School Closure Versus Targeted Control Measures for SARS-CoV-2 Infection

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abstract

OBJECTIVES: To compare effects of school closures with effects of targeted infection prevention and control (IPC) measures in open schools on SARS-CoV-2 infection rates in students.

METHODS: We conducted interrupted time-series analyses to compare trends in infection rates in grades 1–10 in 7 boroughs in Oslo, Norway, between February 15 and April 18, 2021. All schools at all levels had implemented strict IPC measures. While grades 1–4 attended school throughout the study period, school closures were implemented for grades 5–10 from March 17. We obtained individual level data from nationwide registries.

RESULTS: A total of 616, 452, and 446 students in grades 1–4, 5–7 and 8–10, respectively, were registered with a positive SARS-CoV-2 test during the study period, when the α-variant dominated. A statistically significant reduction in postintervention trends was observed for grades 1–4 (coefficient −1.26; 95% confidence interval (CI), −2.44 to −0.09). We did not observe any statistically significant between-group differences in postintervention trends between grades 1–4 and 5–7 (coefficient 0.66; 95% CI, −1.25 to 2.58) nor between grades 1–4 and 8–10 (coefficient −0.63; 95% CI, −2.30 to 1.04). Findings indicate that keeping schools open with strict IPC measures was equally effective as school closures on reducing student infection rates.

CONCLUSIONS: School closure was not more effective than targeted IPC measures in open schools in reducing student infection rates. Our findings suggest that keeping schools open with appropriate IPC measures should be preferred over school closures, considering the negative consequences closures have on students.

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Dr Rotevatn conducted the data management, performed the analyses, contributed to the interpretation of the results, and drafted the initial manuscript; Dr Elstrøm planned and conducted the data management and analyses and contributed to the interpretation of the results; Drs Surén and Greve-Isdahl contributed to the interpretation of the results; Drs Astrup and Johansen contributed to the interpretation of the results and supervised the work; and all authors conceptualized and designed the study, reviewed and revised the manuscript, and approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

We compared the effects of school closures with school-targeted IPC measures on student coronavirus disease 2019 infection rates in grades 1–10 in Oslo, Norway

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WHAT'S KNOWN ON THIS SUBJECT Both long- and short-term school closures have been implemented to limit spread of SARS-CoV-2 during the pandemic, despite the potentially harmful consequences for students and its poorly studied effectiveness.

WHAT THIS STUDY ADDS We observed that school closure did not lead to additional decrease in student infection rates, compared with open schools with IPC measures in place. Keeping schools open with targeted IPC measures should be preferred over school closures.

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Worldwide, both long- and short-term school closures have been implemented as a measure to limit the spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) during the pandemic.[1,2] However, growing evidence show that school closures have harmful consequences for students, both psychosocially and educationally.[3–7] Hence, the current advise in Europe is that school closures only should be used as a last resort.[7] Even though most countries have reopened schools, many children still have less physical learning due to quarantines, part time digital learning, and school closures during outbreaks.[1,2,8]

Although frequently used, the effectiveness of school closures is debated. Some publications indicate that school closures can contribute to a reduction in SARS-CoV-2 transmission, with the largest impact occurring when closing secondary schools and higher education.[7] However, the effects of school closures appeared larger during the first wave than during later waves, which may be related to implementation and adherence of better and more appropriate infection prevention and control (IPC) measures.[7]

In Norway, schools have largely been kept open after an initial period during the first wave in March 2020, when schools were closed for 6 weeks. The mainstay of pandemic management in Norway has been widespread use of testing, isolation, contact tracing and quarantine.[9] In addition, schools were provided with specific IPC guidelines.[10,11] To allow flexibility to adapt measures to the local epidemiologic situation, the guidelines were built on a 3-tier traffic light model. The model has 3 levels; the main difference relating to physical distancing measures. Green level implies a near normal situation; yellow level implies intermediate measures, with cohorts equaling normal classes; and red level means strict measures

