarted for secondary school students in exam years and those with special needs, and gradually expanded to half-occupancy in April 2021. During this period, physical distancing of 1.5 meters between students and between students and teachers was maintained in schools. With the aim of increasing early detection of infected school contacts, the government decided to initiate school-based testing as an extension of the routine SARS-CoV-2 testing policy.

Baseline mitigation measures

The national baseline mitigation measures at the time included stay-home orders for persons with respiratory complaints or fever, physical distancing ($>$ 1.5 meters) for people $>$ 18 years of age, limiting social gatherings to $<$ 2 people, and a maximum of one visitors per day. Bars and restaurants were closed. Individual sports activities were only allowed outdoors and in teams only for people $<$ 18 years of age. Free SARS-CoV-2 testing was available at municipal testing facilities for symptomatic individuals and for all contacts of an infected case, irrespective of symptoms at day 5 after exposure. Close contacts (defined as persons who had contact with the case at less than 1.5 meter distance for at least 15 min) were instructed to self-quarantine for 10 days, or until a day 5 negative test result.

Pilot study

A pilot phase was used to test the school-based testing policy and to collect detailed data on SARS-CoV-2 infections in schools, and on student and teacher contact patterns in- and outside schools. The policy consisted of antigen testing offered twice with an interval of 3 to 5 days to all school contacts of an infected student or teacher (i.e.

risk-based testing). Tests were provided at the school premises immediately following report of an index case.

From January 18th 2021 onwards, a representative selection of schools in the Netherlands providing secondary education to students in grades 1-6 (aged 12-18 years) and located in Central region of the Netherlands (Province of Zuid-Holland, Utrecht, Gelderland) were invited to participate in the pilot study . Participation required that schools adopted the policy of risk-based testing and that they were willing to provide data on school characteristics. The schools were also required to maintain records of the number and characteristics of index cases, number of contacts invited for risk-based testing and aggregated test results. Upon report of an index case, school officials would identify all school-based contacts who had been in contact with the index case during the presumed infectious period for at least one course hour. These students were offered to perform antigen testing on the same day and a repeat test 3-5 days later. Testing was conducted in the school premises. These data, supplemented with data from literature served as the main input for the agent-based transmission model. For a detailed description of the pilot and the data collection we refer to the information provided in Appendix C.

2.2 Agent-based model

We developed an agent-based model to simulate the transmission of SARS-CoV-2 in an average secondary school. We distinguished two types of individuals:

1. *Students*: characterized by the grade, class and possibly group (in case of half occupancy) they belong to.
2. *Teachers*: characterized by the classes that they educate.

Based on data reported in the pilot study, an average secondary school in our model comprises 944 students. The numbers result from the mean number of grades, classes per grade, and students per class reported in the pilot study. The number of classes per grade and the number of students per class used in the model are shown in Table 1. We further assumed that students attend five subjects per day. Based on the reported median and mean number of students educated by a teacher per day (47.8 and 14.5, respectively, see Table 7 Appendix C), teachers are assumed to educate 2 to 3 classes per day. This number takes into account that not all teachers work full time at school every day. For the model, this was averaged to a single value counting 5 days a week per teacher. Based on this assumption, there are 72 teachers working at the school in our model.

We distinguished week days (Monday, Tuesday, Wednesday, Thursday, Friday) and weekends (Saturday, Sunday), and divided the day into three parts consisting of eight hours each:

1. *School hours*: Students and teachers are assumed to have a certain number of within-school contacts.
2. *Outside school hours:*
    (a) *Outside school-related hours*: Students are assumed to have school-related contacts during their leisure time activities.
    (b) *Outside school-unrelated hours*: Students and teachers are assumed to become infected via school-unrelated contacts in the community. We assume that the respective probability is constant over time.
3. *Night hours*: Neither students nor teachers are assumed to have any contacts during this time.

Table 1. School characteristics.

Grade	Number of classes per grade	Number of students per class
1	7	23
2	6	29
3	8	23
4	7	29
5	5	30
6	3	23

2.2.1 Contact network

We defined contacts relevant for transmission based on data from the pilot study, where students and teachers were surveyed about the number of people from their school they had a conversation with, or had physically touched the day before. Results were summarized into contact matrices for contacts in the school environment between students and between teachers. Contacts between teachers and students were estimated from the number of students educated per teacher, as these were not surveyed in a similar way.

Contacts between students

To quantify contacts between students in our model, we used the data reported in the pilot study where students reported the number of contacts with other fellow students within the same grade as well as with other students within the same grade (but outside their class), or with students from other grades. The contact matrix representing the number of contacts relevant for transmission that students have among each other is based on the **mean** reported values from the survey and stratified by type of contact as follows:

$$
\begin{array}{c c}
 & \begin{array}{ccccccc} 1 & 2 & 3 & 4 & 5 & 6 & \text{Within-class} \end{array} \\
\begin{array}{c} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \end{array} &
\begin{bmatrix}
3 & 0 & 0 & 0 & 0 & 0 & 6 \\
2 & 5 & 0 & 0 & 0 & 0 & 5 \\
1 & 1 & 5 & 0 & 0 & 0 & 6 \\
1 & 1 & 2 & 7 & 1 & 1 & 8 \\
0 & 0 & 0 & 1 & 7 & 1 & 8 \\
0 & 0 & 0 & 1 & 2 & 7 & 11
\end{bmatrix}
\end{array}
\tag{1}
$$

, where the first six columns give the number of contacts students of the respective grade have outside of their class and the last column represents the number of contacts within their own class.

Based on data of the pilot study, students are assumed to have one close contact within their class (i.e. within 1.5 meter distance for > 15 minutes) and one close contact outside of their class (but within the school). These close contacts are eligible for quarantine if the student is infected and develops symptoms (see below *Quarantine of close contacts of symptomatic index cases*).

Outside of school hours students are assumed to meet two other students (median number reported in the pilot study). These contacts are randomly picked among their within-school contacts.

Contacts between teachers

Based on the median number of contacts reported in the pilot study, we used six contacts between teachers during school hours and no contacts between teachers outside school hours (Table 9 Appendix C). These contacts were randomly sampled.

Contacts between teachers and students

We assumed that contacts relevant for transmission only occur with a proportion of all students a teacher educates per day, based on close conversations or proximity to the teacher. This proportion is sampled from a Uniform distribution (for parameter values see S1) and yields an effective number of transmission-relevant contacts of 8 to 10 students per day at full occupancy and between 6 to 7 students at half occupancy. At half occupancy this corresponds to about half of the median number of students educated by a teacher per day as reported in the pilot study (see Table 7 Appendix C). This approach does therefore not account for further aerosol transmission where all students present in the classroom would be considered at risk. Since typically, teacher-student contacts are not as close as contacts between students, we assumed that contacts between teachers and students have a reduced probability of transmission relative to contacts between students or contacts between teachers (see Table 2).

2.2.2 Transmission model

Individuals may be in one of the disease states: susceptible (S), asymptomatically infected (I_A), pre-symptomatically infected (I_P), infected with symptoms (I_S), and recovered (R). We did not explicitly model other respiratory tract infections with similar symptoms. Hence, all symptomatic individuals are necessarily infected with SARS-CoV-2. Infected individuals are assumed to be readily infectious.

Infectiousness

We model a time-varying infectiousness following a Weibull distribution (shape=1.6, scale = 6.84) peaking at approx. 3.75 days after the time of infection. This is based on the generation time distribution derived by Sun et al [4] through modelling of an uncontrolled epidemic scenario based on the early epidemic dynamics in Wuhan before lockdown. We further assumed that symptomatically infected individuals recover 7 days after symptom onset while asymptomatically infected individuals recover 7 days after infection. Based on Sun et al [4], the incubation period follows a Weibull distribution (shape=1.58, scale=7.11) with a mean of 6.4 days. Curves for the incubation period distribution and time-varying infectiousness are shown in Figure 1.

Based on estimates of the susceptibility and infectiousness of children aged 11-17 reported in Davies et al [5], we assumed a reduced susceptibility and infectivity of the students with respect to the teachers. The distributions used in the model are reported in Table 2.

Asymptomatic transmission

Infected individuals may be either asymptomatic or symptomatic. The proportion of asymptomatic infections is assumed to be different for students and for teachers. Since there remains significant uncertainty regarding these parameters, we sampled the probability of developing an asymptomatic infection from a Uniform(0.17, 0.25) and Uniform(0.15, 0.6) distribution for teachers and students, respectively. These values are based on data reported in the pilot study and are in agreement with values found in the literature [6].

In addition, we assumed that asymptomatically infected individuals are less infectious than symptomatically infected individuals. While there is still uncertainty about the infectiousness of asymptomatic infections relative to symptomatic infections, a rapid scoping review reported a relative infectiousness between 0.43 and 0.57 [7] and a systematic review reported that SARS-CoV-2 infection in contacts of people with asymptomatic infection were less likely than in contacts of people with symptomatic infection, with a relative risk of 0.35 (95% CI 0.10-1.27) [6]. In our model, we sampled the relative infectiousness of asymptomatic infections from a Uniform(0.3, 0.7) distribution. The infectiousness curve of the asymptomatically infected individual is then assumed to be scaled by the sampled value.

Infection risk from community

We assumed that all susceptible individuals are exposed to a certain school-unrelated probability of infection. This probability was chosen to match the number notified positive cases reported in the pilot study in March 2021 when the community incidence rate of SARS-CoV-2 reported cases varied between 180-300/100.000 per week.

Based on the pilot data, we assumed that this probability is equal for students and teachers. However, we assumed a reduced susceptibility for students (see Table 2). Quarantined individuals are assumed to be excluded from this exposure.

2.2.3 Test sensitivity

We assumed a time-varying test sensitivity for the PCR test and antigen test based on results reported in Smith et al [8]. To account for a reduced test sensitivity due to self-testing, we scaled the antigen test sensitivity curve down by 10%. Curves for the test sensitivities are shown in Figure 1.

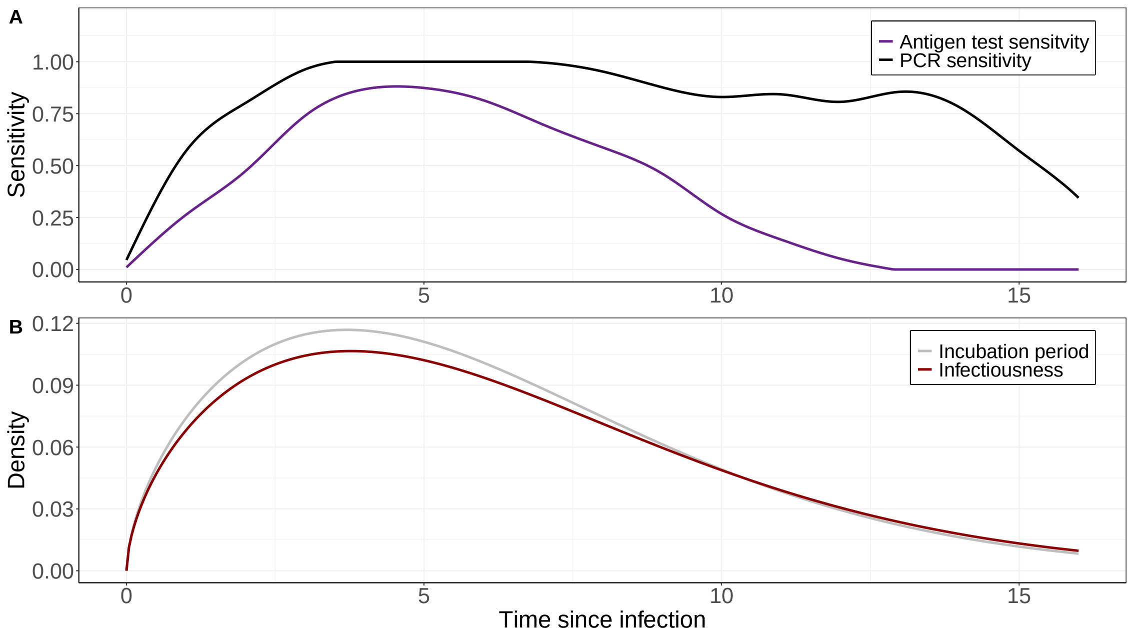

Figure 1. Time-varying sensitivity, infectiousness and incubation period. (A) Time-varying test sensitivity for antigen test and PCR test used in the model. Curves are fit to data points reported in Smith et al[8] using cubic smoothing splines. (B) Incubation period distribution and time-dependent infectiousness curve used in the model. Distributions are given in Table 2.

