*Clinical Infectious Diseases*

MAJOR ARTICLE

# Reopening Schools and the Dynamics of Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) Infections in Israel: A Nationwide Study

**Ido Somekh,[1,2] Tamy Shohat,[2] Lital Keinan Boker,[3,4] Eric A. F. Simões,[5] and Eli Somekh[2,6]**

[1]Department of Pediatric Hematology Oncology, Schneider Children's Medical Center of Israel, Petah Tikva, Israel; [2]Sackler Faculty of Medicine, Tel Aviv University, Tel Aviv, Israel; [3]Israel Center for Disease Control, Israel Ministry of Health, Ramat Gan, Israel; [4]School of Public Health, University of Haifa, Haifa, Israel; [5]University of Colorado School of Medicine, Aurora, Colorado, USA; and [6]Department of Pediatrics, Mayanei Hayeshuah Medical Center, Bnei Brak, Israel

***Background.*** Benefits of school reopening must be weighed against the morbidity and mortality risks and the impact of enhancing spread of coronavirus disease 2019 (COVID-19). We investigated the effects of school reopening and easing of social-distancing restrictions on dynamics of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infections in Israel between March and July 2020.

***Methods.*** We examined the nationwide age-wise weekly incidence, prevalence, SARS-CoV-2 polymerase chain reaction tests, their positivity, COVID-19 hospitalizations, and associated mortality. Temporal differences in these parameters following school reopening, school ending, and following easing of restrictions such as permission of large-scale gatherings were examined.

***Results.*** Incidence of SARS-CoV-2 infections gradually increased following school reopening in all age groups, with a significantly higher increase in adults than children. Higher rate ratios (RRs) of sample positivity rates 21–27 days following school reopening relative to positivity rates prior to openings were found for the age groups 40–59 (RR, 4.72; 95% CI, 3.26–6.83) and 20–39 (RR, 3.37 [2.51–4.53]) years, but not for children aged 0–9 (RR, 1.46 [.85–2.51]) and 10–19 (RR, .93 [.65–1.34]) years. No increase was observed in COVID-19–associated hospitalizations and deaths following school reopening. In contrast, permission of large-scale gatherings was accompanied by increases in incidence and positivity rates of samples for all age groups, and increased hospitalizations and mortality.

***Conclusions.*** This analysis does not support a major role of school reopening in the resurgence of COVID-19 in Israel. Easing restrictions on large-scale gatherings was the major influence on this resurgence.

**Keywords.** COVID-19; SARS-CoV-2; children; schools; reopening.

While the coronavirus disease 2019 (COVID-19) pandemic has been controlled in many countries by lockdowns and potentially early school closings [1], the effect of school closing on reducing severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) spread is less clear [2–4]. Potential reasons include low rates of infection in children [5–7], less severe symptoms [8–10], and lower rates of intrafamily infection than adults [11–14]. Nonetheless, US data suggest that school closure might have prevented up to 128 SARS-CoV-2 infections per 100 000 population and 1.5 fewer deaths per 100 000 population during the lockdown [15], and proactive school closures in China might have reduced the peak incidence by 40–60% [16].

In contrast to the rapidity of closing schools in most countries of the world, reopening has been a challenge in many countries. The benefits of school reopening for students' academic development, social interactions, social equity, and physical fitness are well documented [17]. Nevertheless, the potential impact on public health and economics has tempered widespread reopening of schools [17, 18]. Frameworks for reopening of schools have been drafted by international organizations and countries with differing recommendations, reflecting this current challenge [19–22].

During 2 major waves of COVID-19 in Israel, in March–July 2020, schools were closed (14 March) and later partially and finally completely reopened (3 May and 17 May, respectively). As is routine in Israel, high schools and elementary schools ended the academic year on 19 June and 30 June, respectively. This study examined the dynamics of COVID-19 resurgence in Israel in light of school reopening, school ending, and the easing of social restrictions.

## METHODS

### Data Sources

#### *SARS-CoV-2 Polymerase Chain Reaction Tests*

Data on the daily number of tests performed on the populace were obtained from several public national data sources (the sources of information are detailed in Supplementary Material A).

Received 26 October 2020; editorial decision 12 January 2021; published online 18 January 2021.

Correspondence: E. Somekh, Mayanei Hayeshuah Medical Center, 17 Povarski St, Bnei Brak 51544, Israel (esomekh@gmail.com).

**Clinical Infectious Diseases® 2021;73(12):2265–75**



DOI: 10.1093/cid/ciab035

### *COVID-19 Cases*

Daily counts of COVID-19 cases and fatalities attributed to COVID-19 were obtained from Ministry of Health reports and sites [23]. Indications for SARS-CoV-2 polymerase chain reaction (PCR) testing are detailed in Supplementary Material *A*.

### *Population*

The age-specific breakdown of the Israeli population was obtained from the Israel Central Bureau of Statistics [24]. For purposes of analysis the population was stratified into 2 pediatric/adolescent groups aged 0–9 and 10–19 years and 3 adult groups aged 20–39, 40–59, and 60 years and above, respectively.

### *Relevant Time Periods*

Time periods related to school closure and openings are outlined in Supplementary Material *C*.

### *Learning Conditions and COVID-19 Epidemiology on School Reopening*

During the first stage of school reopening (3 May 2020), children were divided into separate groups who attended school at different times on different days. However, these restrictions were lifted on 17 May; schools were completely reopened resuming all-day in-person learning with instructions to keep social-distancing rules. Children aged older than 7 years were required to wear masks in classrooms and in public areas. Classmates and teachers of SARS-CoV-2–infected pupils or teachers were screened for SARS-CoV-2 regardless of whether they were symptomatic or asymptomatic. Schools were reopened following a substantial decrease in the incidence and positivity rates of SARS-CoV-2 PCR tests from the peak in COVID-19 spread observed at the end of March 2020.

### Statistical Analysis

Temporal trends of the following parameters were examined: the numbers of SARS-CoV-2 PCR tests; the positivity rates of tests and numbers of hospitalizations and deaths from COVID-19 by age group; the prevalence in the different age groups; the daily and weekly incidence of SARS-CoV-2 PCR positivity (for the total population and for children separately), including incidence adjusted for the number of PCR tests; and the cumulative proportions of COVID-19 cases in children as a proportion of all cases. Adjustment of tests was performed on a weekly basis. For each age group, incidence rate (weekly number of new cases/100 000 population of the specific age group) was multiplied by the proportion of this age group in the general population to the proportion of the samples obtained from individuals of this age group. Data were stratified according to SARS-CoV-2 PCR test results, age groups, and date of testing.

The putative effects of partial and complete school reopening and school ending at the close of the academic year and following easing of restrictions on COVID-19 incidence and positivity rates of tests were examined. These were based on data obtained at days 14–20 and 21–27 days following the implemented measures. Differences in the incidence, prevalence, and positivity rates of tests were analyzed using 2-proportion *z*-tests and chi-square tests. Associations with hospitalizations and mortality were examined 14–27 and 21–34 days, respectively, after each measure was instituted. These data were compared with the weekly mortality when each measure was instituted, and also with the weekly number of hospitalized patients and mortality in the prior week.

We examined the weekly combined number of hospitalized patients classified as moderately and severely ill. This was intended to avoid bias derived from changing definitions of severity during the epidemic, and also excluded mildly ill patients who might have been hospitalized not for medical reasons but to ensure appropriate quarantine measures.