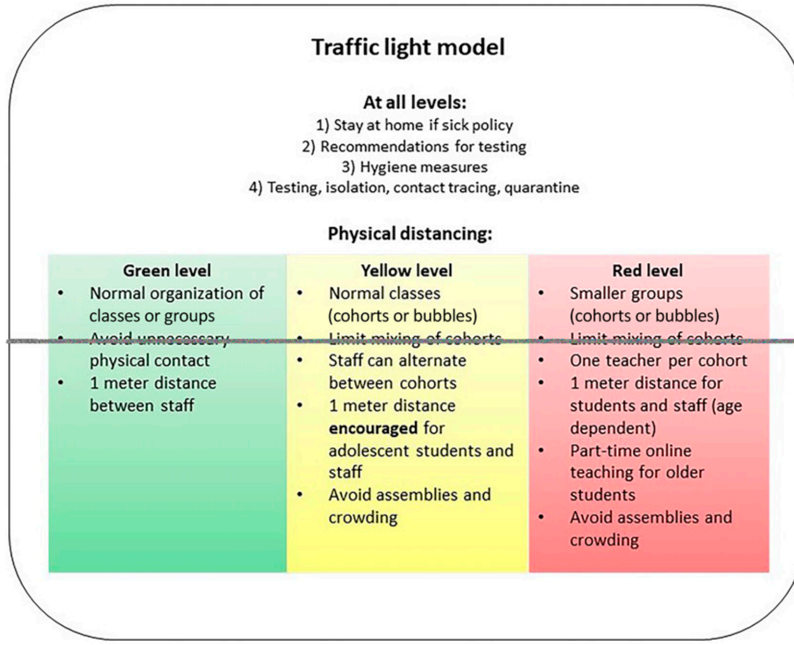

FIGURE 1
The traffic light model. The traffic light model has 3 levels of measures: green, yellow, and red. The main difference between the levels is distance recommendations and cohort sizes. When on red level, stricter distance requirements and small cohorts necessitates part-time digital education for older students. Face masks have been in limited use for staff only.

and smaller cohorts (Fig 1). All levels have hygiene measures. The strict interventions on red level necessitate part-time digital teaching for older students. Face masks have been in very limited use for staff and older students in areas with high ongoing community transmission only.

Although not recommended, short-term and longer-term school closures, involving full-time digital teaching, were still practiced in individual schools and municipalities in Norway during periods with high incidence. The Norwegian capital, Oslo, and surrounding municipalities have seen the highest community infection rates nationally throughout the coronavirus disease 2019 (COVID-19) pandemic. These areas were also most affected during the third wave where the alpha variant dominated, starting in February 2021 and peaking in mid-March. At this time, vaccination had only started for elderly, high risk groups and health care workers. As a response, Oslo implemented the red level of the traffic light model in schools (grades 1–10) in all 15 boroughs on March 10. One week later, on March 17, Oslo decided to close schools for children in grades 5–10 in the 7 boroughs with highest infection rates (Grorud, Stovner, Alna, Bjerke, Gamle Oslo, Grünerløkka, and Søndre Nordstrand). By employing a quasi-experimental interrupted time-series design, we used this situation to compare the effects of the different approaches on student infection rates. We compared the effect of attending open schools with strict IPC measures (red level) and small cohorts (grades 1–4) to digital teaching without school attendance (school closure for grades 5–10).

METHODS

Data

The study used data from the Norwegian COVID-19 emergency preparedness register, Beredt C19, which consists of a compilation of registries with information about the Norwegian population.[12] From within Beredt C19, we obtained demographic information from the National Population Registry, date of positive tests for SARS-CoV-2 from the Norwegian Surveillance System for Communicable Diseases (MSIS), school organizational numbers to identify school affiliation from the National Education Database from Statistics Norway, and data on all registered tests for SARS-CoV-2 (polymerase chain reaction and antigen tests) from the MSIS Laboratory Database. Data were linked at the individual-level using a unique national identity number, which is provided to all residents at birth or when reporting immigration.

Population

Eligible students were children in grades 1–10 who resided in the boroughs of Grorud, Stovner, Alna, Bjerke, Gamle Oslo, Grünerløkka or Søndre Nordstrand, and who were registered in MSIS as SARS-CoV-2 positive between February 15 to April 18, 2021. Students were identified based on birth year (born between 2005 and 2014), as children usually enter school the year they turn 6. The start of the study period reflects the beginning of an infection wave and runs until schools reopened.

Variables

Exposure

The main exposure was whether students were exposed to school closure, which implied full-time digital education from home only (grades 5–10). The control group attended a school that was kept open on red level (grades 1–4). Younger students from eligible boroughs, rather than peers from other boroughs, were selected as controls due to demographic differences across boroughs. Table 1 presents living condition indicators for the included boroughs and for Oslo in total. Red level involved small cohorts with teachers assigned to each cohort and an avoidance of contact between cohorts. Cohorts on red level generally consisted of 15 to 20 students in grades 1–4 and 20 to 25 students in grades 5–10. On red level, periodic part-time digital education could be offered to older students (grades 5–10), but not to younger students (grades 1–4). Within cohorts, distance (1 m) was recommended for older students (grades 8–10) and staff, if possible and appropriate. All grades were subjected to yellow level during the preintervention period between February 15 and March 10. Figure 2 presents a timeline of implemented measures across groups during the study period.