Table 2. Epidemiological parameters

Description	Value/Distribution	Mean/SD	Source
Reproduction number	1.05		Assumed
Incubation period	Weibull(shape=1.58, scale=7.11)	6.4 days	[4]
Generation time	Weibull(shape=1.6, scale=6.84)	6.1 days	[4]
Peak PCR test sensitivity	1		Smith et al [8]
Peak Antigen test sensitivity	0.88		10% lower than reported in Smith et al [8]
Relative susceptibility of students	Truncated Normal($\mu = 0.64, \mathrm{sd} = 0.09$)	0.64	Dattner et al [9]
Relative infectivity of students	Truncated Normal($\mu = 0.85, \mathrm{sd} = 0.1$)	0.85	Davies et al [5]
Relative susceptibility of vaccinated teachers	Uniform(0.04, 0.45)	0.25	Assumed
Scaling of transmission probability for teacher-student contact	Uniform(0.5, 0.85)	0.675	Assumed
Vaccination coverage	85%		Assumed
Seroprevalence among students	25%		Assumed
Seroprevalence among teachers	25%		Assumed
Relative infectiousness of asymptomatic infections	Uniform(0.3, 0.7)	0.5	[7, 6]
Proportion of symptomatic infections			
Students	Uniform(0.4, 0.85)	0.625	Pilot study
Unvaccinated teachers	Uniform(0.75, 0.83)	0.79	Pilot study
Vaccinated teachers	Uniform(0.4, 0.85)	0.5	Assumed

2.2.4 Baseline mitigation measures

In all considered strategies, we assumed that the baseline national mitigation measures will be implemented in schools with full adherence to isolation and quarantine:

Isolation of symptomatic cases

Symptomatically infected individuals are assumed to take a PCR test and isolate themselves at home for 7 days upon symptom onset if the test is positive. We assumed 100% compliance to isolation.

Quarantine of close contacts of symptomatic index cases

Upon symptom onset of a symptomatically infected student, all close contacts have to quarantine for 10 days. They take an antigen test after 5 days and may be released from quarantine if the test result is negative. We assumed 100% compliance to quarantine.

2.2.5 Strategies

In addition to the aforementioned baseline mitigation measures, we compare the following strategies:

Full occupancy

At full occupancy, students are assumed to attend school every day and only baseline mitigation measures will be in place. The per day number of contacts among and between students and teachers are assumed as described in *2.2.1 Contact network.*

Half occupancy

When schools are open at half occupancy, students of one class are divided into two groups and attend school on alternating days. The first group attends school on Monday, Wednesday, and Friday in one week followed by Tuesday and Thursday the subsequent week. For the second group the school attendance days are reversed with respect to the first group. The baseline mitigation measures are also implemented in this strategy. We assumed that the per day number of contacts between students is as described in *2.2.1. Contact network* but are only realized on the day the students attend school.

Risk-based testing at half occupancy (base case strategy)

Upon symptom onset of a symptomatically infected student all classmates of the same group, other contacts in school and teachers are assumed to be tested with an antigen test (self-testing). If tested positive, they are assumed to self-isolate for 7 days with 100% compliance. Based on data reported in the pilot study, we assume that 50% of individuals participate in the risk-based testing. Students attend school at half occupancy representing the situation in the Netherlands from February till May 2021. This strategy is assumed to be the base case to which all other strategies will be compared to.

Vaccination of teachers at full occupancy

Teachers are assumed to be vaccinated before the start of the time period. We assumed a vaccination uptake of 85% [3] and that vaccinated teachers have a reduced susceptibility according to a Uniform(0.04, 0.45) distribution.

Regular screening twice weekly at full occupancy

All students and teachers are assumed to perform an antigen self-test on Mondays and Wednesday before attending school. If the test is positive, they are assumed to self-isolate for 7 days with 100% compliance. We assumed 50% adherence to screening in our main analysis. To assess the effect of screening adherence to the results, we also considered 30% and 75% adherence to screening.

Vaccination of teachers combined with regular screening twice weekly at full occupancy

Combination of the two previous strategies.

2.3 Outcome parameters

Strategies were evaluated in terms of total number of school-related infections (stratified by students and teachers) over the period of time of 28 days ($\approx$ 1 calendar month). School-related infections are infections from students or teachers either during school hours or outside school hours but via transmissions from school contacts. Infections from the community are excluded in this outcome measure. The total number of school-related infections in the Netherlands are crudely estimated by multiplying the median number of school-related infections in one school by 1000, assuming that the results of the model school are representative for all schools in the Netherlands. We summarized the results using 100 simulation runs.

2.4 Sensitivity analyses

We have performed the following scenarios for sensitivity analyses

1. *Low infection risk from community*: We performed simulations with a risk of infection from the community equal to half of the value assumed in the main analysis. This scenario represents the expected infection risk in the community in the coming weeks.

2. *Imperfect compliance*: In this scenarios, we loosen the assumption on 100% compliance to isolation and quarantine. We assumed 87% compliance to isolation and quarantine, based on data from the behavioural research conducted by RIVM National Institute for Public Health and the Environment [10].

2.5 Implementation

The model was implemented in R (Version 4.0.1) [11]. The full code is available from `https://github.com/tm-pham/covid19_school_transmission.git`.

3 Results

3.1 Pilot study

Between February and April 2021, a total of 45 schools participated, with a total of 33,274 students and XXX teachers, for a period of 5-12 weeks (mean 9 weeks). The number of index cases reported to the school varied between 0 and 9 per week, with corresponding incidence rates between 19.5 and 47.7 per 100.000 person weeks. Among index cases, 79.6% (n=121) were students and 20.4% (n=31) were teachers. Table 3 summarizes the main results from school-based antigen testing. Each round of testing followed reporting of an index case.

Table 3. Overview of pilot study data.

	Index cases[1]	Index cases with at least one detected secondary case	Classroom contacts participating in antigen testing[2]	Classroom contacts with positive antigen test	Classroom contacts per index case Mean (SD) [3]	
					Close contacts [4]	Non-close contacts
Students	121 (79.6%)	11 (61.1%)	2863 (78.4%)	21 (87.5%)	1.7 (2.2)	23.6 (22.6)
Teachers	31 (20.4%)	7 (38.9%)	774 (21.2%)	3 (12.5%)	2.7 (5.1)	28.8 (29.3)
Total	155	18	3652	24	1.9 (3.0)	24.4 (23.6)

[1] Index case: student or teacher with SARS-CoV2 infection reported to the school and identified at testing facility outside school.

[2] Classroom contacts with at least one antigen test performed

[3] Based on the numbers available (58 student index cases and 14 teacher index cases).

[4] Close contacts are defined as individuals who had a contact with the index case ¡1.5 metres for at least 15 minutes, or a household member of the index case.

3.2 Simulation results

We set the transmission probability from the community such that the number of notified positive students and teachers as reported in the pilot study roughly matched the number of symptomatically infected students and teachers predicted by our model for the risk-based testing scenario at half occupancy (visual inspection). This resulted in a school-unrelated transmission probability of 0.0012 per day. Figure 2 shows that the total number of symptomatic cases and the weekly incidence of symptomatic cases predicted by the baseline model (risk-based testing at half occupancy) are in good agreement with the number of notified positive cases in March 2021 reported in the pilot study.

Figure 3 shows the number of students and teachers that become infected through school-related contacts (during school-hours or outside school hours via school contacts) within 28 days. The model predicts that at full occupancy with only baseline mitigation measures in place, the mean number school-related infections increases from 1.4 to 49.1 among students and from 1.7 to 5.1 among teachers when going from the base case strategy to full occupancy. There is no significant difference between the base case scenario of risk-based testing at half occupancy and the half occupancy scenario with only baseline mitigation measures implemented ()

We compared the number of school-related infections with the number of school-unrelated infections from the community (Figure 4). This is an indication for whether, given a certain incidence in the community, schools can be seen as amplifiers of the current pandemic in the community as school-related infections may lead to onward transmission in the community (in particular in the households of students or teachers). At half occupancy, the

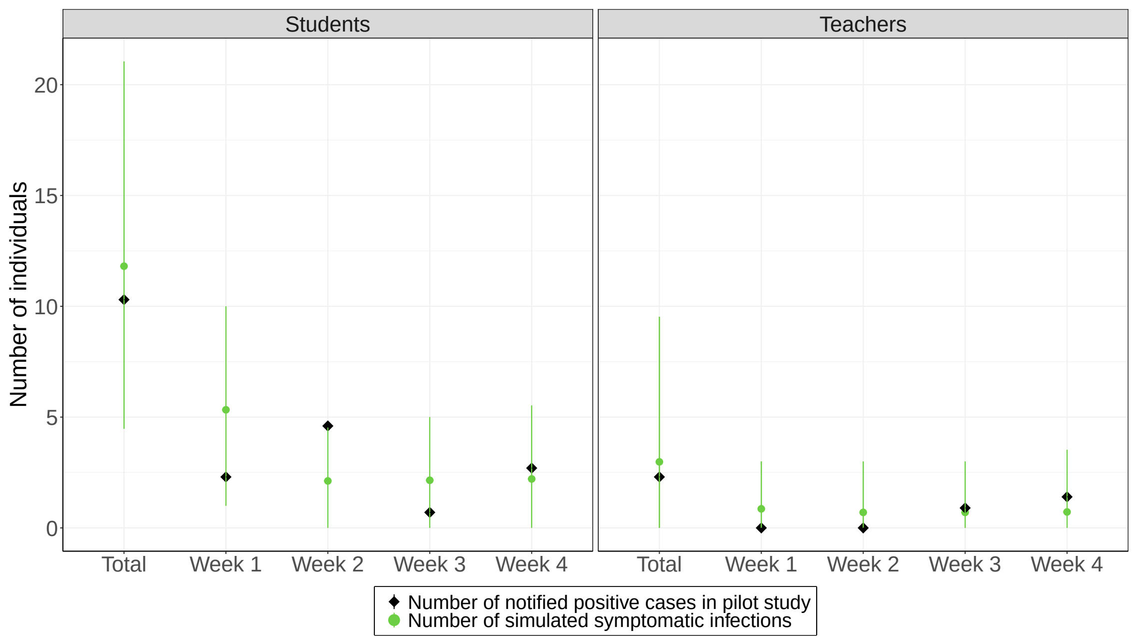

Figure 2. Comparison of number of simulated symptomatic cases and notified positive cases reported in pilot per week and during the whole time period. The green points are the mean number of symptomatic infections over 100 simulations as predicted by our model with baseline mitigation measures and risk-based testing at half occupancy (base case scenario). The green lines represent the corresponding 95% quantiles. The black squares are the mean number of notified positive cases per 1000 students as reported in the pilot study.

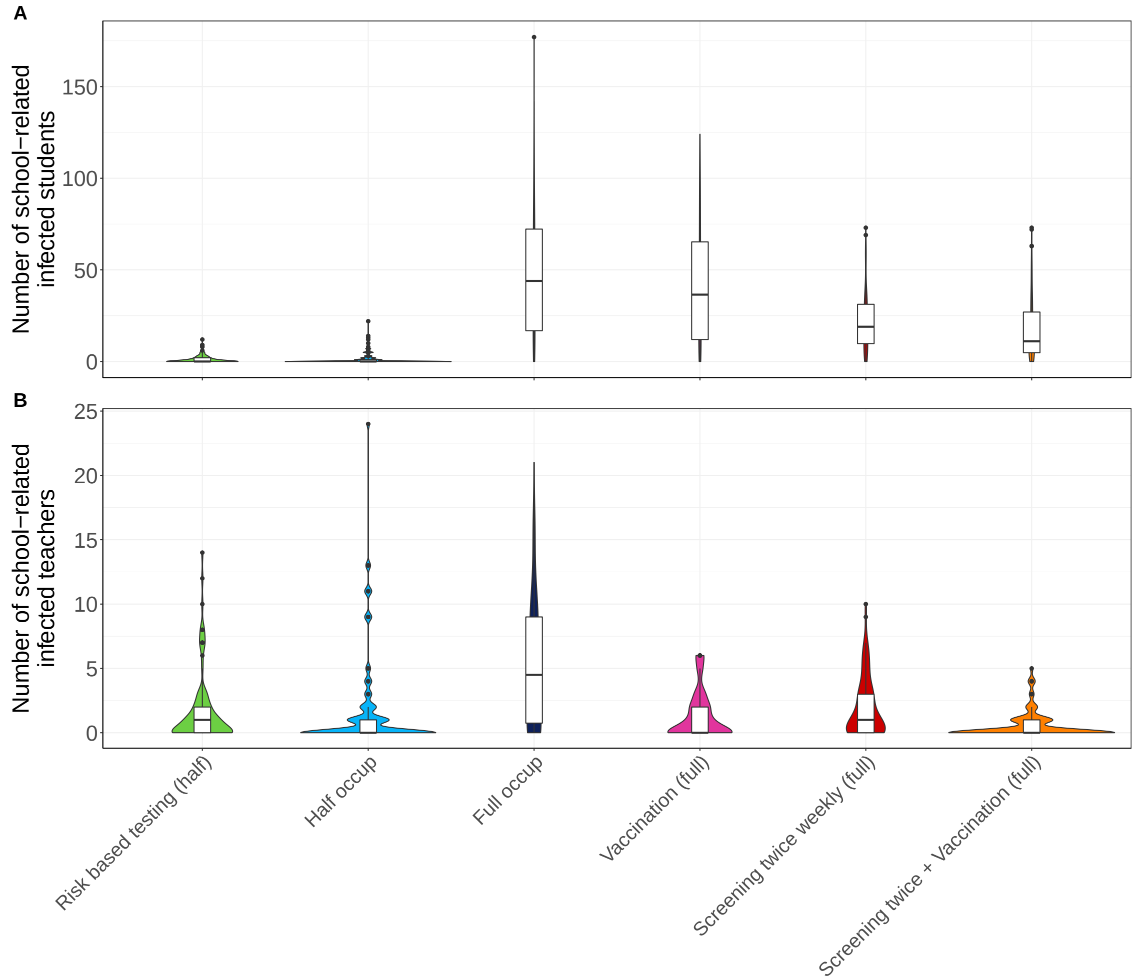

Figure 3. Total number of school-related infected individuals during the time period of 28 days. Adherence to screening and risk-based testing is assumed to be 50%.