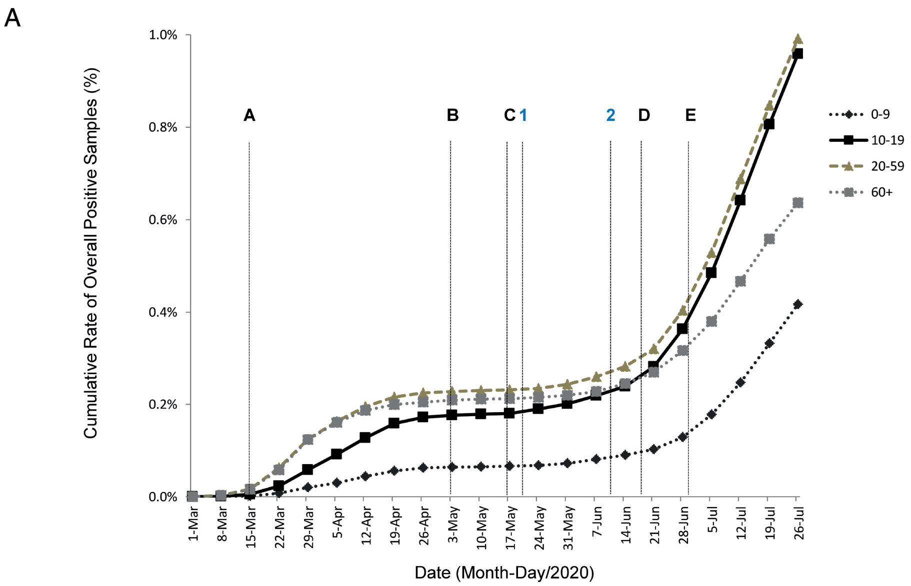
A lag period of 21–34 days between possible exposure and mortality that was based on an average time of 17 days between symptoms and mortality and inclusion of an additional period of 4–6 days for a child who was infected in school to infect an adult was used. This period was extended to a lag time of 34 days to account for the possible effect of several rounds of infection.

Weekly data were used in order to avoid incidental daily fluctuations. Categorical variables were expressed as counts and percentages.

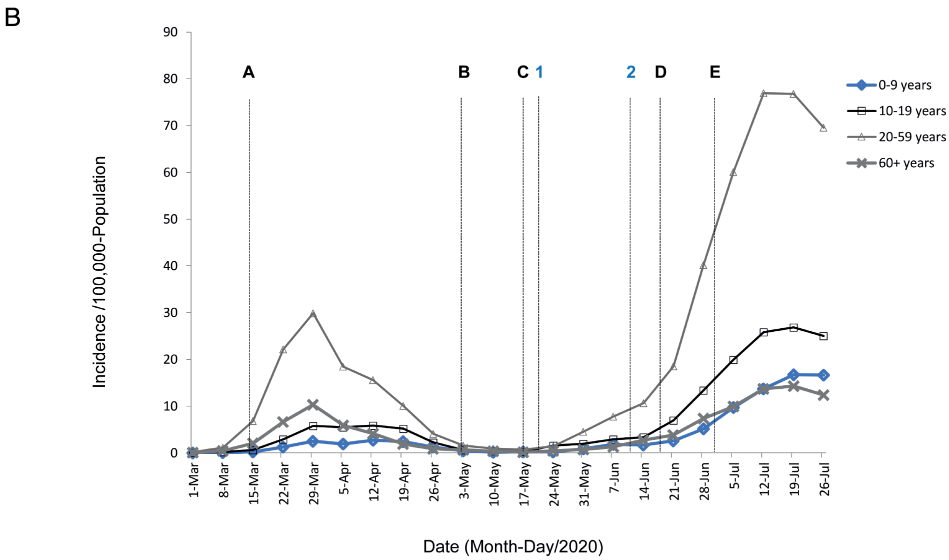
## RESULTS

The incidence rates, adjusted incidence rates (incidence rates adjusted for the number of SARS-CoV-2 tests), and prevalence of SARS-CoV-2 infection gradually increased following complete school reopening in all age groups (Figure 1A–C and Supplementary Tables 1–3). During this period, the number of SARS-CoV-2 PCR tests performed also increased for all age groups, and particularly for the 0–9- and 10–19-year age groups (7.1- and 8.2-fold higher than the reference, respectively) (Figure 1D and Supplementary Table 4). Positivity rates of samples increased gradually following complete school reopening for the adult age groups but not for pediatric age groups. Positivity rate ratios (RRs) of samples obtained 21–27 days following school reopening relative to positivity rates prior to openings were as follows: 1.46 for children aged 0–9 years (95% confidence interval [CI], .85–2.51), .93 for children aged 10–19 years (95% CI, .65–1.34), 3.37 for adults aged 20–39 years (95% CI, 2.51–4.53), 4.72 for adults aged 40–59 years (95% CI, 3.26–6.83), and 2.75 for adults older than 60 years of age (95% CI, 3.26–6.83). A similar trend was observed when analyzing data 14–21 days following reopening (Tables 1 and 2 and Supplementary Table 3).

A single peak of a high rate of SARS-CoV-2 infections was observed at the end of May 2020 in children aged 10–19 years, related to a single cluster of COVID-19 in a high school in



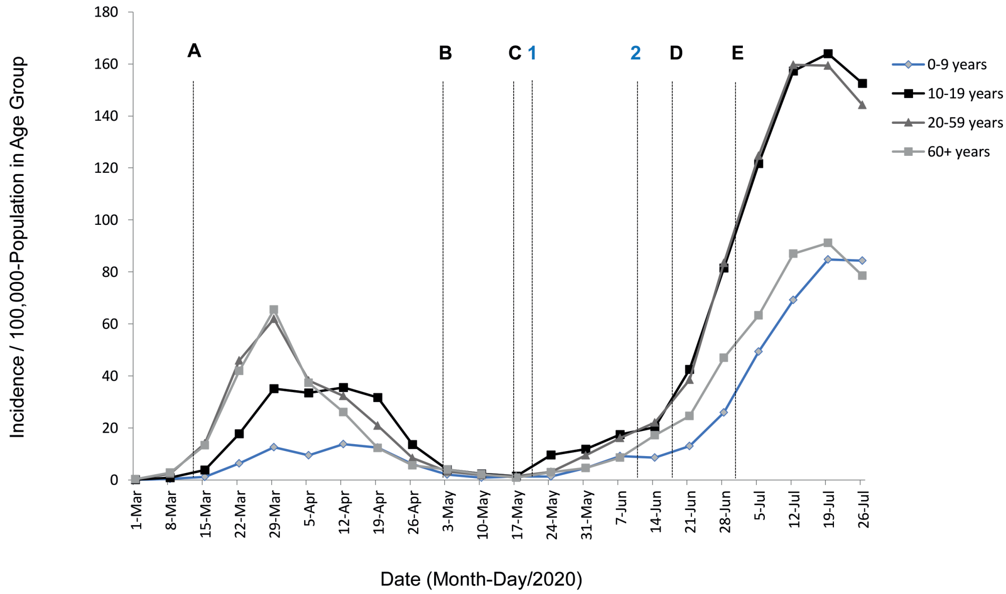

**A** closure of schools (March 14, 2020)
**B** partial reopening of schools (May 3, 2020)
**C** complete reopening of schools (May 17, 2020)
**D** end of academic year in high schools (June 19, 2020)
**E** end of academic year in elementary schools (June 30, 2020)
Dates outlined represent day 1 of the studied week
1 ease of social restrictions; e.g., opening of synagogues and beaches (May 20, 2020)
2 further ease of social restrictions; e.g., permitted gatherings in events of up to 250 people (June 12, 2020)