TABLE 1 Living Condition Indicators For the Included Boroughs and For Oslo in Total.

Indicator	Included Boroughs	Oslo in Total
Proportion of population with immigrant background[a]	34	26
Population with ≤10 y education[b]	26	17
Population not completed upper secondary school, aged 21–29 y[b]	30	24
Unemployed population, aged 30–59 y[b]	27	21
Proportion of crowded households[b]	15	13
Low-income households with children <18 y[c]	17	11
Population with disabilities[d]	17	13

Numbers are proportion of population (%). Data are obtained from Oslo Municipality websites (https://bydelsfakta.oslo.kommune.no/) and origins from Statistics Norway (https://www.ssb.no/en). Immigrant background is defined as people born outside of Norway who have 2 foreign-born parents and 4 foreign-born grandparents. Crowded households are defined as households where (1) the number of residents exceeds the number of rooms (excluding kitchen, bathroom, hallway etc.) or where 1 resident lives in a 1-bedroom apartment and (2) each resident has less than 25 m^2.

[a] Numbers are from 2021.
[b] Numbers are from 2020.
[c] Numbers are from 2019.
[d] Numbers are from 2018.

Outcome

The age-adjusted number of SARS-CoV-2 cases per 100 000 was set as the main outcome to study between-group differences in student infection rates.

Analysis

First, we plotted the total number of SARS-CoV-2 cases in Oslo against the number of new cases per 100 000, per week, to obtain an overview of the epidemiologic situation during the study period. Second, we identified infection clusters in schools registered in the eligible boroughs to study patterns in how infections clustered within schools before and after implementation of measures. An infection cluster was defined as 3 or more positive COVID-19 cases registered in MSIS among children from the same birth cohort at the same school over a period of 14 days. The cluster continued growing until 14 days without new cases had passed. Furthermore, we calculated test activity and share of positive tests to study between-group differences in testing rates in the study period, as differences in testing rates could affect the results of the main analysis. Testing activity was calculated based on all tests registered in the MSIS Laboratory Database by dividing the number of registered tests with the number of children from the eligible birth cohorts registered as residents in the eligible boroughs. Tests taken by the same individual with less than 7 days apart were excluded.

The main analysis was performed using interrupted time-series regression models.[13] Here, we

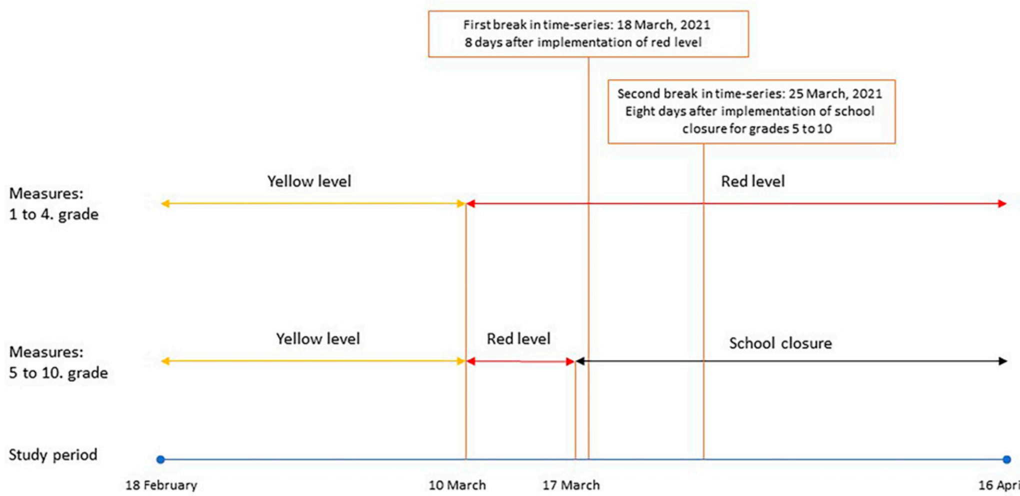

FIGURE 2
Timeline of implemented measures across groups between February 18 and April 16, 2021.

compared trends in infection rates in the period after implementing red level and school closure to what the trends would have been if trends continued at the same level as before interventions were implemented. Red level was implemented for all grades 1 week before school closure was implemented for grades 5–10, which is why we introduced 2 interruptions in the model: (1) 8 days after red level was implemented in all grades (March 18) and (2) 8 days after school closure was implemented in grades 5–10 (March 25). This was done to rule out effects of red level from the period with school closure. Interruptions were set 8 days after the actual implementation date, as we expected a delay in effects. We adjusted the postintervention infection trend in students subjected to school closure with the corresponding trend observed in students subjected to red level, to study whether school closure had any additional effects on infection rates than the effect observed for children exposed to red level only. Grades 5–7 and 8–10 were handled separately in all analyses even though they were equally exposed to school closures, as these grades are normally situated in different schools.