number of school-related infected students does not exceed the number of infections introduced from the community through school-unrelated contacts (points do not exceed the identity line in Figure 4A). Risk-based testing at half occupancy and the half occupancy scenario again do not show significant results. On the contrary, at full occupancy, without and with preventive strategies, there is a larger number of school-related infected students than introductions from the community. With only baseline mitigation measures in place, there are more school-related infected students than school-unrelated infected students in 77% of the simulations (proportion of points in the scatter plot above the identity line). For screening twice weekly and vaccination of teachers, the respective proportion is 66% and 73%, respectively. The combination of these strategies leads to a proportion of simulations of 40% where there were more school-related infected students than school-unrelated infected students. Thus, screening twice weekly is more effective in preventing SARS-CoV-2 transmissions in schools than vaccination of teachers. The combination of the two strategies is more effective than each strategy on its own.

We computed the expected increase in school-related infections among students and teachers following a reopening of schools at full occupancy from the base case strategy of risk-based testing at half occupancy. Since the half occupancy scenario and the base case scenario do not show significant differences, we omit the results for the half

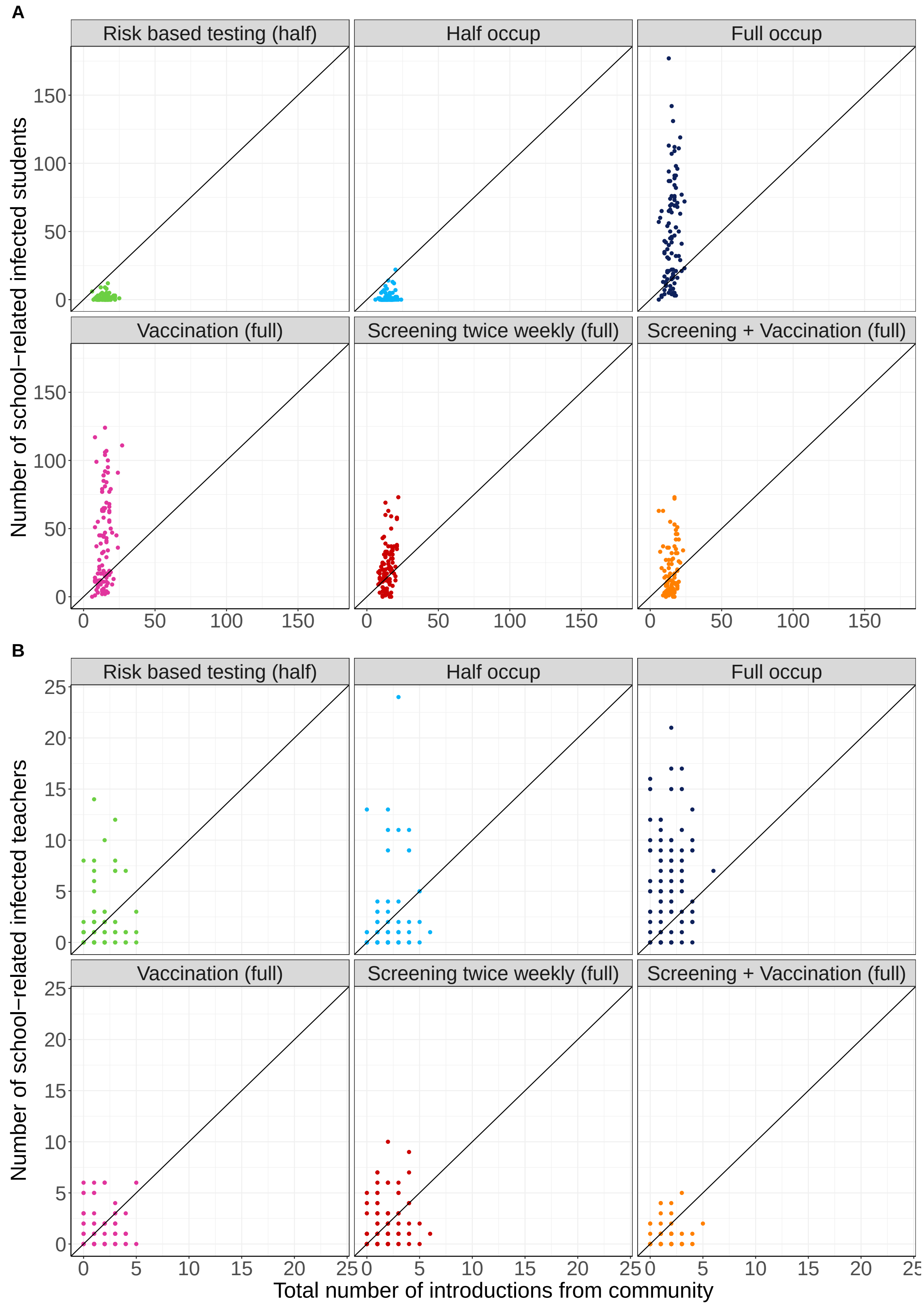

Figure 4. Relationship between simulated number of infections from the community and the number of school-related infections. Adherence to screening and risk-based testing is assumed to be 50%. The diagnoal represents the identity line. (A) Y-Axis represents the number of school-related infected students and x-axis represents the number of infected students in the community unrelated to school contacts. (B) Same as (A) but for teachers.

occupancy scenario. To extrapolate our model results from one school to the Netherlands at a country-level, we multiplied the increase of school-related infections as predicted by our model by 1000, accounting for approximately 1000 schools of comparable size in the Netherlands. Figure 5 shows the increase of the median of school-related infections for the considered scenarios for both students and teachers with respect to the base case strategy. For students, reopening of secondary schools at full occupancy leads to an increase in the number of school-related infections even with the considered preventive measures in place. Without any further preventive strategies, about 44,000 additional school-related infections were to be expected among students in the Netherlands. Screening twice weekly can lead to a significant lower increase of 19,000 at 50% screening adherence, a decrease by 57%. At both 30% and 50% screening adherence levels, the combination of screening and vaccination may further reduce the number of school-related infected students. Vaccination of teachers also reduces the number of school-related infections in students, though the effect is smaller than the effect of screening (increase of 36,5000 school-related infections with respect to base case strategy). Our model simulations predict that only few teachers would become infected, even at full occupancy with baseline mitigation measures (see Figure 3B). Per school, about 3 teachers ($\approx$ 4%) are expected to get infected. Extrapolated to the country-levels, this corresponds to 3000 additional school-related infected teachers. The effect of preventive strategies on school-related infections is different for teachers and students. All scenarios where vaccination of teachers is involved may even lead to a reduction of school-related infections in teachers. However, the per school reduction is small (about 1 infected teacher per school). Screening twice weekly does not lead to an increase if screening adherence is at least 50%. If screening adherence is as low as 30%, 2 additional teachers are expected to get infected per school.

Sensitivity analyses

Our sensitivity analyses show that the relative impact of the preventive strategies are preserved when assuming a lower infection risk from community of imperfect compliance. For a low infection risk from the community (half of value assumed in main analysis which corresponded to March 2021), reopening at full occupancy would lead to only one additional school-related infected teacher per school. No additional school-related infected teachers are expected if vaccination of teachers is implemented prior to reopening or screening twice weekly with 50% adherence is performed in the school. The relative impact of vaccination of teacher on school-related infections in students is lower than in the main analysis, reducing the increase in school-related infection rates by only approx. 4%. Screening twice weekly reduces the increase by 36%. A combination of screening twice weekly and vaccination of teachers reduces the increase in infection rates by 52%. For imperfect compliance, the increase in school-related infections are higher both for students and teachers than in the main analysis. In both high and low infection risk from community, there is an increase of school-related infections in teachers for full occupancy and screening twice weekly at 50% adherence (at full occupancy). The maximum increase of school-related infected teachers is 5 teachers per school ($\approx$ 6.9%) at full occupancy with a high infection risk from community. The maximum increase in school-related infected students is 55 students per school ($\approx$ 5.8%) at full occupancy with high infection risk from community. A more detailed analysis of the sensitivity analysis can be found in the Appendix B.

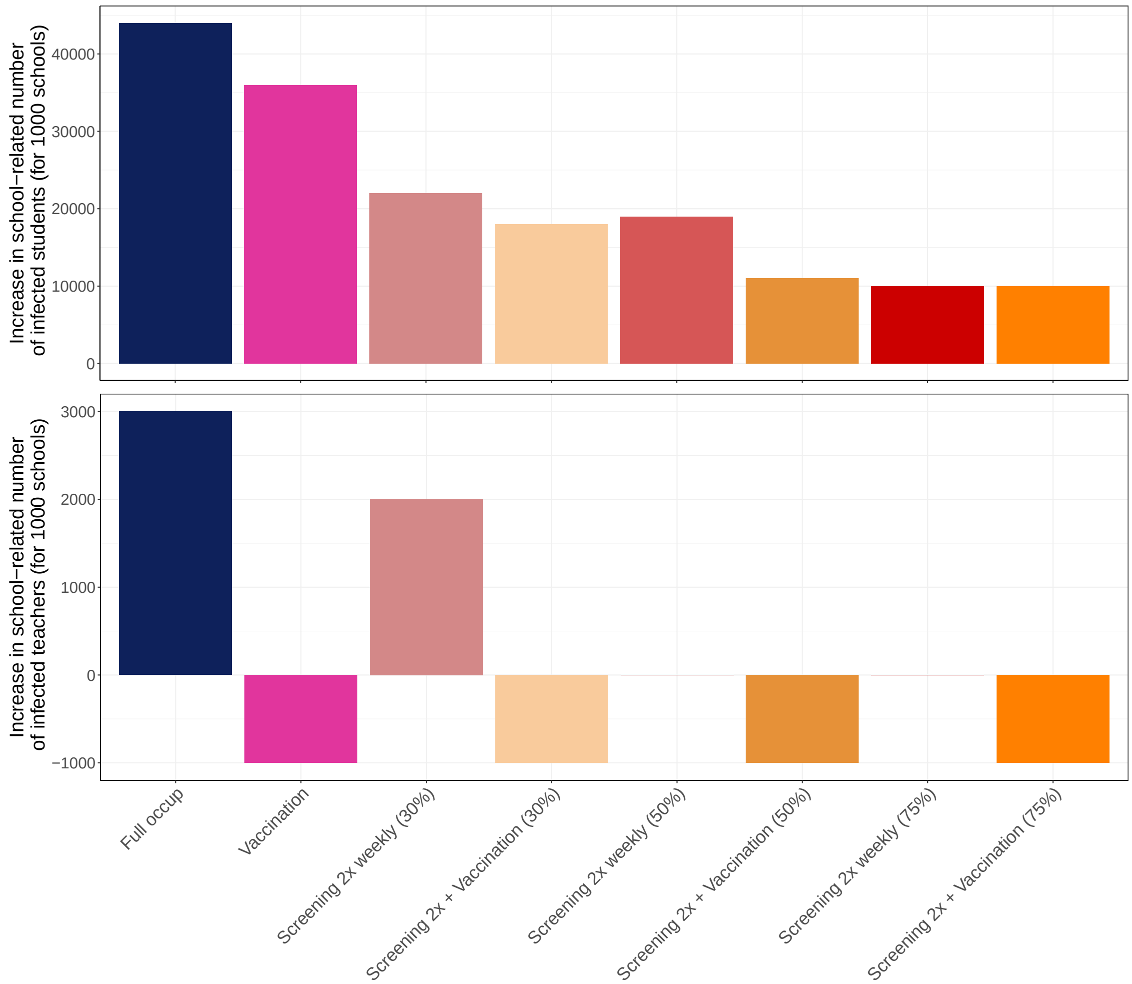

Figure 5. Increase in school-related infections extrapolated for the Netherlands. Adherence to screening is assumed to be 30%, 50%, and 75%. Adherence to risk-based testing is assumed to be 50%. The increase is computed with respect to the median number of school-related infections for the risk-based testing strategy at half occupancy.