**A** closure of schools (March 14, 2020)
**B** partial reopening of schools (May 3, 2020)
**C** complete reopening of schools (May 17, 2020)
**D** end of academic year in high schools (June 19, 2020)
**E** end of academic year in elementary schools (June 30, 2020)
Dates outlined represent day 1 of the studied week
1 ease of social restrictions; e.g., opening of synagogues and beaches (May 20, 2020)
2 further ease of social restrictions; e.g., permitted gatherings in events of up to 250 people (June 12, 2020)

**Figure 1.** *A*, Prevalence of SARS-CoV-2, by age. Weekly prevalence rates of COVID-19 were calculated during March–July 2020 in 4 distinct age groups. For each age group, the number of positive samples was divided by its absolute number in the overall population. Major time points, including school closure, reopening, and school ending at the end of the academic year, as well as easing of social restrictions, are noted. *B*, Weekly unadjusted incidence of SARS-CoV-2, by age. The weekly numbers of SARS-CoV-2–positive samples tested during March–July 2020 in the various age groups are shown. The incidence for each age group was calculated per 100 000 population. The "two epidemic waves" of COVID-19 in Israel are depicted, and the lag of new SARS-CoV-2 infections in children compared with adults is demonstrated, following school reopenings. Major time points, including school closure, reopening, and school ending at the end of the academic year, as well as easing of social restrictions, are noted. *C*, Weekly age-group–specific incidence of SARS-CoV-2. The weekly numbers of SARS-CoV-2–positive samples tested during March–July 2020 were calculated for children (aged 0–9 and 10–19 years) and for adults (aged 20–59 and 60+ years), as the number of new weekly SARS-CoV-2 cases per 100 000 of the specific age-group population. The increase in the proportions of children aged 10–19 years infected during the "second wave" is shown. Major time points, including school closure, reopening, and school ending at the end of the academic year, as well as easing of social restrictions, are noted. *D*, Number of SARS-CoV-2 tests performed, by age. The monthly numbers

C




**A** closure of schools (March 14, 2020)
**B** partial reopening of schools (May 3, 2020)
**C** complete reopening of schools (May 17, 2020)
**D** end of academic year in high schools (June 19, 2020)
**E** end of academic year in elementary schools (June 30, 2020)
Dates outlined represent day 1 of the studied week
1 ease of social restrictions; e.g., opening of synagogues and beaches (May 20, 2020)
2 further ease of social restrictions; e.g., permitted gatherings in events of up to 250 people (June 12, 2020)

D

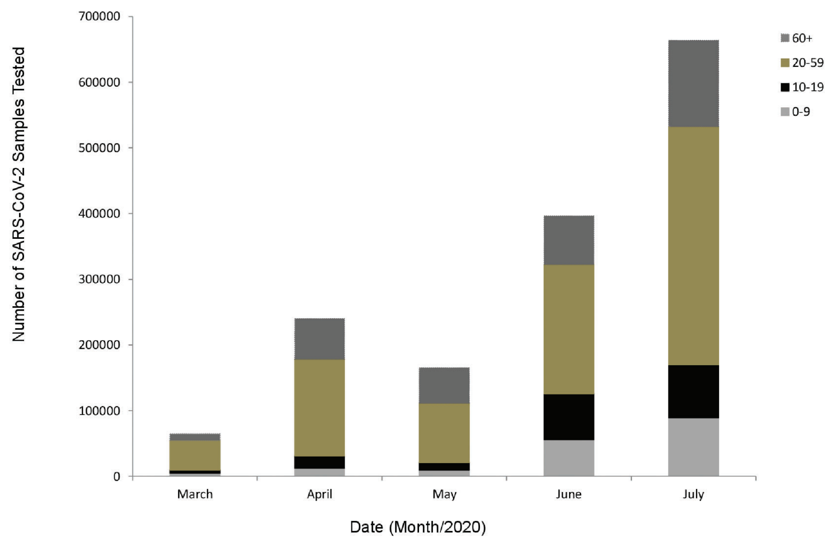



**Figure 1.** Continued.

of SARS-CoV-2 nasopharyngeal swabs tested by PCR are shown for the different age groups during March–July. An increase in testing, particularly in children, is depicted, following school reopenings in May 2020. *E*, SARS-CoV-2 positivity rate of tests, by age. Weekly SARS-CoV-2 positivity rates of samples tested during March–July 2020 are shown. Positivity rates were calculated for each age group as the positive SARS-CoV-2 samples of all samples tested, by week. Major time points, including school closure, general lockdown, school reopening, and school ending at the end of the academic year, as well as easing of social restrictions, are noted. Abbreviations: COVID-19, coronavirus disease 2019; PCR, polymerase chain reaction; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

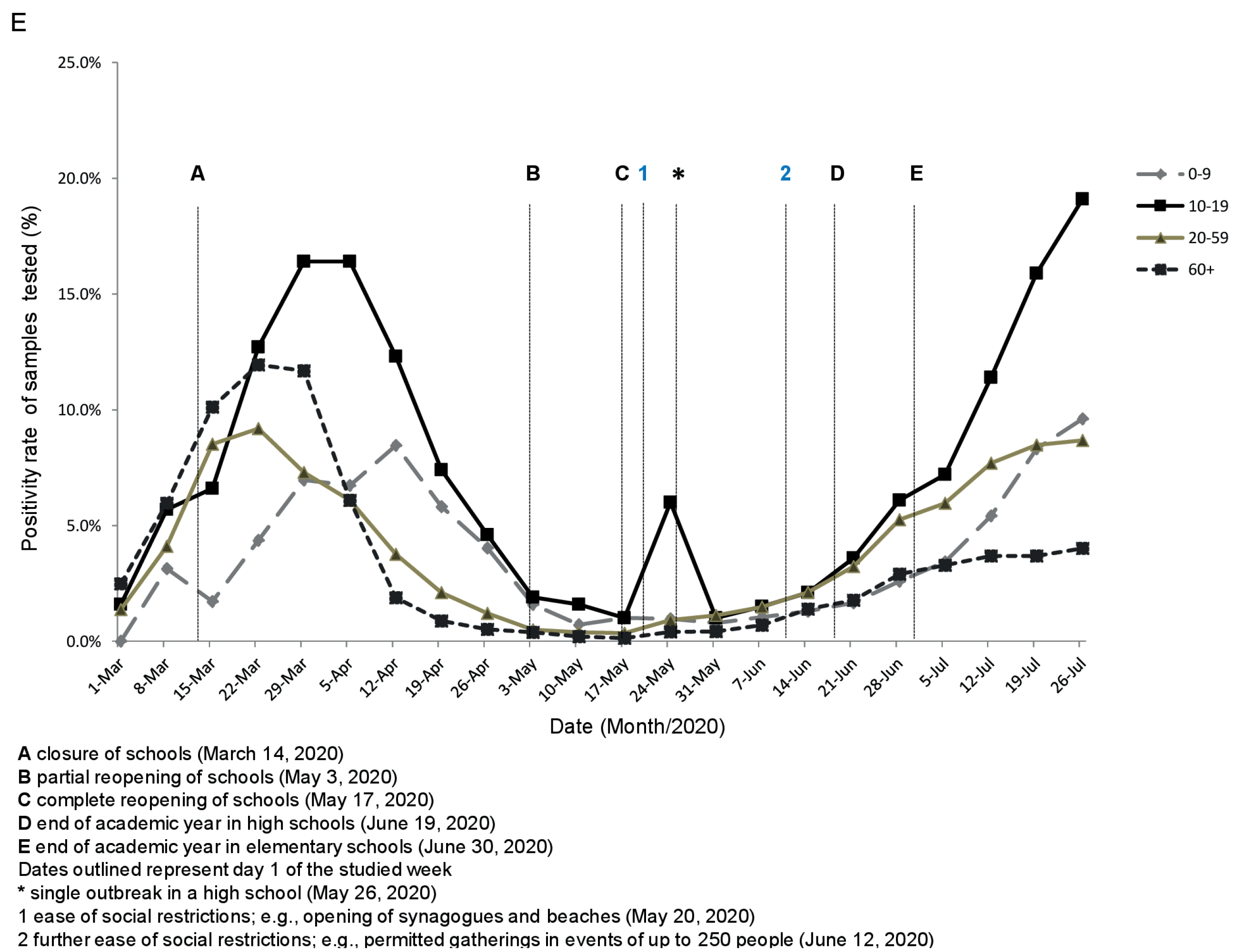



**Figure 1.** Continued.

Jerusalem [25] (Figure 1E and Supplementary Figure 1B). This resulted in a weekly 6% sample positivity from May 24 to May 30 in that age group. However, during the 2 subsequent weeks (31 May–13 June), the proportions of positive samples in children aged 10–19 years were substantially reduced to baseline levels (1.0% and 1.5%, respectively) (Figure 1E and Supplementary Table 3).