Statistical analyses were performed using R Statistical Software (version 3.6.2) and Stata version 17.0 (StataCorp, College Station, Texas, USA). The Stata package was used to conduct interrupted time-series analysis.[13]

Ethics

The emergency preparedness register, BEREDT C19, was established according to the Health Preparedness Act §2-4,[14] and the project was approved by the Ethics Committee of South-East Norway (March 9, 2021, #198964).

RESULTS

Table 2 gives an overview of the sampled population. A total of 1514 eligible children were registered with a positive SARS-CoV-2 test during the study period. Of these, 616 attended grades 1–4, 452 grades 5–7, and 446 grades 8–10. The infection prevalence in the study population during the study period was 4.7%, while the corresponding number for the total population in the eligible boroughs was 2.9%. The same number was 2.0% for the total population in all of Oslo. The incidence (number of new cases per 100 000) among students in grades 1–7 peaked in week 10 before steadily decreasing, while the peak occurred 1 week

TABLE 2 The Number of Students and Covid-19 Cases, Prevalence During the Study Period (February 18 to April 16), and the Number of Schools in Eligible Boroughs

	Grades			
	1–4	5–7	8–10	Total
Number of students[a]	13 308	9661	9060	32 029
Number of cases	616	452	446	1514
COVID-19 prevalence (%)	4.6	4.7	4.9	4.7
Number of schools	–	–	–	68[b]

[a]The number of children, according to Statistics Norway, who were registered as residents in the boroughs Grorud, Stovner, Alna, Bjerke, Gamle Oslo, Grunerløkka, and Søndre Nordstrand on the December 31, 2020.
[b]This includes 43 primary schools (grades 1–7), 16 lower secondary schools (grades 8–10), and 9 combined schools (grades 1–10).