4 Discussion

We estimated the effect of reopening secondary school at full occupancy on the number of school-related infections in the Netherlands within the first month by using an agent-based model parameterized with data on the contact structure in schools from a pilot study. Our results indicate reopening secondary school with only baseline mitigation measures in place will lead to a large increase of school-related infections, in particular in students. The effect may be mitigated with preventive strategies such as vaccination of teachers prior to reopening and/or regular screening of all individuals at school twice per week.

Screening twice weekly at high adherence levels (e.g. 75%) limits the increase in school-related infections in both teachers and students. If screening adherence is low, the combination of vaccination and screening may further reduce the number of school-related infections.

Our model predicts that per school, only few teachers would become infected through school contacts. Screening at 30% adherence level will still lead to an increase of school-related infections but the absolute number is still small (approx. 3% of teachers per school). However, this number increases with lower compliance to isolation and quarantine and with a higher number of effective contacts (in terms of transmission) between teachers and students as shown in our sensitivity analyses (see appendix B.2).

Our results and findings have several limitations. We considered *effective* contacts between teachers and students, defined by a prolonged face-to-face conversation or touching. In our main analysis, we assumed that teachers have approx. 6 to 7 of these effective contacts with students per day at half occupancy and approx. 8 to 10 at full occupancy. This is based on the assumption that teachers educate 2 to 3 classes per day with approx. 12 to 30 students per class depending on half or full occupancy. In reality, teachers might educate more classes on one day but no classes on another day. We did not account for such a heterogeneity. We further did not account for additional aerosol transmission that might play an important role in (poorly ventilated) class rooms. Hence, the number of teacher-student contacts with potential transmissions may be higher than we assumed in our model. Therefore, the number of school-related infections in teachers and the impact of vaccination of teachers might be underestimated in our results. On the other hand, we did not take the current vaccination coverage of teachers into account. Based on the age distribution of teachers, approx. 30% of teachers were already eligible for their first vaccine shot at the time of writing. Hence the effect of vaccination on the increase of school-related infections may be over-estimated.

In our main analysis and at the time when the presentation was delivered to the Ministry of OCW and the OMT, we assumed perfect compliance to isolation and quarantine. We have loosened this assumption in our sensitivity analysis (with 87% compliance to isolation and quarantine). While there is an increase in the absolute number of additional school-related infections, the results on the relative impact of the different strategies did not change.

Finally, to extrapolate to the total number of school-related infections in the Netherlands, we simply multiplied the respective median by 1000. We acknowledge that this is a very crude estimate. We do not expect that this impacts the results on the relative impact of the strategies.

In conclusion, reopening secondary schools at full occupancy will unavoidably lead to additional (school-related) infections. Screening twice weekly represents an effective strategy to reduce the infection rates. For protecting students as well as teachers, a screening adherence of at least 50% is recommended.

Data availability

Data underlying this study will be provided open access.

Competing Interest Statement

The authors have declared no competing interest.

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Author Declarations

I confirm all relevant ethical guidelines have been followed, and any necessary IRB and/or ethics committee approvals have been obtained.

Here something about METC?

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A Simulation scenarios for the main analysis

Table S1. Parameters for simulation scenarios.

Simulation scenario	Adherence		Scaling of transmission probability	Approximate number of contacts of teachers with students per day	
	Screening	Risk-based testing		Half occupancy	Full occupancy
A	50%	50%	Uniform(0.5, 0.85)	6	8
B	30%	50%	Uniform(0.5, 0.85)	6	8
C	75%	50%	Uniform(0.5, 0.85)	6	8

B Sensitivity analyses

B.1 Lower infection risk from community

We performed the simulations for a risk of infection from the community equal to half of the value used in the main analysis. In comparison with the main analysis, the absolute number of school-related infections in students and teachers is much lower. In particular, reopening at full occupancy would lead to only one additional school-related infected teacher per school (comparing the median school-related infection rates). No additional school-related infected teachers are expected if teachers were vaccinated or screening twice weekly at 50% adherence is implemented. However, the uncertainty in the number of school-related infections is quite high. The relative impact of vaccination of teacher on school-related infections in students is lower than in the main analysis, reducing the increase in school-related infection rates by only approx. 4%. Screening twice weekly reduces the increase by 36%. A combination of screening twice weekly and vaccination of teachers reduces the increase in infection rates by 52%.

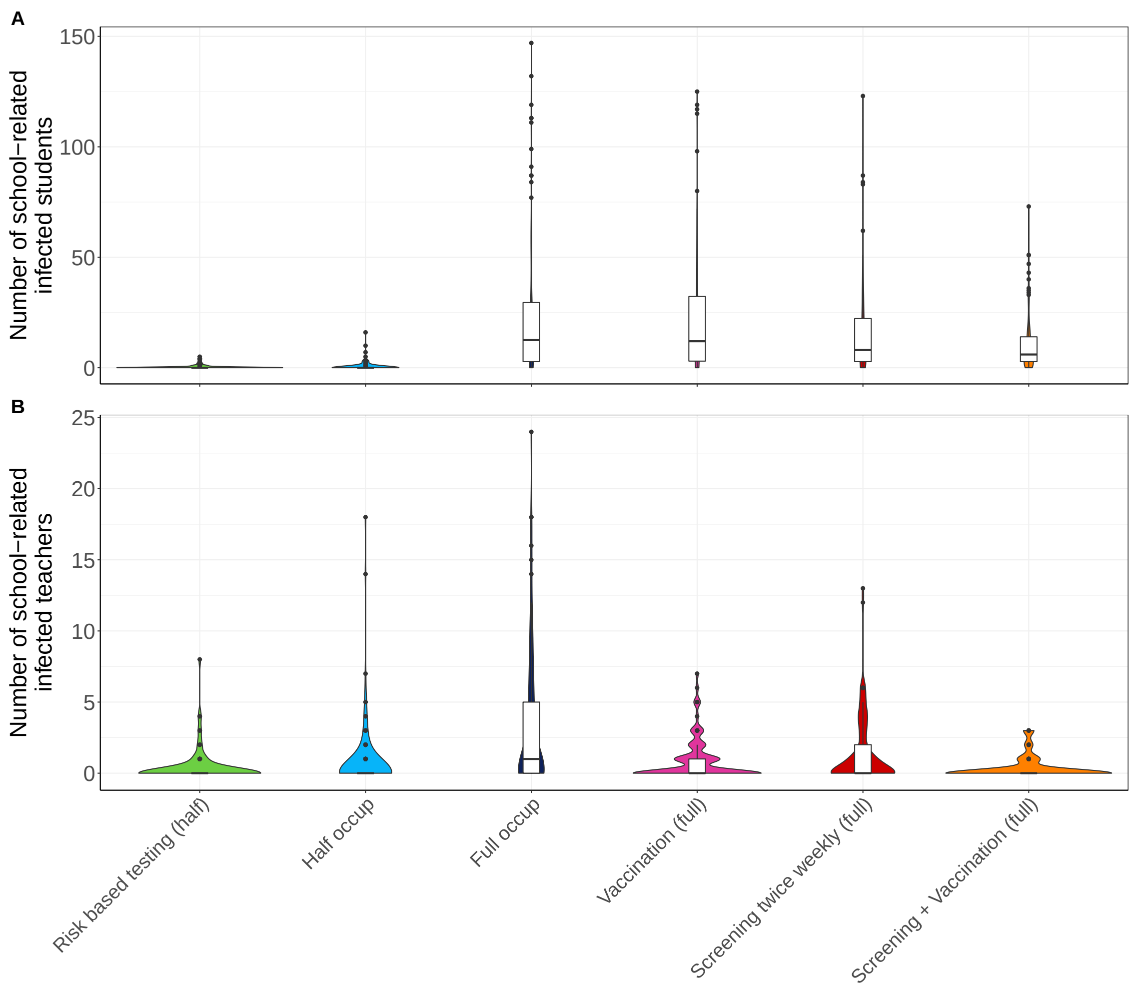

Figure S1. Total number of school-related infected individuals for low infection risk from community during the time period of 28 days. Adherence to screening and risk-based testing is assumed to be 50%.

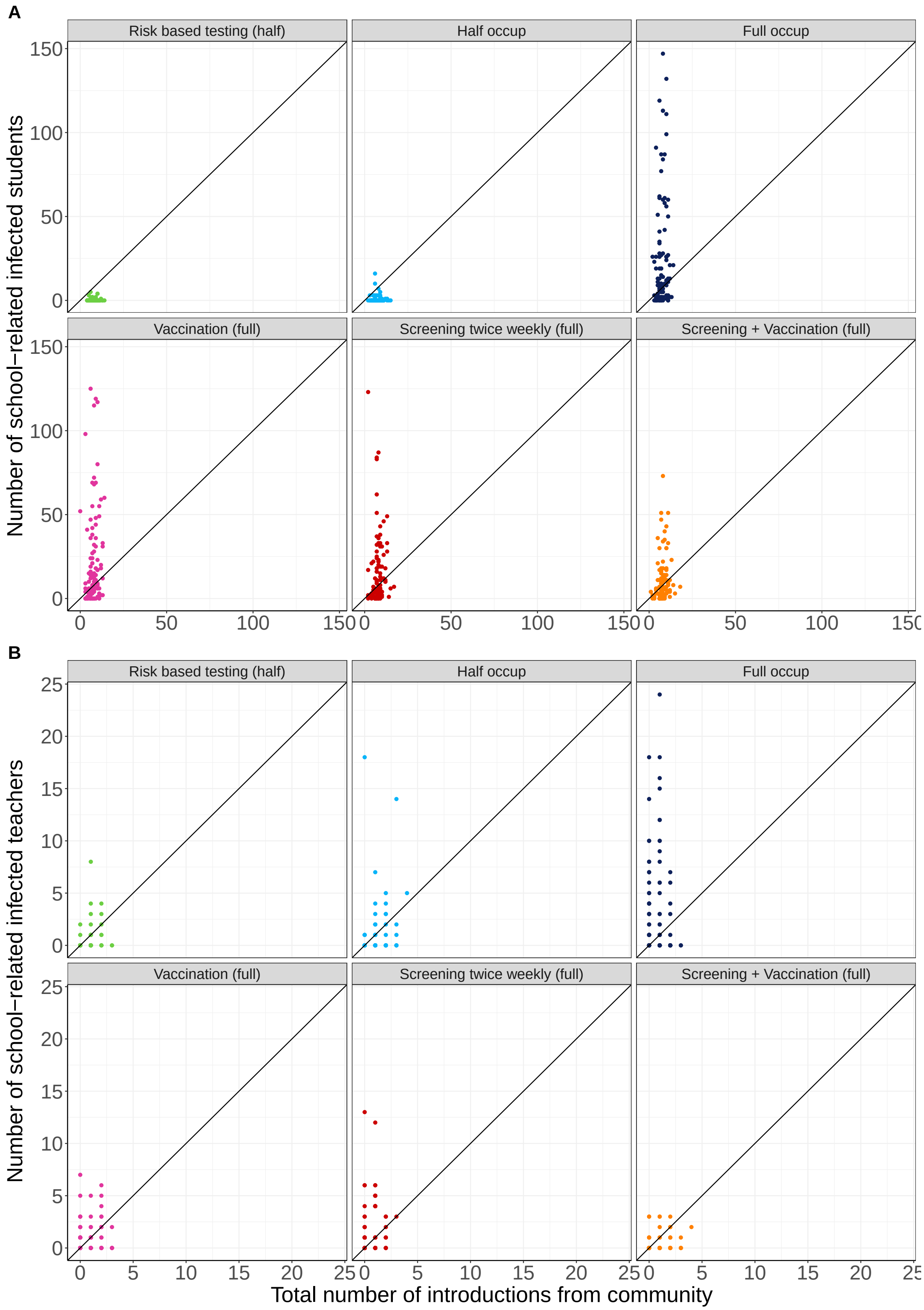

Figure S2. Relationship between simulated number of infections from the community and the number of school-related infections for low infection risk from community. Adherence to screening and risk-based testing is assumed to be 50%. The diagnoal represents the identity line. (A) Y-Axis represents the number of school-related infected students and x-axis represents the number of infected students in the community unrelated to school contacts. (B) Same as (A) but for teachers.