Following the identification of the first 2 SARS-CoV-2 cases in a high school in Jerusalem, the school was closed, quarantine instructions were implemented, and all students and staff members were tested for SARS-CoV-2. No additional mitigation protocols were implemented following the reopening of this school after the outbreak. The source of this outbreak has remained unknown [25]. Infection rates in the community were similar to the low rates observed prior to school reopening; however, some increases in incidence rates were noted mainly in adults aged 20–59 years (Figure 1B and 1C).

Adjusted incidence rate ratios (aIRRs) were calculated by comparing the incidence adjusted for the number of SARS-CoV-2 tests performed during the 14–20 and 21–28 days following complete school reopening with the adjusted incidence during the week prior to reopening. The aIRRs increased for all age groups, but mostly in adults. (Figure 2A and 2B and Tables 1 and 2) The increase in aIRR 14–20 days following reopening was most prominent in individuals aged 40–59 (aIRR, 6.22; 95% CI, 3.6–10.7) and 20–39 (aIRR, 5.25 [3.5–7.8]) years. The smallest increase was observed in children aged 0–9 (aIRR, 2.2 [1.56–3.11]) and 10–19 (aIRR, 1.29 [.94–1.76]) years. Higher aIRRs were also demonstrated in adults compared with children 21–28 days following school reopening (Figure 2B and Tables 1 and 2).

Increases in all the above-mentioned parameters (eg, incidence, prevalence, number of samples tested, and their positivity rates) were observed for all age groups after school ending at the close of the academic year (Figure 1A–C, Figure 2C, and Supplementary Table 5). It should be mentioned that school endings occurred in conjunction with the relaxation of social restrictions. The highest increments following school ending were in children aged 10–19 years (Supplementary Table 5). As of 31 July 2020, children aged 0–9 and 10–19 years comprise

Table 1. **SARS-CoV-2 Positivity Rates of Tests and Adjusted Incidence Rate Ratio Following Complete School Opening (17 May)**

| | A. 1–7 Days Prior to Reopening:10–16 May | | B. 14–20 Days Following Reopening: 31 May–6 June | | | | C. 21–27 Days Following Reopening: 7 June–13 June | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Age | Positive/Samples Tested | % | Positive/Samples Tested | % | RR (95% CI)[a] | aIRR (95% CI)[a] | Positive/Samples Tested | % | RR (95% CI)[b] | aIRR (95% CI)[b] |
| 0–9 years | 14/1950 | 0.7 | 78/9853 | 0.8 | 1.1 (.63–1.94) | 2.2 (1.56–3.11) | 158/15 081 | 1.0 | 1.46 (.85–2.51) | 3.51 (2.54–4.85) |
| 10–19 years | 33/2092 | 1.6 | 168/16 431 | 1.0 | .65 (.45–.94) | 1.29 (1.7–2.98) | 250/16 952 | 1.5 | .93 (.65–1.34) | 2.25 (1.69–2.98) |
| 20–39 years | 49/11 169 | 0.4 | 229/19 884 | 1.2 | 2.62 (1.93–3.57) | 5.25 (3.53–7.82) | 396/26 779 | 1.5 | 3.37 (2.51–4.53) | 8.13 (5.52–11.96) |
| 40–59 years | 32/9311 | 0.3 | 167/15 626 | 1.1 | 3.1 (2.13–4.5) | 6.22 (3.61–10.7) | 276/17 568 | 1.6 | 4.72 (3.26–6.83) | 11.1 (6.5–18.7) |
| 60+ years | 35/13 762 | 0.3 | 64/14 739 | 0.4 | 1.7 (1.13–2.58) | 3.42 (1.76–6.69) | 111/15 889 | 0.7 | 2.75 (1.88–4.01) | 6.73 (3.5–12.4) |

Abbreviations: aIRR, adjusted incidence rate ratio (adjusted to number of tests); RR, rate ratio; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

[a]Values in column B compared with A.

[b]Values in column C compared with A.

10% and 19% of all patients with COVID-19, respectively (Figure 2D and Supplementary Table 6).

Following easing of social restrictions undertaken on 20 May (Supplementary Figure 2, Supplementary Material C), RRs to increased SARS-CoV-2 PCR positivity test rates were initially similar to those of school reopening (Supplementary Table 3). However, following the lifting of restrictions on large-scale gatherings on 12 June, increased RRs, aIRRs, and positivity rates were observed in all age groups (Figure 2A and 2B and Tables 1 and 2)

The weekly number of hospitalizations and fatal cases in patients with COVID-19 did not increase following partial and complete school reopening (Supplementary Figures 3 and 4, Tables 3 and 4, Supplementary Tables 7 and 8). The lack of increased mortality was observed even up to 49 days following school reopening (Supplementary Table 7). In contrast, the weekly number of COVID-19 fatal cases significantly increased following high school and elementary school ending for summer vacation (Supplementary Figure 4 and Table 3). Risk ratios were 15.2 (5.5–41.9) and 17.2 (6.3–47.3) following 28–34 days of each measure, respectively. A significant increase in mortality was also observed following a lag time of 21 days (Supplementary Figure 4 and Table 3). No significant increases in mortality and hospitalizations were observed following partial easing of social restrictions on 20 May (Supplementary Tables 7 and 8). However, a significant increase in hospitalizations (rate ratio, 3.95; 95% CI, 3.2–4.8) and in mortality (risk ratio, 4 [1.9–8.3]) occurred at 21–28 days and 28–34 days, respectively, following the permission to attend large-scale social events. A significant increase in hospitalizations and mortality was also observed following a lag time of 14 and 21 days, respectively (Tables 3 and 4 and Supplementary Tables 7 and 8). There were no fatalities among SARS-CoV-2–infected children during the study period.