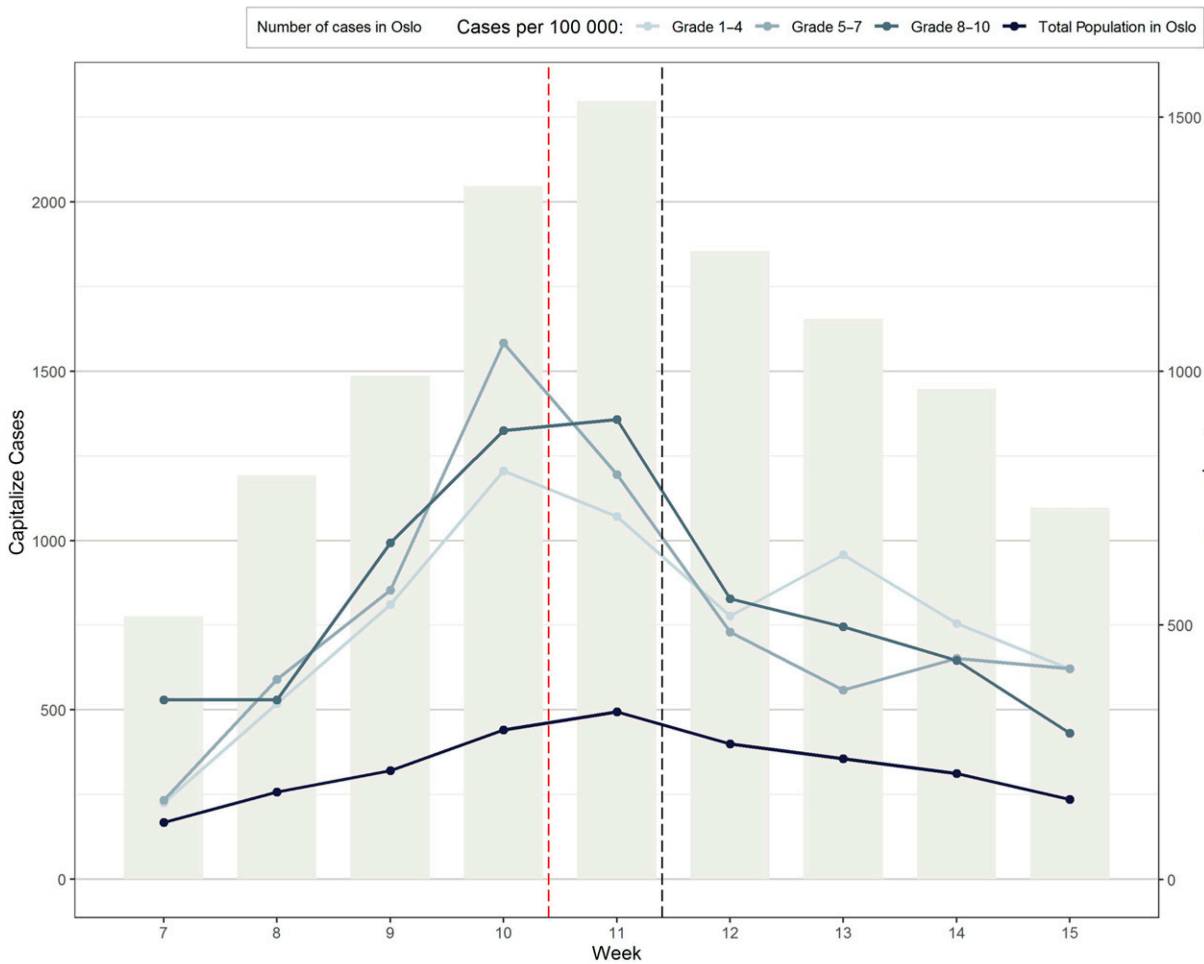

FIGURE 3

The number of COVID-19 cases in Oslo and the number of cases per 100 000 per week in the study population during the study period. The red and black dashed line represent the time of implementation of red level for all students (March 10) and school closure for grades 5–10 (March 17). Schools were closed in week 13 due to the Easter holiday.

later both among the older students (grades 8–10) and the general population in Oslo (Fig 3).

We registered 160 infection clusters during the study period, of which 66 (41%) were registered in grades 1–4, 46 (29%) in grades 5–7, and 48 (30%) in grades 8–10. The number of infection clusters peaked in week 9 for grades 1–7, and in week 10 for grades 8–10 (Supplemental Fig 6), 1 week earlier than the incidence peak in the respective age groups. The number of infection clusters subsequently decreased and largely followed the trend of the infection rates.

During the study period, the MSIS Laboratory Database registered 25 158 SARS-CoV-2 tests taken from eligible students in the study population. Of these, 11 199 (45%) were tests from children in grades 1–4, 6629 (26%) from children in grades 5–7 and 7330 (29%) from children in grades 8–10. Test activity peaked for all groups in week 10 (Supplemental Fig 7). After introduction of red level (week 10) and school closure (week 11), test activity rapidly declined. It was particularly low in children in grades 5–10 following school closure. The proportion of positive tests increased in parallel to the reduction in test activity. Correspondingly, we observed a particularly high positive proportion for these age groups (grades 5–10) from week 13 and onward.

In the main analyses we compared infection trends in grades 5–7 and 8–10 (school closure) to trends in grades 1–4 (red level). We observed no statistically significant differences in preintervention trends (February 15 and March 17) between groups (Table 3, Figs 4 and 5). Similar results were observed for the period between March 18 and 24, where we evaluated effects of red level in all

TABLE 3 Results (Coefficients and 95% CI) Obtained From the Interrupted Time Series Model Estimating Infection Trends.

	Coefficient	95% CI
Grades 5–7 (school closure) vs 1–4 (red level)		
Differences in trends before March 18	1.60	−0.32 to 3.51
Trend for children in grades 1–4 after March 25	−1.26	−2.44 to -0.09
Trend for children in grades 5–7 after March 25	−0.60	−2.11 to 0.92
Differences in trends after March 25	0.66	−1.25 to 2.58
Grades 8–10 (school closure) vs 1–4 (red level)		
Differences in trends before March 18	0.35	−1.67 to 2.36
Trend for children in grades 1–4 after March 25	−1.26	−2.44 to -0.09
Trend for children in grades 8–10 after March 25	−1.89	−3.08 to -0.71
Differences in trends after March 25	−0.63	−2.30 to 1.04

The table shows results from the period before March 18 and after March 25 for students in grades 1–4, 5–7, and 8–10.

grades (grades 5–7 vs 1–4: coefficient −8.43; 95% confidence interval (CI), −25.16 to 8.29, grades 8–10 vs 1–4: coefficient, −6.71; 95% CI, −24.79 to 11.37). We did observe a statistically significant reduction in infection rates in the period after March 25th in grades 1–4. We also observed a similar reduction in infection rates in grades 8–10, but not in grades 5–7, when adjusting for the trend in grades 1–4. However, we did not observe any statistically significant between-group differences in trends in the period after March 25th when comparing trends in grades 5–7 and 1–4, or when comparing trends in grades 8–10 and 1–4. In sum, we could therefore not find any signs of any additional effects of school closure on student infection rates in comparison with the effect measured at red level.