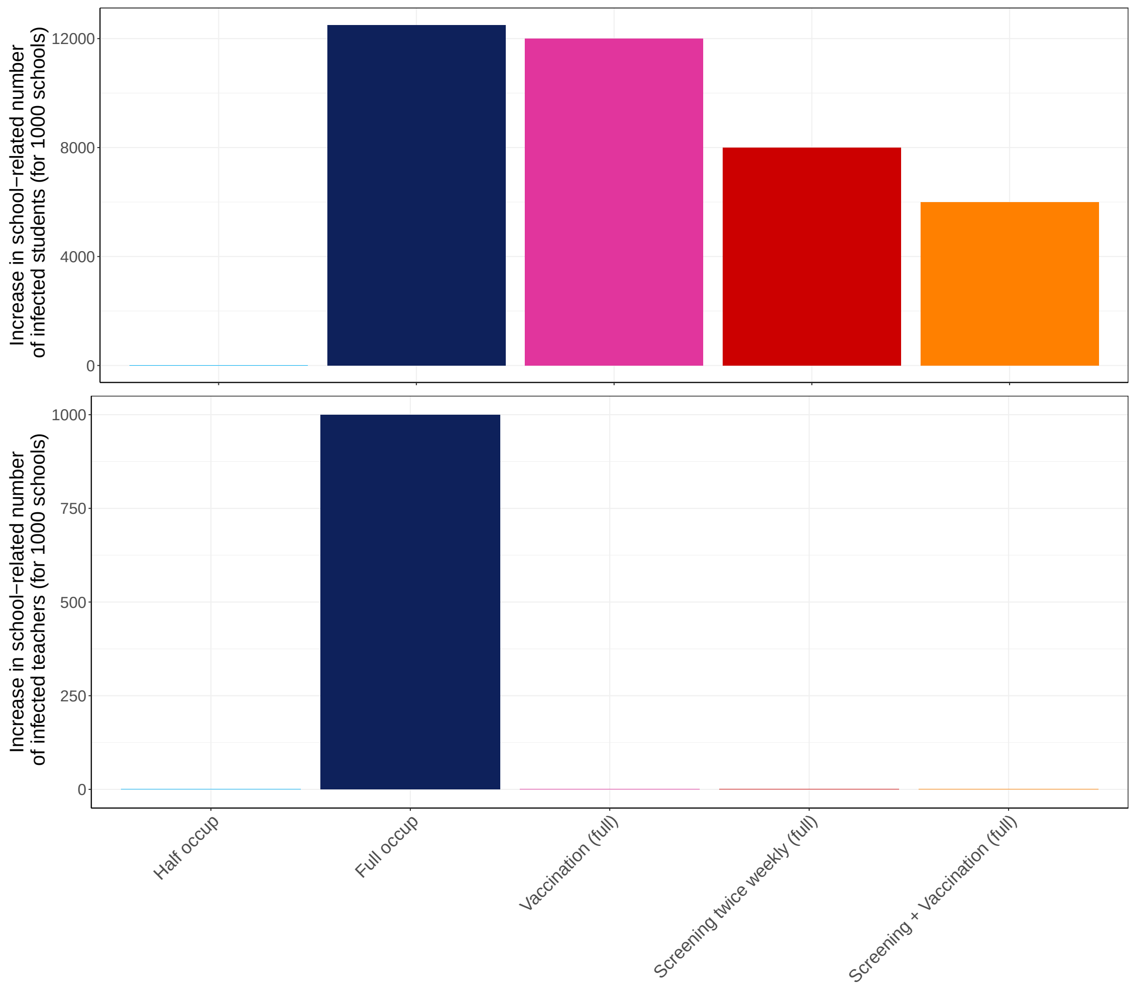

Figure S3. Increase in school-related infections extrapolated for the Netherlands for low infection risk from community. Adherence to screening and risk-based testing is assumed to be 50%. The increase is computed with respect to the median number of school-related infections for the risk-based testing strategy at half occupancy.

B.2 Imperfect compliance

In our main analysis, we assumed perfect compliance to isolation and quarantine. Here, we have loosened this assumption, considering an imperfect compliance of 87% to both isolation and quarantine and high as well as low introduction risk from community, based on data from the behavioural research conducted by RIVM National Institute for Public Health and the Environment [10]. Since results for half occupancy without risk-based testing are not significantly different from the base case scenario, we have omitted the results from the plots below. Qualitatively, the relative impact of the strategies have not changed. However, the increase in school-related infections are higher both for students and teachers than in the main analysis. In both infection risk scenarios, there is an increase of school-related infections in teachers for full occupancy and screening twice weekly at 50% adherence (at full occupancy). The maximum increase of school-related infected teachers is 5 teachers per school ($\approx$ 6.9%) at full occupancy with a high infection risk from community. The maximum increase in school-related infected students is 55 students per school ($\approx$ .5.8%) at full occupancy with high infection risk from community.

B.2.1 High introduction risk

We depicted the total number of and the increase in school-related infections in students and teachers in Figures S4-S5 for the scenario with high infection risk from the community. The model predicts five additional school-related infected teachers at the end of the first month. This corresponds to approx. 6.9% of the teachers working in one school. Vaccination of teachers does not lead to any increase in school-related infected teachers. Screening twice weekly at 50% adherence leads to two additional school-related infected teachers ($\approx$ 2.8%). The combination of screening and vaccination leads to a reduction of one school-related infected teacher per school.

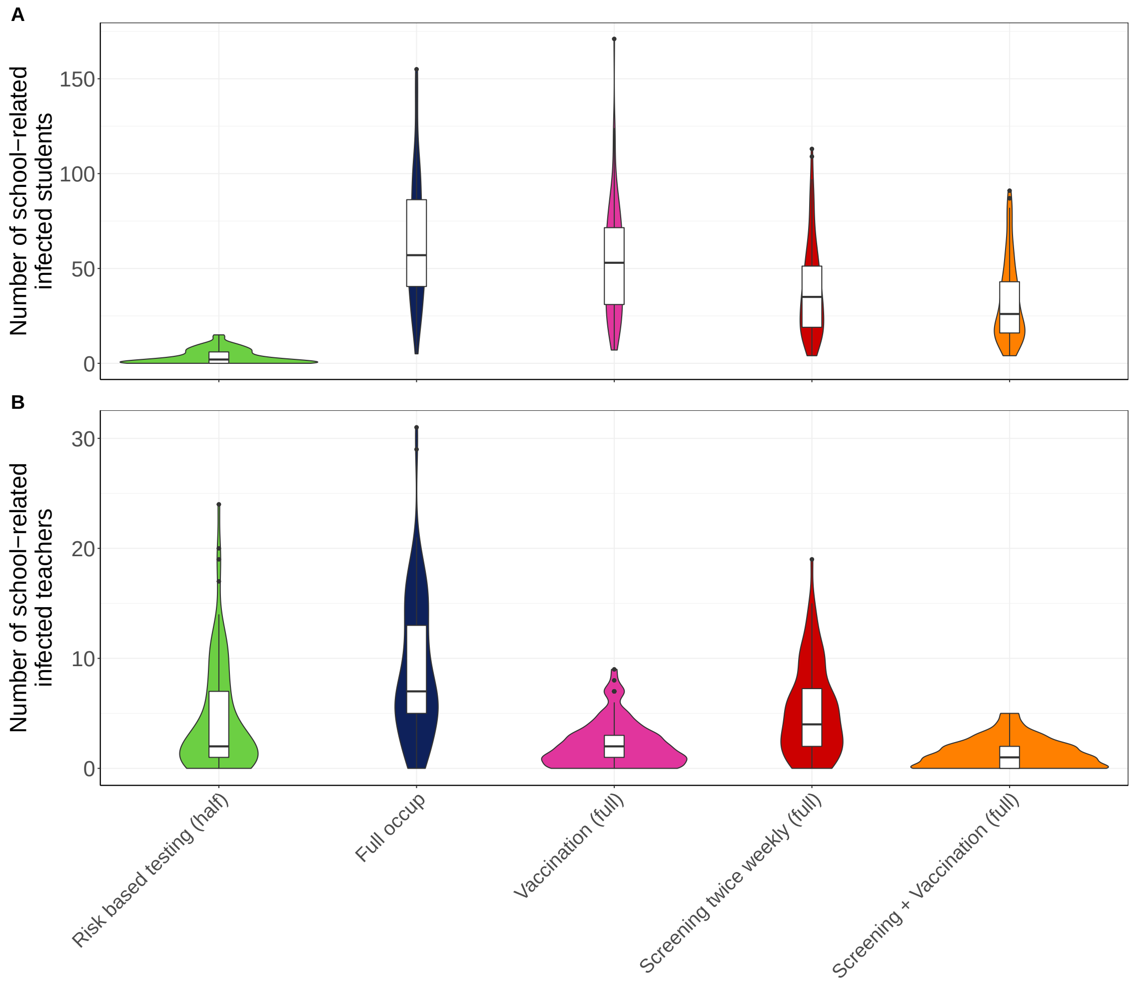

Figure S4. Total number of school-related infected individuals during the time period of 28 days for imperfect compliance and high infection risk from community. Adherence to screening and risk-based testing is assumed to be 50%. Compliance to isolation and quarantine is assumed to be 87%.

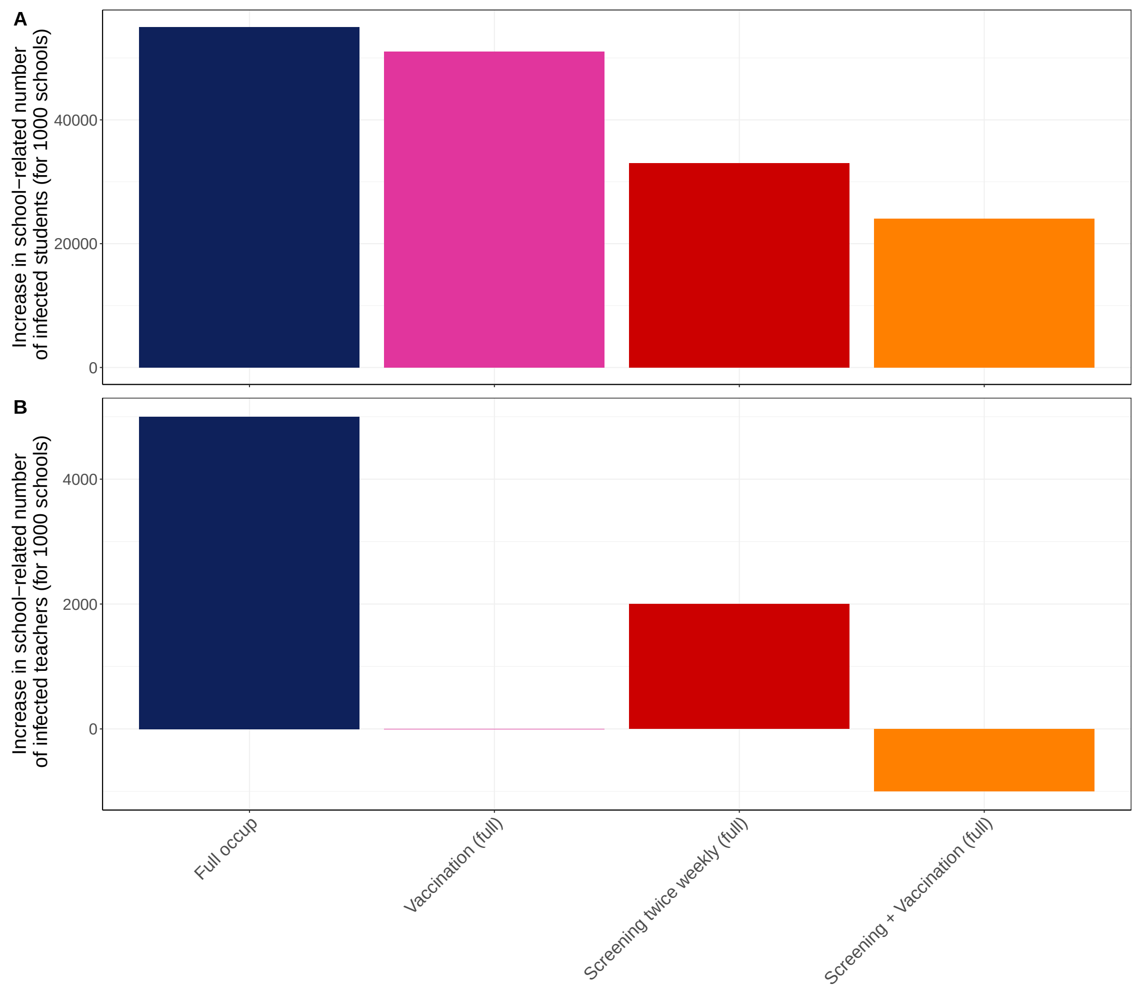

Figure S5. Increase in school-related infections extrapolated for the Netherlands for imperfect compliance and high infection risk from community. Adherence to screening and risk-based testing is assumed to be 50%. Compliance to isolation and quarantine is assumed to be 87%. The increase is computed with respect to the median number of school-related infections for the risk-based testing strategy at half occupancy.