## DISCUSSION

National data from Israel suggest that school reopening during May 2020 had a limited effect on SARS-CoV-2 infection rate in children and adults, and that it was

Table 2. **SARS-CoV-2 Positivity Rates of Tests and Adjusted Incidence Rate Ratio Following Permitted Large Events (12 June)**

| | A. 1–7 Days Prior to Measure: 5–11 June | | B. 14–20 Days Following Measure: 26 June–2 July | | | | C. 21–27 Days Following Measure:3 July–9 July | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Age | Positive/Samples Tested | % | Positive/Samples Tested | % | RR (95% CI)[a] | aIRR (95% CI)[a] | Positive/Samples Tested | % | RR (95% CI)[b] | aIRR (95% CI)[b] |
| 0–9 years | 131/15 530 | 0.8 | 370/15 832 | 2.3 | 2.77 (2.27–3.38) | 3.11 (2.48–3.92) | 719/23 377 | 3.1 | 3.64 (3.03–4.39) | 5.6 (4.5–6.96) |
| 10–19 years | 226/21 055 | 1.1 | 1019/18 512 | 5.5 | 5.13 (4.45–5.92) | 5.77 (4.77–6.98) | 1551/23 122 | 6.7 | 6.25 (5.44–7.18) | 9.6 (8–11.6) |
| 20–39 years | 339/28 182 | 1.2 | 1806/34 846 | 5.2 | 4.31 (3.84–4.83) | 4.85 (4.04–5.8) | 3120/51 182 | 6.1 | 5.07 (4.53–5.66) | 7.8 (6.5–9.3) |
| 40–59 years | 265/20 320 | 1.3 | 1087/24 951 | 4.4 | 3.34 (2.92–3.82) | 3.8 (3.14–4.5) | 1701/33 998 | 5.0 | 3.84 (3.37–4.36) | 5.99 (4.97–7.02) |
| 60+ years | 109/16 310 | 0.7 | 534/20 036 | 2.7 | 3.99 (3.25–4.9) | 4.5 (3.51–5.74) | 800/24 612 | 3.3 | 4.86 (3.98–5.94) | 7.52 (5.91–9.5) |

Abbreviations: aIRR, adjusted incidence rate ratio (adjusted to number of tests); RR, rate ratio; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

[a]Values in column B compared with A.

[b]Values in column C compared with A.

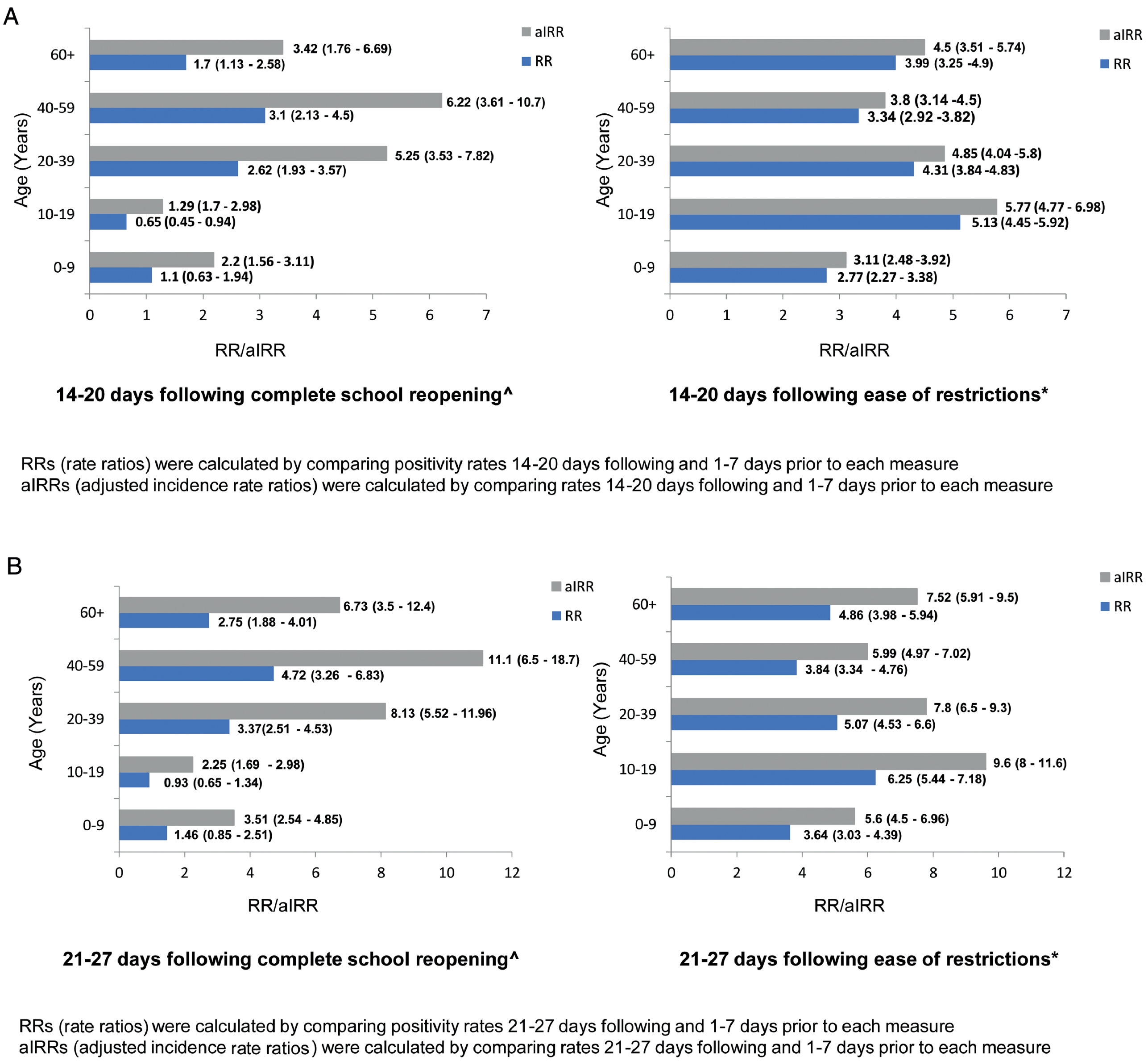
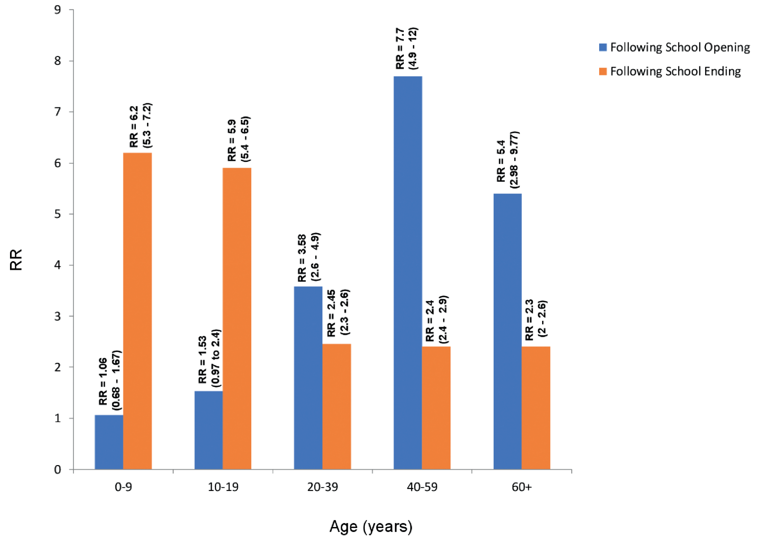