DISCUSSION

This natural experiment showed that school closure did not lead to a further reduction in infection rates than did school attendance with stringent IPC measures (red level). We observed a statistically significant reduction in cases per day after schools went from yellow to red level, which is a strong indication that targeted IPC measures can effectively limit

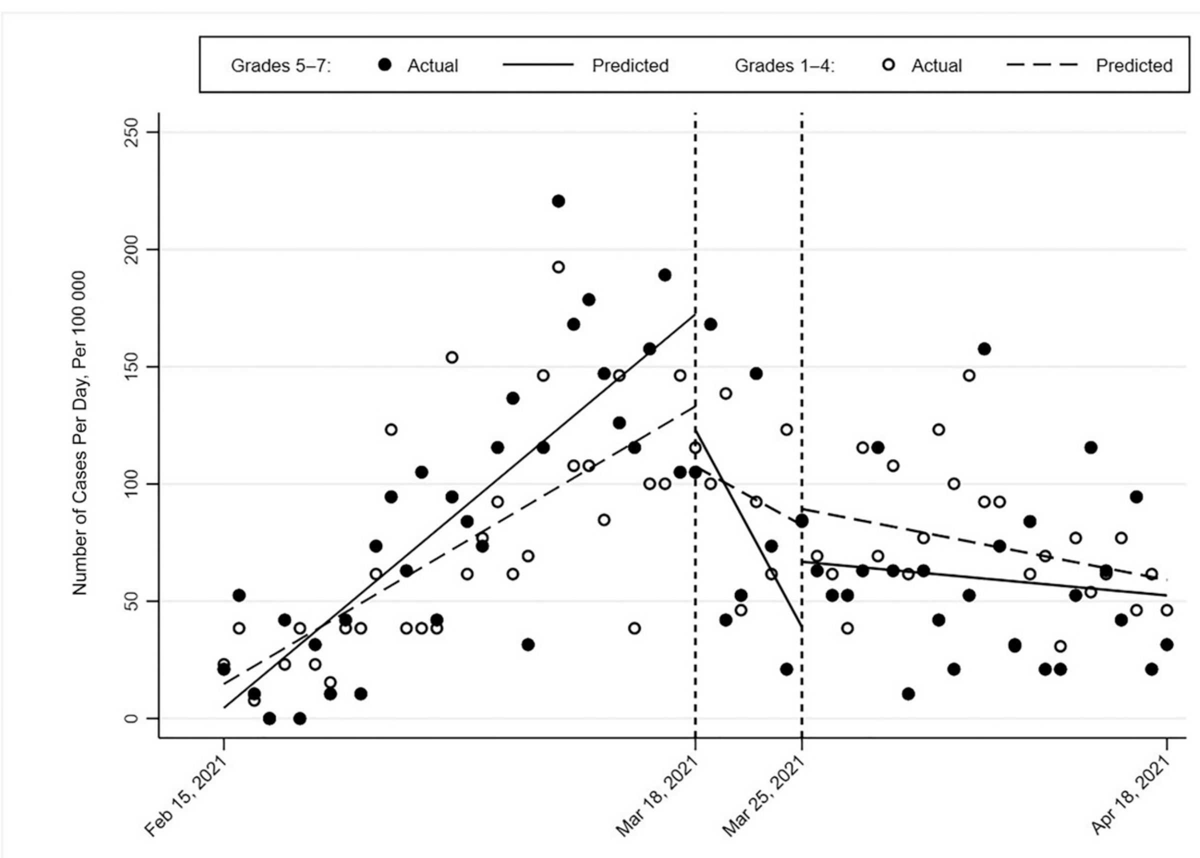

FIGURE 4
Incidence (cases per 100 000) and infection rate trends in grades 5–7 and grades 1–4 in the study population during the study period. Interruptions in time series were made 8 days after implementing red level for all grades (March 18) and school closures for grades 5–7 (March 25).