B.2.2 Low introduction risk

For low introduction risk, there is also an increase in school-related infected teachers for the half occupancy scenario compared to the base case scenario (risk-based testing strategy at half occupancy). However, the increase is smaller (2.5 teachers per school). We performed a pairwise Mann-Whitney test to compare the number of school-related infections between the base case scenario and the other scenarios. The p-values are shown in Table S2. Thus, while there is an increase in the median number of school-related infected teachers for screening twice weekly at 50% adherence, the increase is small (0.5 teachers per school) and non-significant.

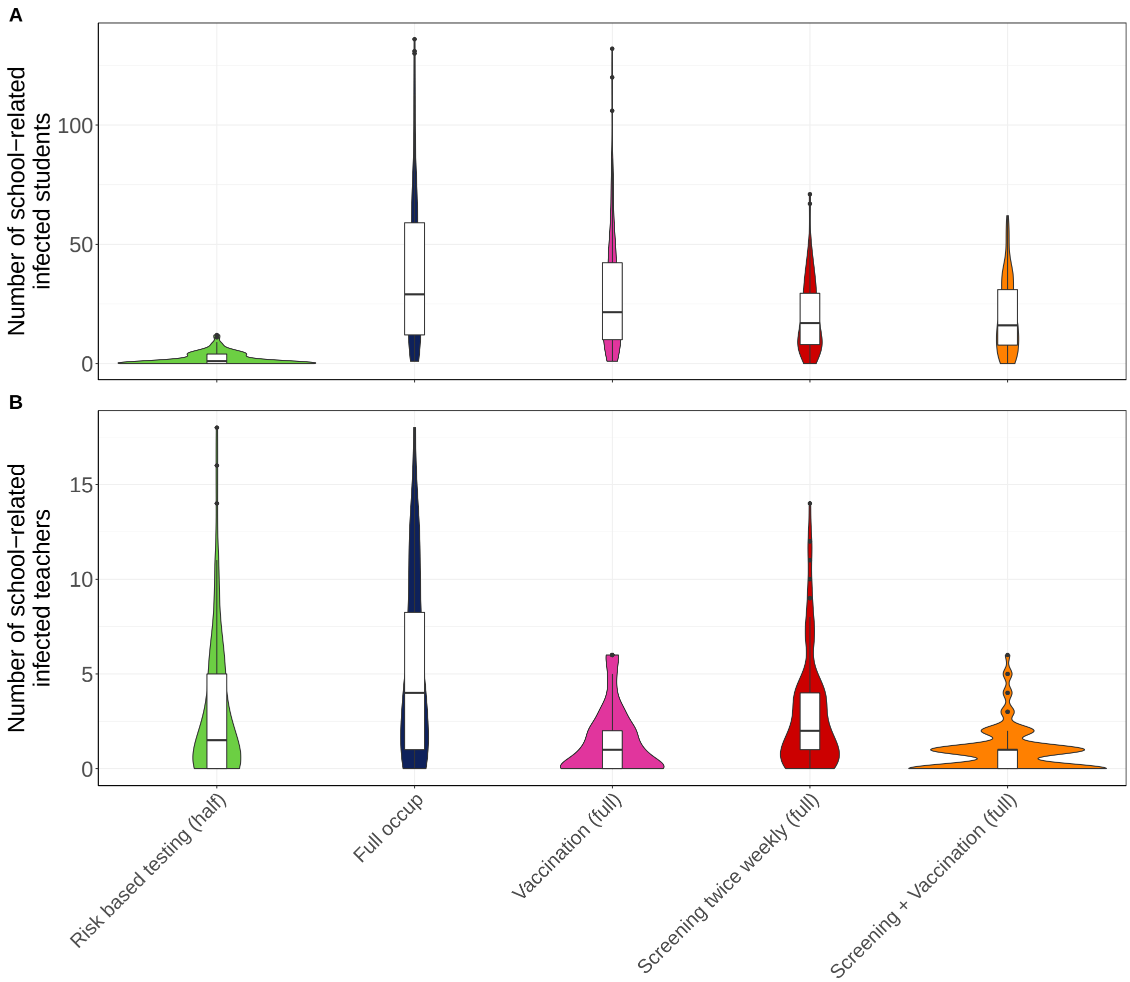

Figure S6. Total number of school-related infected individuals during the time period of 28 days for imperfect compliance and low infection risk from community. Adherence to screening and risk-based testing is assumed to be 50%. Compliance to isolation and quarantine is assumed to be 87%.

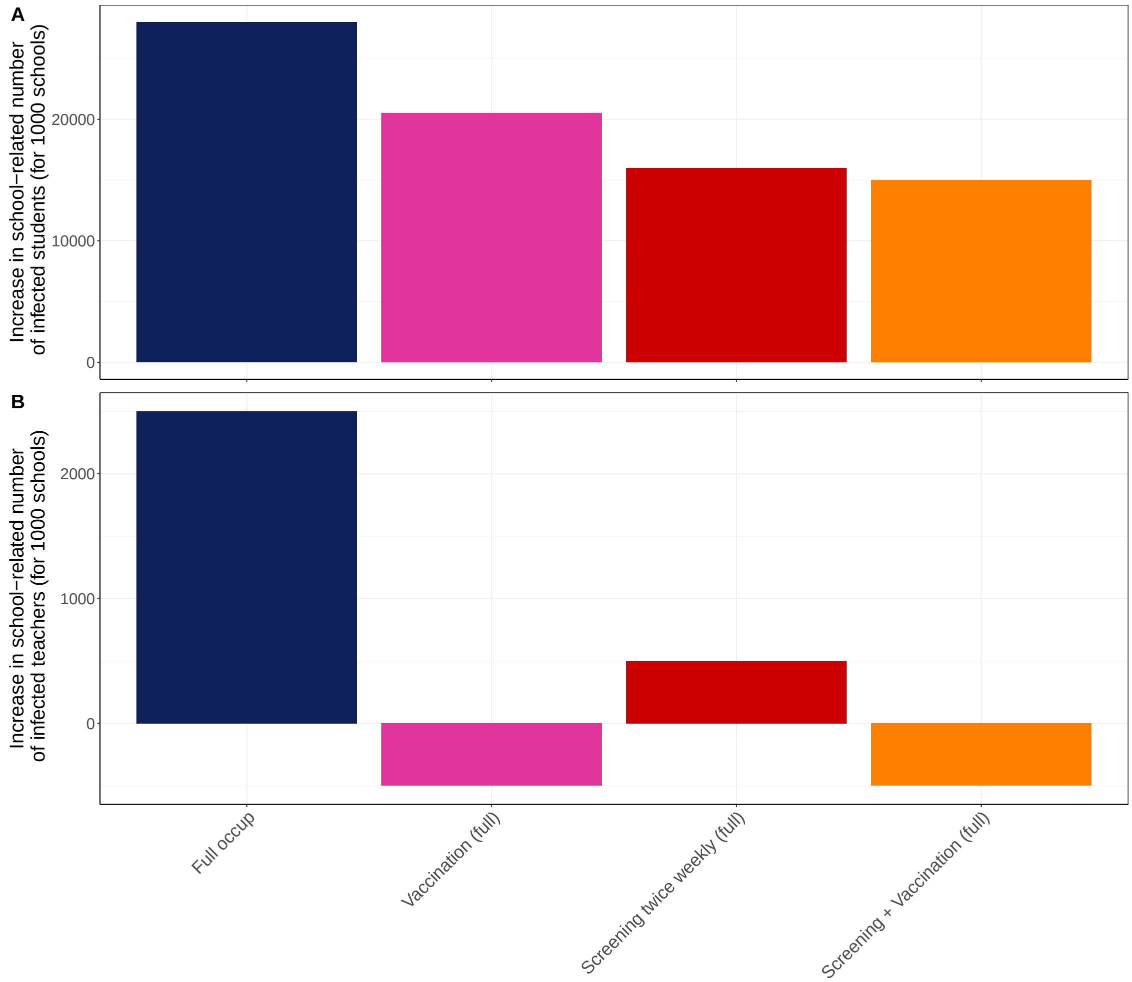

Figure S7. Increase in school-related infections extrapolated for the Netherlands for imperfect compliance and low infection risk from community. Adherence to screening and risk-based testing is assumed to be 50%. Compliance to isolation and quarantine is assumed to be 87%. The increase is computed with respect to the median number of school-related infections for the risk-based testing strategy at half occupancy.

Table S2. Results for Mann-Whitney test for pairwise comparison of school-related infections between base case scenario and other strategies.

Strategies	p-value	
	Students	Teachers
Full occupancy	0.0000	0.0001
Vaccination of teachers	0.0000	0.0143
Screening twice weekly	0.0000	0.3694
Screening + Vaccination	0.0000	0.0002

B.3 Exploring screening adherence

Comparison of reopening schools at full occupancy with screening strategies at different adherences to screening for *low infection risk from community*. Compliance to isolatiom and quarantine is assumed to be 100% in this sensitivity analysis. There is a linear effect in increasing screening adherence for school-related infected students. At this low introduction risk scenario, the number of school-related teachers remains small and is not further reduced by further increase of screening adherence.

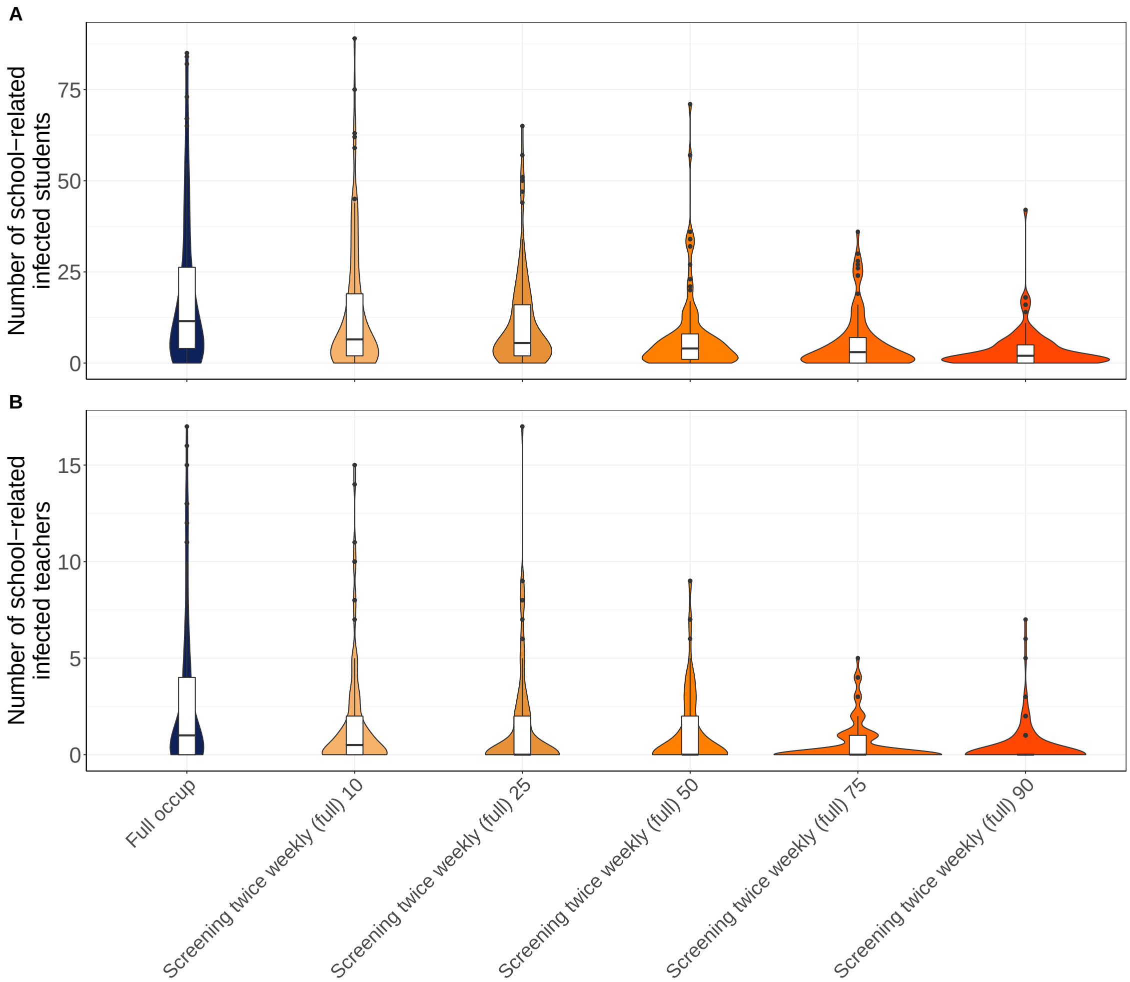

Figure S8. Total number of school-related infected individuals during the time period of 28 days for full occupancy and different screening adherences.