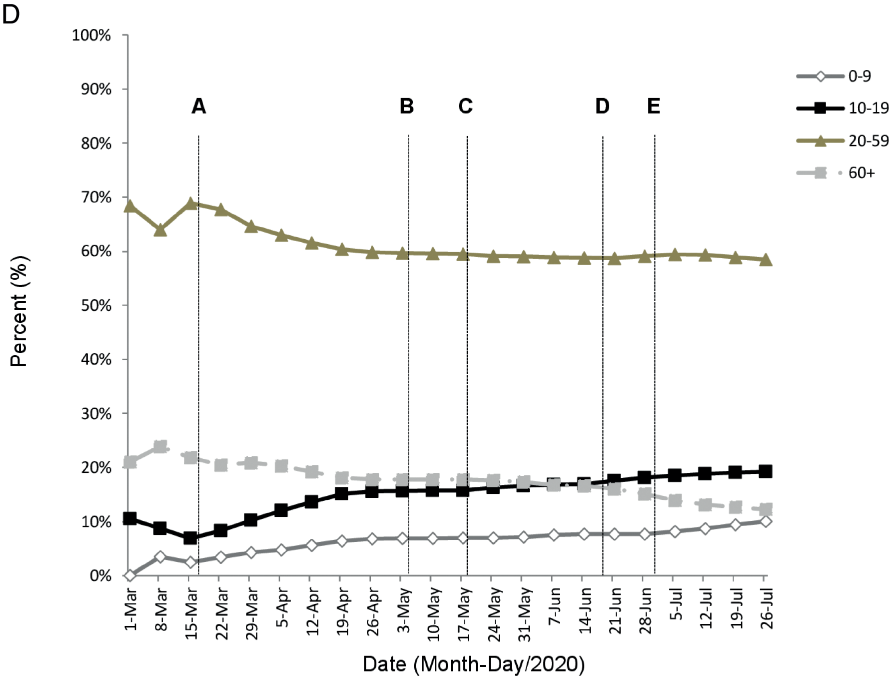

**Figure 2.** *A*, RRs and aIRRs of SARS-CoV-2 infections, 14–20 days following different measures, by age. RRs and aIRRs 14–20 days following complete school reopening (17 May) and permission of large gatherings (12 June) are shown. Increases are depicted in RRs and aIRRs, particularly among adults aged 20–39 years and 40–59 years, following complete school reopening. On the other hand, increases in all age groups, and particularly among 10–19-year-old children, are shown, following permission of large gatherings. RRs were calculated by comparing positivity rates 14–20 days following and 1–7 days before each measure. aIRRs were calculated by comparing rates 14–20 days following and 1–7 days before each measure. *B*, RRs and aIRRs of SARS-CoV-2 infections, 21–27 days following different measures, by age. RRs and aIRRs 21–27 days following complete school reopening (17 May) and permission of large gatherings (12 June) are shown. Increases are depicted as RRs and aIRRs, particularly among adults aged 20–39 years and 40–59 years, following complete school reopening. On the other hand, increases in all age groups, and particularly among 10–19-year-old children, are shown following permission of large gatherings. RRs were calculated by comparing positivity rates 21–27 days following and 1–7 days before each measure. aIRRs were calculated by comparing rates 14–20 days following and 1–7 days before each measure. *C*, RRs of SARS-CoV-2 positivity rate of tests, by age. The RRs of SARS-CoV-2 positivity rate of samples tested following school reopening and ending were calculated for each age group. RRs shown were calculated by comparing positivity rates of tests between 7–13 June and 17–23 May for school reopening, and comparing positivity rates of tests between 26 July–1 August and 19–25 June for school ending. *D*, Cumulative proportions of SARS-CoV-2–infected persons. The cumulative proportions of SARS-CoV-2–infected persons according to age group (of overall infected persons) are shown. An increase in the proportion of infected children is depicted, whereas the proportion of older adults (aged 60+ years) decreased over time. Major time points, including school closure, reopening, and school ending at the end of the academic year, as well as easing of social restrictions, are noted. Children 0–9 and 10–19 years comprise 19% and 16% of the general population in Israel, respectively. ^Complete school reopening (17 May 2020). *Permitted gatherings in events of up to 250 people (12 June 2020). Abbreviations: aIRR, adjusted incidence rate ratio; RR, rate ratio; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

C




RRs following school reopening were calculated by comparing positivity rates of tests during 7-13-June, 2020 and the 17-23-May.
RRs following school ending were calculated by comparing positivity rates of tests during 26- July - 1-August, 2020 and the 19 - 25-June.

D




**A** closure of schools (March 14, 2020)
**B** partial re-opening of schools (May 3, 2020)
**C** complete re-opening of schools (May 17, 2020)
**D** end of academic year in high schools (June 19, 2020)
**E** end of academic year in elementary schools (June 30, 2020)
Dates outlined represent day 1 of the studied week

**Figure 2.** Continued.

not a major contributor to the SARS-CoV-2–attributed mortality. On the other hand, this analysis suggests that easing of restrictions on large-scale gatherings may have been related to the resurgence of the COVID-19 epidemic in Israel and may explain the observed increased mortality.

The prevalence of SARS-CoV-2 infection increased gradually in all age groups following complete school reopening. Due to the high proportion of asymptomatic and mildly symptomatic cases, any analysis of COVID-19 incidence must consider the number of SARS-CoV-2 PCR tests performed.

In contrast to the above, school reopening during May 2020 did not have a significant impact on the positivity rates in children and adolescents. These age groups had the lowest RRs for increased COVID-19–positive rates as well as the lowest aIRRs compared with the weeks before opening. On the other hand, adults in the 40–59- and 20–39-year age groups had the highest RRs and aIRRs. A single-day surge in positivity rates of children aged 10–19 years, due to a cluster in a Jerusalem high school [25], constituted the only exception to this trend. This outbreak could be at least partially related to the temporary lift of restrictions on wearing masks from 19 to 22 May in classrooms and in open spaces in the absence of additional mitigation protocols. However, this cluster was followed by a drop in the positivity rate in this age group to a lower rate than was observed during the period preceding school reopening.

This negative association led us to explore the other well-established potential role of lifting social-distancing restrictions on the epidemic curve.

We found that easing of restrictions related to large-scale gatherings was temporally followed by significantly increased incidence and positivity rates of samples taken from all age groups. This was followed by significant increases both in the number of patients hospitalized in moderate to severe condition and in mortality following a lag period.

Also, individuals aged 20–59 years, and not children, seem to have the leading role in the increasing numbers of COVID-19 infections following school reopening. These findings contrast to those seen in influenza epidemics, in which children had a leading role and their relative risk of infection was higher than that of adults [26, 27]. Nevertheless, school reopening should be accompanied by efforts to reduce crowding and to implement appropriate infection-control practices in the classroom [17, 21]. In addition, schools should probably reopen only when the SARS-CoV-2 epidemic is under control.

The rates of SARS-CoV-2 infection among children in Israel are high compared with those reported in other countries. As of 31 July 2020, the proportions of children aged 0–9 and 10–19 years infected with SARS-CoV-2 in Israel were 9.5% and 19%, respectively [23]. The respective proportions of these age groups in the total population are 19% and 16% [24]. In comparison, according to the European Center for Disease Prevention and Control (ECDC) report, as of 26 July, children made up 4% of cases detected in the European Union/European Economic Area and in the United Kingdom [28]; US data demonstrate that the number of COVID-19 cases in children younger than 18 years has reached 10% of the total for US cases and this age group consists of 22% of the population [29].

The increased SARS-CoV-2 testing in Israel following reopening of schools may account for some of the discrepancy between the countries. Another possible explanation for the high proportion of SARS-CoV-2 detection rates in the 0- to 19-year population in Israel is the high person-to-room ratio among populations with disproportionately high rates of SARS-CoV-2 detection, such as ultraorthodox Jews and Arabs. In addition, young people in Israel, including children, tend to have high degrees of social interaction, which contributes to the high rate of infection.

However, it seems that school attendance per se does not seem to have been a significant explanation for this finding since the relative proportion of SARS-CoV-2–infected children out of the total SARS-CoV-2 cases has not increased during school weeks and did not decrease during school ending.

In the Israeli model of school reopening, all the students were admitted to schools simultaneously. This is in contrast to school openings in Northern Europe where class sizes were limited and teachers were assigned to 1 class at a time whenever possible [30]. Clearly, SARS-CoV-2 did spread in classes and schools in Israel, but this does not seem to have been the major cause for the June–July resurgence in Israel. Our findings regarding the seeming lack of a relation between school reopening during May 2020 and the surge in cases in the community are in agreement with the experience in several countries worldwide [17, 31–35]. and with a recent ECDC perspective [27]. Probably one of the major factors that contributed to the unsubstantial effect of school reopening on COVID-19 resurgence during June–July 2020 was that on May 2020 the epidemic was under control with a low incidence of SARS-CoV-2 infections among all age groups.