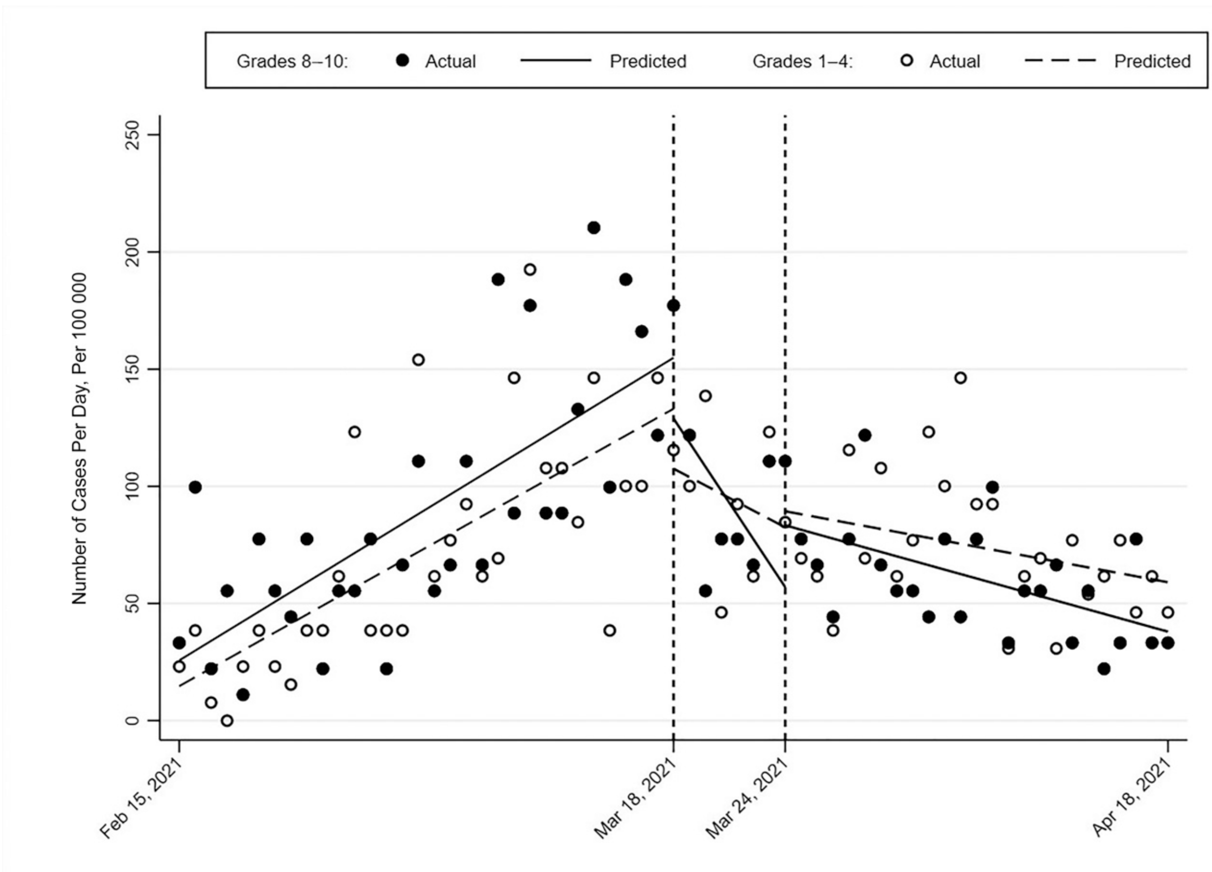

FIGURE 5
Incidence (cases per 100 000) and infection rate trends in grades 8–10 and grades 1–4 in the study population during the study period. Interruptions in time series were made 8 days after implementing red level for all grades (March 18) and school closures for grades 5–7 (March 25).

transmission of SARS-CoV-2 in schools during periods and in areas with high infection rates. The same trend was observed for the number of new infection clusters, as we observed a considerable decrease in the number of clusters after implementation of red level and school closure. For grades 1–4, the number of clusters increased again during Easter vacation (week 13) and the week after, but this was only temporary. Overall, susceptibility and transmissibility of the virus seems to be lower in children than in older age groups,[7,15,16] and our findings support that it can be safe to keep schools open if appropriate IPC measures are in place. Also, taking the negative consequences of school closures into account,[3–7] implementation of targeted IPC measures should be preferred over school closures.