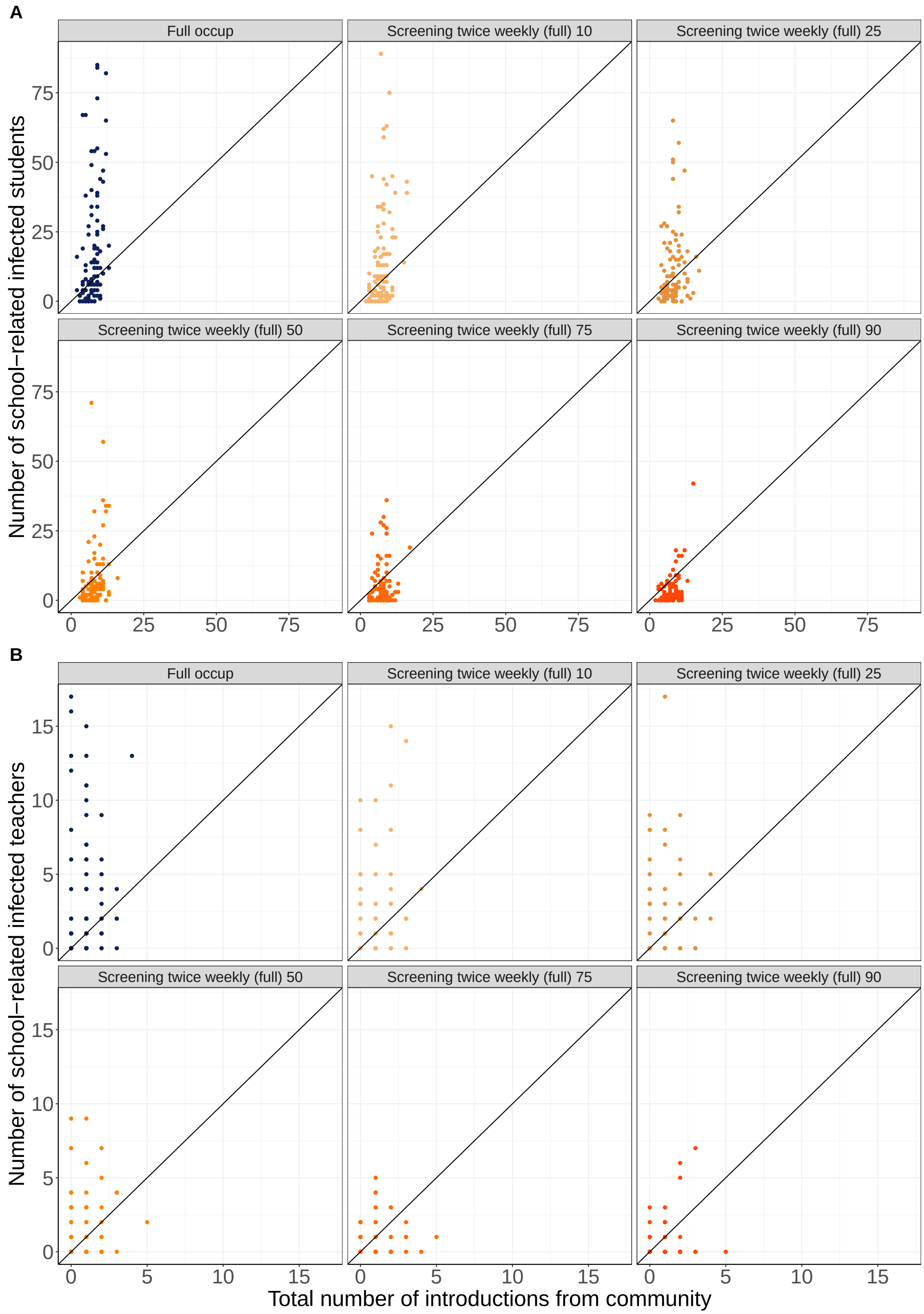

Figure S9. Relationship between simulated number of infections from the community and the number of school-related infections for full occupancy and different screening adherences. Adherence to screening and risk-based testing is assumed to be 50%. The diagnoal represents the identity line. (A) Y-Axis represents the number of school-related infected students and x-axis represents the number of infected students in the community unrelated to school contacts. (B) Same as (A) but for teachers.

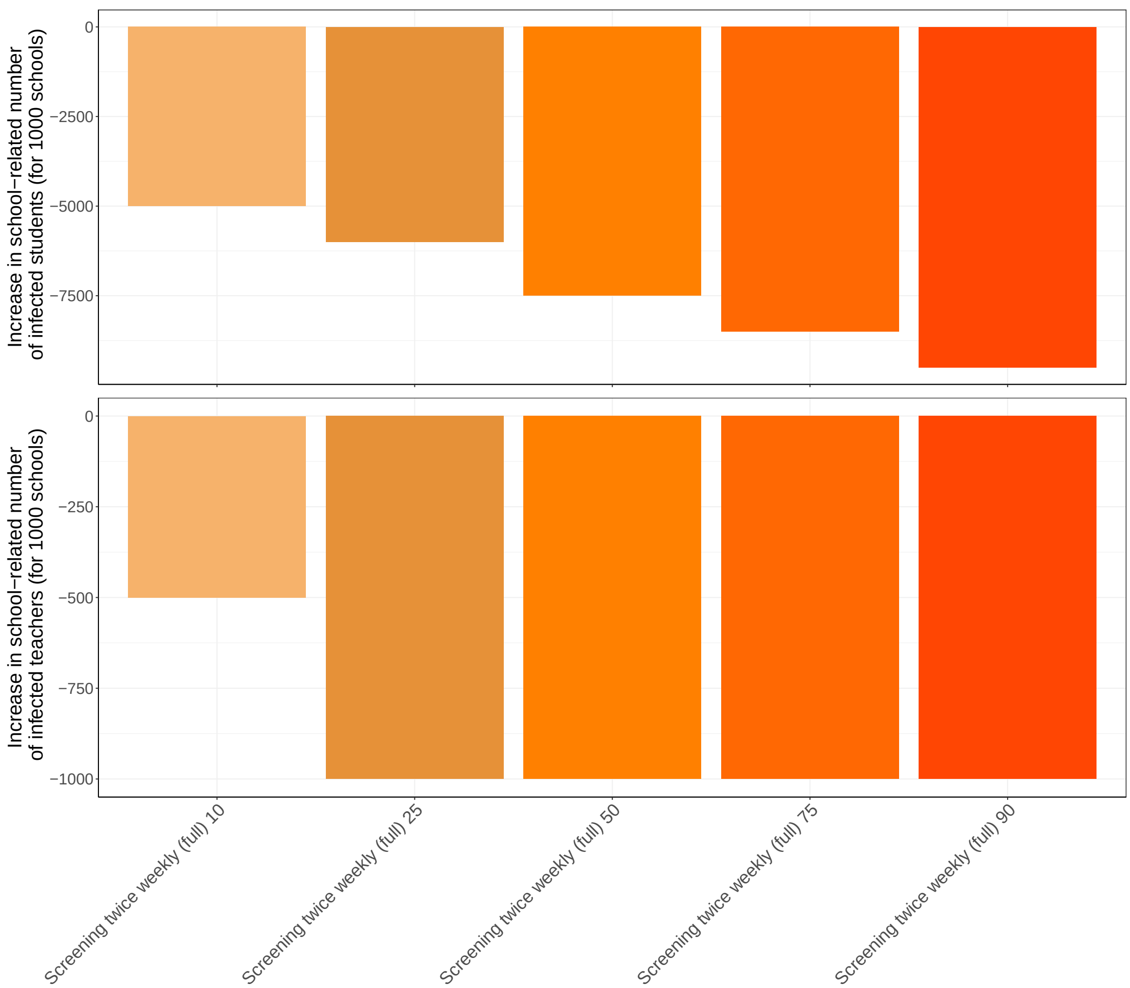

Figure S10. Increase in school-related infections extrapolated for the Netherlands comparing full occupancy and different screening adherences. The increase is computed with respect to the median number of school-related infections for the risk-based testing strategy at half occupancy.

Appendix C Data pilot study

Results regarding index cases and secondary cases

Table 1 Notified positive cases to the pilot schools. Based on data available (7 schools) and scaled to 1000 students per school.

	Students		**Teachers**	
Week	mean (SD)	Median (IQR)	mean (SD)	Median (IQR)
all	14 (23.6)	7.5 (1-11.5)	2.6 (5.8)	0 (1.5-7)
1-3	2.3 (6)	0 (0-0)	0 (0)	0 (0-0)
8-3	4.6 (6.2)	0.5 (0-8)	0 (0)	0 (0-0)
15-3	0.7 (1.3)	0 (0-1)	0.9 (2.4)	0 (0-0)
22-3	2.7 (4.8)	0 (0-3)	1.4 (3.6)	0 (0-0)
29-3	1.9 (4.7)	0 (0-0.5)	0.3 (0.5)	0 (0-0.5)
5-4	0.3 (0.7)	0 (0-0)	0 (0)	0 (0-0)
12-4	1.6 (2.7)	0 (0-2.5)	0.1 (0.2)	0 (0-0)
19-4	0.9 (0.2)	0 (0-0)	0 (0)	0 (0-0)

Table 2 Number of participants in antigen testing during the pilot. Based on data available (84 index cases & testing in 24 schools)

	Overall		**Average of test rounds**	
	Number exposed	Number tested	Mean (SD)	Median (IQR)
Test round 1	3156	1426 (45%)	56.3% (28%)	53.3% (31.6-78.0)
Test round 2	3156	1165 (37%)	47.1 (28.3%)	44.4% (25.8-62.8%)
Participated in at least in one test round	3156	1621 (51%)	61.5% (27.2)	58.2 (43.4-90.4%)

Table 3 Secondary attack rate stratified by teacher and student. Secondary attack rate is defined as the number of index cases with at least one secondary case divided by the number of index cases. This includes the index cases for which antigen rapid testing was applied.

	Total number of index cases	**Index cases with secondary transmission**	**Index cases without secondary transmission**	**Secondary attack rate**	**CI 95%**	**P-value**
Teachers	31	7	24	22.60%	10.3-41.5	0.042
Students	119	11	108	9.20%	4.9-16.3	

Table 4 Susceptibility of getting secondary infected stratified by teacher and student. Transmission rate is defined as the number of secondary cases divided by the number of participants.

	Total tested	**Secondary cases**	**Not secondary infected**	**Transmission rate**	**CI 95%**	**P-value**
Teachers	762	3	759	0.39%	0.1-1.3	0.29
Students	2813	21	2792	0.75%	0.48-1.17	

Table 5 Symptoms of secondary cases.

Symptoms†	**All**	**Students**	**Teachers**
- Symptomatic infection	18 (75.0%)	15 (71.4%)	3 (100%)
- Pre-symptomatic	3 (12.5%)	3 (14.3%)	0 (0.0%)
- Asymptomatic infection	3 (12.5%)	3 (14.3%)	0 (0.0%)
† Symptomatic: symptoms during antigen application; Pre-symptomatic: symptom onset in week after antigen test; Asymptomatic: no symptoms.			

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Table 6 Overview of participating school, antigen testing via pilot and the number of secondary cases.

Week	Number of participating schools	Number of students of participating schools Mean (SD)	Number of schools with testing	Average number of students of schools with testing Mean (SD)	Number of schools with positive cases	Average number of students of schools with positive cases Mean (SD)	Number of index cases with testing	number of index cases with positive cases	Number of positive cases (range per index)
1-3	29	601,4 (445,6)	2	1329 (172,5)	2 (100%)	1329 (172,5)	2	2 (100%)	5 (1-4)
8-3	33	623,1 (497,5)	5	789,8 (542,7)	1 (20%)	438	6	1 (16.7%)	2
15-3	46	768,8 (562,3)	19	1011,8 (574)	3 (15.8%)	903,7 (254,1)	34	5 (14.7%)	7 (1-2)
22-3	46	768,8 (562,3)	17	962,5 (636,4)	3 (17.6%)	927 (1103,8)	32	3 (9.4%)	3 (1)
29-3	46	768,8 (562,3)	18	1092,9 (608,7)	2 (11.1%)	1168 (55,2)	21	2 (9.5%)	3 (1)
5-4	46	768,8 (562,3)	12	937,3 (519,8)	0 (0.0%)		16	0 (0.0%)	0
12-4	45	780,1 (564,7)	18	1096,3 (574,9)	2 (11.1)	950,5 (330,2)	30	2 (6.7%)	2 (1)
19-4	45	780,1 (564,7)	11	1019,9 (502,5)	2 (18.2%)	1156,5 (38,9)	12	2 (16.7%)	2 (1)

Student and teacher contact network

Questionnaire for participants regarding contact network

Questionnaire was sent to teachers and students when they were part of the test population (category 3 non-close contacts with consent for pilot).