Our analysis did not demonstrate any mitigating effect of school ending at the close of academic year on all the parameters examined. Apparently, school closure may reduce the spread of SARS-CoV-2 infection mainly when combined with a lockdown, as recently described [15]. On the other hand, in the absence of a lockdown, children may contract infection during regular and casual social encounters outside schools, while at school, children are expected to be supervised and infection-control measures are encouraged and can be enforced.

The physical conditions in schools in Israel, which are more crowded than most Organization for Economic Co-operation and Development countries, and the lack of cohorting that accompanied full reopening of schools suggest that even under these conditions that would promote the spread of SARS-CoV-2,

Table 3. **Weekly Fatal Cases Following Different Measures**

| Date | Measure | 1–7 Days Prior | 21–27 Days Following | RR (95% CI) | *P* | 28–34 Days Following | RR (95% CI) | *P* |
|---|---|---|---|---|---|---|---|---|
| 3 May | Partial school reopening | 30 | 7 | .23 (.1–.5) | .003 | 11 | .36 (.18–.7) | .005 |
| 17 May | Complete school reopening | 21 | 5 | .2 (.1–.6) | .003 | 5 | .2 (.1–.6) | .003 |
| 20 May | Opening of synagogues and beaches | 13 | 5 | NS | NS | 4 | .3 (.1–.9) | .03 |
| 12 June | Permitted large gatherings | 9 | 26 | 2.9 (1.4–6.2) | .006 | 36 | 4 (1.9–8.3) | <.0001 |
| 19 June | High school ending | 4 | 36 | 9 (3.2–25.3) | < .0001 | 61 | 15.2 (5.5–41.9) | <.0001 |
| 30 June | Elementary school ending | 12 | 57 | 15.2 (5.5–41.9) | < .0001 | 69 | 17.2 (6.3–47.3) | <.0001 |

Abbreviations: NS, nonsignificant; RR, rate ratio.

spread of the virus was not an important factor in the resurgence. These results thus might be translated to other countries where there is cohorting and less classroom crowding.

The main limitation of our study is its ecological design and the possibility that some findings presented here may have been related to other concurrent interventions. Due to the observational design, this study cannot inform causal relationships. Since the demographic, cultural, and socioeconomic features of Israel evidently affect our results, particular attention should be given to such factors in assessing reopening in specific geographic areas.

Another limitation is that the indication for testing may affect the unadjusted incidence among specific age groups. In addition, even incidence adjusted by the number of samples tested could be affected by the testing policies. For these reasons, we examined the putative effects of school reopening and other nonpharmacologic measures by several analyses, namely, incidence adjusted by the number of tests, positivity rates of samples, weekly number of SARS-CoV-2–related hospitalizations, and weekly number of deaths.

The main strength of our study is that it is based on a solid and reliable national database and that its main findings are supported by several lines of evidence, as previously mentioned. In addition, we have used several time periods after each measure examined to increase the sensitivity of the study and to strengthen the reliability of the results.

In conclusion, our findings suggest that school reopening did not have a substantial effect on the SARS-CoV-2 infection rate in the general population and suggest a major effect of easing of social restrictions on the COVID-19 resurgence in Israel. Although complete reopening of schools may have contributed to the spread of infection, it does not seem to have played a primary role per se in the June–July 2020 resurgence.

Table 4. **SARS-CoV-2–Related Hospitalizations of Moderate–Severely Ill Patients, by Age**

| | Age (Years) | | | | |
|---|---|---|---|---|---|
| | 0–9 | 10–19 | 20–39 | 40–59 | 60+ |
| A. Partial school reopening | | | | | |
| *26 April–2 May | 0 | 2 | 16 | 68 | 254 |
| &17–23 May | 0 | 1 | 8 | 21 | 95 |
| &24–30 May | 0 | 0 | 5 | 19 | 82 |
| B. Complete school reopening | | | | | |
| *10–16 May | 0 | 1 | 9 | 30 | 121 |
| &31 May–6 June | 0 | 0 | 4 | 25 | 86 |
| &7–13 June | 1 | 0 | 5 | 29 | 83 |
| C. Ease of restrictions | | | | | |
| *7–13 June | 1 | 0 | 5 | 29 | 83 |
| &28 June–4 July | 0 | 1 | 15[a] | 60[a] | 206[a] |
| &5–11 July | 1 | 1 | 23[b] | 103[b] | 338[b] |

Number of SARS-CoV-2–related hospitalizations of moderate–severely ill patients was calculated 1–7 days prior to (*) and 0–6 and 7–13 days following (&) each measure. RR was calculated for the time periods "following" as compared with "prior to" each measure. Statistically significant increasing rates are noted.
Abbreviations: RR, rate ratio; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

20–39 years: [a]RR = 3 (1.1–8.2); [b]RR = 4.6 (1.7–12.1).

40–59 years: [a]RR = 2.1 (1.3–3.2); [b]RR = 3.6 (2.4–5.4).

60+ years: [a]RR = 2.48 (1.9–3.2); [b]RR = 4.1 (3.2–5.2).

## Supplementary Data

Supplementary materials are available at *Clinical Infectious Diseases* online. Consisting of data provided by the authors to benefit the reader, the posted materials are not copyedited and are the sole responsibility of the authors, so questions or comments should be addressed to the corresponding author.

## Notes

***Author contributions.*** I. S. and E. S. conceptualized the study; I. S., E. A. F. S., and E. S. analyzed the data and drafted the manuscript; T. S. and L. K. B. participated in the study design, data collection, and analysis of results. All co-authors reviewed and approved the manuscript.

***Acknowledgments.*** The authors thank Ms Cindy Cohen for comprehensively reviewing the manuscript.

***Sources of information.*** (1) Ministry of Health, Israel (https://datadashboard.health.gov.il/COVID-19/general?utm_source=go.gov.il&utm_medium=referral, https://data.gov.il/dataset/covid-19/resource/6ad74663-9f40-4bfc-9626-f22da3976355/download/readme-.pdf, https://data.gov.il/dataset/covid-19); (2) National Information and Knowledge Center for COVID-19 Pandemic (https://www.gov.il/he/departments/corona-national-information-and-knowledge-center); (3) Information and Research Center of the Israeli Knesset (https://main.knesset.gov.il/Activity/Info/mmm/pages/default.aspx); (4) Israeli Center for Diseases Control (https://www.health.gov.il/UnitsOffice/ICDC/Pages/default_new.aspx); (5) The Hebrew University, Jerusalem, Israel (https://new.huji.ac.il/sites/default/files/mainsite/files/huji_3107.pdf).

***Financial support.*** This work was supported by the Ministry of Science and Technology, Israel (grant number 3-16983).

***Potential conflicts of interest.*** E. A. F. S. reports grants, personal fees, and nonfinancial support from AstraZeneca, Inc; Merck & Co; Regeneron, Inc; and Pfizer, Inc; personal fees, nonfinancial support, and other from Abbvie, Inc; personal fees from Alere, Inc; grants, personal fees, and nonfinancial support from Roche, Inc; other from GSK, Inc; grants from Johnson and Johnson; and grants and nonfinancial support from Novavax, Inc, outside the submitted work. All other authors report no potential conflicts. The authors have submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. Conflicts that the editors consider relevant to the content of the manuscript have been disclosed.