Previous studies have reported varying effects of school closures. Half of the studies with the lowest risk of bias in a systematic review from July 2021 reported that school closures were associated with reductions in transmission, while the other half reported no such effects.[17] The isolated effects of school closure and targeted IPC measures are generally hard to quantify, as other nonpharmaceutical intervention (NPI) measures are typically implemented in the general public at the same time. This was also the case in Oslo, where a partial lockdown (including a ban on social gatherings and mass gatherings, closed shops, services and restaurants) was already in place when red level and school closure was implemented. These measures came in addition to the national policies, such as staying at home when sick, hygiene measures and active contact tracing and testing strategy.[9] The community measures were similar for all student groups in our study. Therefore, we believe that the effects of these measures did not substantially affect our findings. On the other hand, school-targeted measures alone cannot be credited for the reduction on infection rates observed in this study. Our findings support existing recommendations that community NPI measures must be in place in addition to school-targeted measures when community transmission rates are high, to reduce transmission in school children.[15,18,19]

It is well documented that school closures have profound negative consequences for students' learning, well-being, and mental health.[3–5, 20] A recent Dutch study showed that primary school students experienced a learning loss equivalent to the period that schools remained closed with only digital education during spring 2020.[6] The loss was even greater in students from less-educated homes, illustrating that school closure may widen existing socioeconomic gaps in learning outcomes. Another negative consequence of school closure observed in our study was impact on test activity. We observed reduced testing rates after implementation of red level and even further reduction for children in grades 5–10 after implementation of school closure. Lower testing rates were accompanied by high proportions of positive tests. Reduced testing rates and high proportion of positive tests was probably an indication of a higher number of undetected infections. When schools are open, students are more accessible for testing and effective contact tracing, which again gives better access to contract tracing within affected households. The experience from Oslo indicates that keeping schools open is important to reach all inhabitants and especially, to detect cases in hard-to-reach groups.[21]

Despite the vague evidence base for school closure effectiveness, as well as the well-documented negative consequences, school closure may still be indicated in certain situations,[7] such as when large numbers of staff members and students are in quarantine or when experiencing large outbreaks. In these cases, it is vital to ensure that children receive digital education and individual follow-up, and that the closure is limited to as few classes or schools and as short duration as possible. When reopening, targeted IPC measures should be in place. At the time of the study period, the majority of students and staff was not yet offered vaccination. As vaccine uptake in the population increases, this is an important factor to consider when deciding necessary mitigation measures in schools and in the society in periods and areas with high infection rates.

Strengths and Limitations

Data applied in this study was not collected solely for the study purpose, and application of the data may therefore be associated with some limitations. First, we did not have data describing where the students were infected, hence we could not study effects only related to transmission happening at school. Previous studies indicates that most students are infected at home or in other social settings outside of school,[15,22] rather than at school,[15,23] which gives additional support to keep schools open. Second, we did not have specific information on the epidemiologic link between cases in infection clusters identified through the register-based surveillance system. We defined clusters based on common school- and birth cohort affiliation. Lack of this information may have led to an overestimation of number of clusters, as some clusters probably occurred due to transmission outside of school.

We used a simple regression model without covariates to study our aim, which may potentially have introduced bias. However, we do believe that the risk of selection bias is low, as we compared highly similar groups from the same geographical area. Furthermore, potential between-group differences due to age were ruled out by using an age-adjusted outcome.

Due to complexity, we did not introduce information on when other community-targeted measures were implemented into the model. Community-targeted measures introduced before and during the study period may have affected intervention effects.[24] However, we do not believe that this has changed our main findings, as all student groups were equally affected by these broader community-targeted measures. Furthermore, the decrease in test activity observed after implementing strict measures may have led to detection of fewer cases and a decrease in case detection could potentially increase the risk of type II error. However, we do believe that the considerable size of the study population and the number of cases included give us sufficient power to draw valid conclusions. Also, the strategy of testing, isolation, contact tracing and quarantine was strongly embedded as a national strategy during the study period, and testing was free and relatively easy to access. All test results were reported to the MSIS Laboratory Database, which is why we altogether believe our data material had a high degree of completeness. In addition, reporting communicable diseases, including COVID-19, to MSIS is mandatory in Norway,[25] which ensures a high-quality surveillance system that furthermore reduced the risk of reporting bias.

Finally, we cannot draw conclusions for other school levels or areas based on data presented here, and future studies need to test whether our results are transferrable to other settings. Yet, our findings are in keeping with observations from other municipalities in Norway.[26]

CONCLUSION

School closure was not more effective in reducing student infection rates than keeping schools open with specific school-targeted IPC measures in areas and periods with high community transmission of SARS-CoV-2. Our findings suggest that keeping schools open with measures is the best choice in such situations. This knowledge can aid decision makers in selecting appropriate school-targeted IPC measures, which in these situations should be combined with mitigation measures in society at large.

ABBREVIATIONS

CI: confidence interval
SARS-CoV-2: severe acute respiratory syndrome coronavirus 2
IPC: Infection prevention and control
MSIS: the Norwegian Surveillance System for Communicable Diseases
NPI: nonpharmaceutical intervention

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