	Dutch	Translated to English	Questionnaire
1	Welke leerjaren geef je les?	Which grades do you educate?	Teachers
2	Aan hoeveel leerlingen in totaal geef je ongeveer les op deze school?	How many students in this school do you educate in total?	Teachers
3	Met hoeveel leerlingen zit je samen in de les voor alle vakken bij elkaar?	With how many students do you have class for all subjects together?	Students
4	Met hoeveel medeleerlingen waar je les mee had heb je gisteren of de voorgaande schooldag een praatje gemaakt of aangeraakt?	How many of your classmates did you chat or touch with yesterday or the previous day at school?	Students
5	Met hoeveel medeleerlingen waar je geen les mee had heb je gisteren of de voorgaande schooldag een praatje gemaakt of aangeraakt?	How many other students you did not have class with did you chat or touch with yesterday or the previous day at school?	Students
6	Met hoeveel medeleerlingen waar je les mee hebt heb je gisteren buiten school een praatje gemaakt of aangeraakt? Let op; Als het vandaag maandag is, vul dat het aantal in waarmee je op zaterdag en zondag praatje mee had gemaakt of had aangeraakt?	How many of your classmates did you chat with or touched outside of school yesterday? Note; If today is Monday, enter the number you interacted with or touched on Saturday and Sunday?	Students
6.1	Hoeveel hiervan zie je gemiddeld meer dan één keer per week buiten school?	How many of them do you meet at least once a week outside of school?	Students
7	Met hoeveel medeleerlingen van je school waar je geen les mee hebt heb je gisteren buiten school een praatje gemaakt of aangeraakt? Let op; Als het vandaag maandag is, vul dat het aantal in waarmee je op zaterdag en zondag praatje mee had gemaakt of had aangeraakt?	How many of your schoolmates with whom you are not in class did you chat or touched outside of school yesterday? Note; If today is Monday, enter the number you interacted with or touched on Saturday and Sunday?	Students
7.1	Hoeveel hiervan zie je gemiddeld meer dan één keer per week buiten school?	How many of them do you meet at least once a week outside of school?	Students
8	Met hoeveel leerlingen waaraan je wel les gaf heb je gisteren of de voorgaande schooldag een praatje gemaakt of aangeraakt?	How many students that you educated did you chat or touch with yesterday or the previous day at school?	Teachers
9	Met hoeveel leerlingen waaraan je geen les gaf heb je gisteren of de voorgaande schooldag een praatje gemaakt of aangeraakt?	How many students you did not teach did you chat or touch with yesterday or the previous day of school?	Teachers
10	Met hoeveel collega's heb je gisteren of de voorgaande schooldag een praatje gemaakt of aangeraakt?	How many colleagues did you chat or touch with yesterday or the previous day at school?	Teachers
11	Met hoeveel collega's heb je gisteren buiten werktijd een praatje gemaakt of aangeraakt? Let op; Als het vandaag maandag is, vul dat het aantal in waarmee je op zaterdag en zondag praatje mee had gemaakt of had aangeraakt?	How many colleagues did you chat or touch with yesterday outside working hours? Note; If today is Monday, enter the number you interacted with or touched on Saturday and Sunday?	Teachers
11.1	Hoeveel hiervan zie je gemiddeld meer dan één keer per week buiten school?	How many of them do you meet at least once a week outside school?	Teachers
12	Met hoeveel andere personen (gezinsleden uitgezonderd) heb je gisteren een praatje gemaakt of aangeraakt? Let op; Als het vandaag maandag is, vul dat het aantal in waarmee je op zaterdag en zondag praatje mee had gemaakt of had aangeraakt?	How many other people (excluding family members) did you chat or touch yesterday? Note; If today is Monday, enter the number you interacted with or touched on Saturday and Sunday?	Teachers and students
12.1	Hoeveel hiervan zie je gemiddeld meer dan één keer per week?	How many of them do you meet at least once a week?	Teachers and students

13	Ben je in de twee weken voorafgaand aan de test in nauw contact geweest met een persoon met een bevestigde coronavirus infectie buiten school?	In the two weeks prior to the test, have you been in close contact with a person with a confirmed coronavirus infection outside school?	Teachers and students
14	Heb je in de afgelopen twee weken deelgenomen aan hobby en/of sportactiviteiten in groepsverband?	Have you participated in group sports and / or activities in the past two weeks?	Teachers and students
15	Hoe vaak ben je in de afgelopen twee weken met niet-gezinsleden in één ruimte binnenshuis verbleven langer dan 15 minuten (uitgezonderd winkels en school)?	In the past two weeks, how often have you stayed indoors with non-family members in one room for longer than 15 minutes (excluding shops and school)?	Teachers and students
16	Waar heb je in de week voorafgaand aan de test contact gehad met de besmette persoon waarom je deze test doet?	In the week prior to the test, where did you contact the infected person for whom you are taking this test?	Teachers and students

Questionnaire for schools regarding contact network

Questionnaire was sent at pilot completion.

	Dutch	Translated to English
1	Hoeveel leerlingen kregen in de periode van 1 maart t/m 24 april minimaal 1 dag per week onderwijs op school?	How many students were educated at school at least 1 day a week in the period from 1 March to 24 April?
2	Hoeveel leerlingen zijn er sinds 1 maart gemiddeld per lesdag op school?	How many students have been at school on average per day of class since 1 March?
3	Wat is het gemiddeld aantal dagen onderwijs op school per leerjaar per week in sinds 1 maart?	What is the average number of days of education at school per grade per week since 1 March?
4	Wat is het gemiddeld aantal uren da teen student aanwezig is in school per lesdag per leerjaar op school sinds 1 maart?	What is the average number of hours a student is present in school per grade since 1 March?
5	Wat is het gemiddeld aantal leerkrachten waarvan een leerling les krijgt op school per lesdag per leerjaar sinds 1 maart?	What is the average number of teachers of which a student has been taught at school per day per grade since March 1?
6	Hoeveel leerkrachten gaven in de periode van 1 maart t/m 24 april minimaal 1 dag per week onderwijs op school?	How many teachers taught at school at least 1 day a week in the period from 1 March to 24 April?
7	Hoeveel leerkrachten zijn er sinds 1 maart gemiddeld per lesdag op school?	How many teachers have there been on average per day at school since 1 March?
8	Hoeveel klassen geeft een leerkracht sinds 1 maart gemiddeld fysiek onderwijs per lesdag?	How many classes does a teacher give on average education per day at school since 1 March?
9	Hoeveel leerlingen geeft een leerkracht sinds 1 maart gemiddeld fysiek onderwijs per lesdag?	How many students does a teacher educate per day at school since 1 March?
10	Hoeveel verschillende leerjaren geeft een leerkrach sinds 1 maart gemiddeld fysiek onderwijs per lesdag?	How many different grades does a teacher educate per day at school since 1 March?

Results regarding contact network

Table 7 Overview of occupancy of students and teachers in VO school since 1 march. Based on data available (12 schools); Schools with special and practical education excluded.

	Mean (SD)	Median (IQR)
Number of students per day in school (per 1000 students)	572.9 (160.4)	500 (496-563)
Number of teachers at school per week (per 1000 students)	98.6 (38.8)	106 (76.5-125)
Number of teachers at school per day (per 1000 students)	75.1 (30.3)	68 (58.5-104)
Number of grades a teacher educates per day	3 (1.0)	3 (2.5-4)
Number of classes educated by a teacher per day	4.6 (0.9)	5 (4-5)
Number of students educated by a teacher per day	47.8 (35.6)	14.5 (13.5-16.5)

Table 8 Occupancy stratified by grade since 1 march. Based on data available (12 schools); Schools with special and practical education excluded.

Grade†	Age	Average number of days of education in school		Average number of hours present at school per school day		Average number of teachers a student is educated by at school per school day	
		Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)
Grade 1	12	2.3 (0.7)	2.5 (2-2.5)	5.2 (1.3)	5 (4.5-6)	4.7 (1.3)	5 (3.5-5)
Grade 2	13	2.5 (0.9)	2.5 (2-2.5)	5.2 (1.3)	5 (4.5-6)	4.8 (1.3)	5 (4.5-6)
Grade 3	14	2.5 (0.9)	2.5 (2-2.5)	5.1 (1.1)	5 (4.5-6)	4.7 (1.3)	5 (3.5-5)
Grade 4 - Exam year	15	4.0 (1.3)	5 (2.5-5)	5.5 (1.2)	5 (5-6.5)	4.9 (1.4)	5 (4-6)
Grade 4 - No Exam year	15	2.2 (0.3)	2.5 (2-2.5)	5.2 (1.1)	5 (5-6)	5.1 (1.1)	5 (5-5)
Grade 5 - Exam year	16	3.9 (1.3)	5 (2.5-5)	5.3 (1.2)	5 (5-6)	5.2 (1.2)	5 (4.5-6)
Grade 5 - No Exam year	16	2.2 (0.4)	2.5 (2-2.5)	5.3 (1.2)	5 (5-6)	5.1 (1.2)	5 (4.5-5.5)
Grade 6 - Exam year	17	4.1 (1.2)	5 (3-5)	5.3 (1.2)	5 (5-6)	5.2 (1.2)	5 (4.5-6)

† Number of grades differs per level.

Table 9 Contacts outside school. Questions completed by 2867 students and 663 teachers. A contact was defined as a person with who the participant had a conversation with or touched.

		Number of contacts they met the day before/weekend outside school†		Number of these contacts they meet at least twice a week†	
		Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)
Students	Contact with classmates	2.1 (3.7)	1 (0-3)	1.1 (2.4)	0 (0-1)
	Contacts with other students (excl. classmates)	1.4 (3.7)	0 (0-2)	0.8 (2.2)	0 (0-1)
	Other contacts (excl. household members)	3.6 (5.9)	2 (0-5)	2 (4.7)	0 (0-2)
Teachers	Contact with colleagues	0.5 (1.4)	0 (0-0)	0.1 (0.4)	0 (0-0)
	Other contacts (excl. household members)	3.3 (4.9)	2 (0-4)	1.3 (3.3)	0 (0-2)

† Contacts of the weekend (reported on monday) were divided by 2 to correct.

Table 10 Participant contact with index case.

Contact with index	All participants	Secondary cases	Not secondary infected
Seated within 1.5 meter from index	196 (14,2%)	6 (33,3%)	190 (13,9%)
Outside school	20 (1,4%)	1 (5,6%)	19 (1,4%)
During lunch break	102 (7,4%)	3 (16,7%)	99 (7,2%)
In same class	760 (54,9%)	4 (22,2%)	756 (55,3%)
Other	70 (5,1%)	1 (5,6%)	69 (5,0%)
Unknown	237 (17,1%)	3 (16,7%)	234 (17,1%)

Table 11 Contact matrix of students having contact with students

Respondents per year	Contacts with students within the same class		Contacts with students from other classes/years per year											
			1		2		3		4		5		6	
	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)
1	5.5 (3.8)	5.0 (3-7)	3.1 (5.4)	1 (0-3.0)	0.20 (0.77)	0 (0-0)	0.13 (0.43)	0 (0-0.0)	0.07 (0.29)	0 (0-0)	0.05 (0.25)	0 (0-0)	0.03 (0.22)	0 (0-0.0)
2	5.2 (3.9)	4.0 (3-7)	2.37 (6.46)	0 (0-0.5)	4.69 (5.95)	2 (0-6)	0.81 (2.52)	0 (0-0.5)	0.47 (2.31)	0 (0-0)	0.31 (2.31)	0 (0-0)	0.32 (2.34)	0 (0-0.0)
3	5.6 (4.1)	5.0 (3-8)	0.60 (3.10)	0 (0-0.0)	0.79 (3.33)	0 (0-0)	4.66 (5.68)	3 (1-6.0)	0.32 (0.84)	0 (0-0)	0.04 (0.32)	0 (0-0)	0.05 (0.34)	0 (0-0.0)
4	8.1 (8.0)	6.0 (3-10)	1.42 (5.82)	0 (0-0.0)	1.32 (5.60)	0 (0-0)	1.76 (5.79)	0 (0-1.0)	7.03 (7.71)	5 (2-10)	1.22 (3.45)	0 (0-1)	0.54 (2.97)	0 (0-0.0)
5	8.3 (7.7)	6.0 (4-10)	0.09 (0.64)	0 (0-0.0)	0.08 (0.37)	0 (0-0)	0.09 (0.32)	0 (0-0.0)	0.95 (2.56)	0 (0-1)	7.05 (9.09)	5 (2-10)	0.78 (1.80)	0 (0-1.0)
6	10.6 (8.8)	8.5 (5-15)	0.42 (3.18)	0 (0-0.0)	0.43 (3.09)	0 (0-0)	0.43 (3.12)	0 (0-0.0)	0.71 (3.63)	0 (0-0)	1.49 (3.77)	0 (0-1)	6.78 (7.13)	5 (2-10.0)