## References


1. Chen N, Zhou M, Dong X, et al. Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study. Lancet **2020**; 395:507–13.
2. Viner RM, Russell SJ, Croker H, et al. School closure and management practices during coronavirus outbreaks including COVID-19: a rapid systematic review. Lancet Child Adolesc Health **2020**; 4:397–404.
3. Flaxman S, Mishra S, Gandy A, et al. Estimating the effects of non-pharmaceutical interventions on COVID-19 in Europe. Nature **2020**; doi: 10.1038/s41586-020-2405-7.
4. Lee B, Raszka WV Jr. COVID-19 transmission and children: the child is not to blame. Pediatrics **2020**; 146:e2020004879.
5. Lu X, Zhang L, Du H, et al; Chinese Pediatric Novel Coronavirus Study Team. SARS-CoV-2 infection in children. N Engl J Med **2020**; 382:1663–5.
6. Dong Y, Mo X, Hu Y, et al. Epidemiology of COVID-19 among children in china. Pediatrics **2020**; 145:e20200702.
7. Zheng F, Liao C, Fan QH, et al. Clinical characteristics of children with coronavirus disease 2019 in Hubei, China. Curr Med Sci **2020**; 40:275–80.
8. Somekh I, Yakub Hanna H, Heller E, Bibi H, Somekh E. Age-dependent sensory impairment in COVID-19 infection and its correlation with ACE2 expression. Pediatr Infect Dis J **2020**; 39:e270–2.
9. Zhen-Dong Y, Gao-Jun Z, Run-Ming J, et al. Clinical and transmission dynamics characteristics of 406 children with coronavirus disease 2019 in China: a review. J Infect **2020**; 81:e11–5.
10. CDC COVID-19 Response Team. Coronavirus disease 2019 in children—United States, February 12–April 2, 2020. Morb Mortal Wkly Rep **2020**; 69:422–6. doi:10.15585/mmwr.mm6914e4
11. Somekh E, Gleyzer A, Heller E, et al. The role of children in the dynamics of intra family coronavirus 2019 spread in densely populated area. Pediatr Infect Dis J **2020**; 39:e202–4.
12. Jing QL, Liu MJ, Zhang ZB, et al. Household secondary attack rate of COVID-19 and associated determinants in Guangzhou, China: a retrospective cohort study. Lancet Infect Dis **2020**; 20:1141-50. doi:10.1016/S1473-3099(20)30471-0
13. Stringhini S, Wisniak A, Piumatti G, et al. Seroprevalence of anti-SARS-CoV-2 IgG antibodies in Geneva, Switzerland (SEROCoV-POP): a population-based study. Lancet **2020**; 396:313–9.
14. Posfay-Barbe KM, Wagner N, Gauthey M, et al. COVID-19 in children and the dynamics of infection in families. Pediatrics **2020**; 146:e20201576.
15. Auger KA, Shah SS, Richardson T, et al. Association between statewide school closure and COVID-19 incidence and mortality in the US. JAMA **2020**; 324:859–70.
16. Zhang J, Litvinova M, Liang Y, et al. Changes in contact patterns shape the dynamics of the COVID-19 outbreak in China. Science **2020**; 368:1481–6.
17. Levinson M, Cevik M, Lipsitch M. Reopening primary schools during the pandemic. N Engl J Med **2020**; 383:981–5.
18. Vermund SH, Pitzer VE. Asymptomatic transmission and the infection fatality risk for COVID-19: implications for school reopening. Clin Infect Dis **2020**:ciaa855. doi: 10.1093/cid/ciaa855.
19. Centers for Disease Control and Prevention. Operating schools during COVID-19. Available at: https://www.cdc.gov/coronavirus/2019-ncov/community/schools-childcare/prepare-safe-return.html. Accessed 2 February 2021.
20. European Center for Disease Prevention and Control. Considerations relating to social distancing measures in response to COVID-19—second update. Available at: https://www.ecdc.europa.eu/sites/default/files/documents/covid-19-social-distancing-measuresg-guide-second-update.pdf. Accessed 2 February 2021.
21. UNICEF. Safe back to school: a practitioner's guide. Available at: https://www.cpaor.net/sites/default/files/2020-05/GEC%20CP%20AoR_Safe%20Back%20to%20School%20Guide.pdf. Accessed 2 February 2021.
22. World Health Organization. Country & technical guidance: coronavirus disease (COVID-19). Available at: https://www.who.int/emergencies/diseases/novel-coronavirus-2019/technical-guidance-publications?publicationtypes=10ac82f5-5000-468d-94f9-c27a46127852. Accessed 2 February 2021.
23. Israel Ministry of Health: National coronavirus disease-19 (COVID-19) knowledge center. Available at: https://www.gov.il/he/departments/corona-national-information-andknowledge-center. Accessed 2 February 2021.
24. "Israel" Central Bureau of Statistics. Available at: https://old.cbs.gov.il/shnaton69/st02_03.pdf. Accessed 2 February 2021.
25. Stein-Zamir C, Abramson N, Shoob H, et al. A large COVID-19 outbreak in a high school 10 days after schools' reopening, Israel, May 2020. Euro Surveill **2020**; 25:2001352. doi: 10.2807/1560–7917.ES.2020.25.29.2001352.
26. Worby CJ, Chaves SS, Wallinga J, Lipsitch M, Finelli L, Goldstein E. On the relative role of different age groups in influenza epidemics. Epidemics **2015**; 13:10–6.
27. Copeland DL, Basurto-Davila R, Chung W, et al. Effectiveness of a school district closure for pandemic influenza A (H1N1) on acute respiratory illnesses in the community: a natural experiment. Clin Infect Dis **2013**; 56:509–16.
28. European Center for Disease Prevention and Control. COVID-19 in children and the role of school settings in COVID-19 transmission. Available at: https://www.ecdc.europa.eu/sites/default/files/documents/COVID-19-schools-transmission-August%202020.pdf.
29. The American Academy of Pediatrics. Children and COVID-19: state-level data report. Available at: services.aap.org/en/pages/2019-novel-coronavirus-covid-19-infections/children-and-covid-19-state-level-data-report. Accessed 2 February 2021.
30. Centers for Disease Control and Prevention. Operating schools during COVID-19. Available at: https://www.cdc.gov/coronavirus/2019-ncov/community/schools-childcare/reopening-schools.html. Accessed 2 February 2021.
31. Guthrie BL, Tordoff DM, Meisner J, et al. Summary of school re-opening models and implementation approaches during the COVID-19 pandemic. Available at: https://www.doh.wa.gov/Portals/1/Documents/1600/coronavirus/20200706-SchoolsSummary.pdf. Accessed 2 February 2021.
32. Macartney K, Quinn HE, Pillsbury AJ, et al. Transmission of SARS-CoV-2 in Australian educational settings: a prospective cohort study. Lancet Child Adolesc Health **2020**; doi: 10.1016/S2352-4642(20)30251-0.
33. Otte Im Kampe E, Lehfeld AS, Buda S, Buchholz U, Haas W. Surveillance of COVID-19 school outbreaks, Germany, March to August 2020. Euro Surveill **2020**; 25:2001645.
34. The Public Health Agency of Sweden: Covid-19 in schoolchildren: a comparison between Finland and Sweden. Available at: https://www.folkhalsomyndigheten.se/contentassets/c1b78bffbfde4a7899eb0d8ffdb57b09/covid-19-school-aged-children.pdf. Accessed 2 February 2021.
35. Ismail SA, Saliba V, Bernal JL, Ramsay ME, Ladhani SN. SARS-CoV-2 infection and transmission in educational settings: cross-sectional analysis of clusters and outbreaks in England. Lancet Infect Dis 2020; 8:S1473-3099(20)30882-3. doi:10.1016/S1473-3099(20)30882-3