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Previous Infection and Effectiveness of COVID-19 Vaccination in Middle- and High-School Students

Olivia M. Almendares, MSPH[a], **Jasmine D. Ruffin, MPH**[a], **Abigail H. Collingwood, MPH**[c], **Leisha D. Nolen, MD, PhD**[c], **William A. Lanier, DVM, MPH, DACVPM**[b,c,d], **Sarah Rebecca Dash, BS**[c], **Allison Avrich Ciesla, PhD**[a], **Ryan Wiegand, PhD**[a], **Jacqueline E. Tate, PhD**[a], **Hannah L. Kirking, MD**[a]

[a]COVID-19 Response Team

[b]Center for Preparedness and Response, Division of State and Local Readiness, Career Epidemiology Field Officer Program, Centers for Disease Control and Prevention, Atlanta, Georgia

[c]Utah Department of Health and Human Services, Salt Lake City, UT

[d]US Public Health Service, Rockville, Maryland

Abstract

BACKGROUND AND OBJECTIVES: Understanding the real-world impact of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) mitigation measures, particularly vaccination, in children and adolescents in congregate settings remains important. We evaluated protection against SARS-CoV-2 infection using school-based testing data.

METHODS: Using data from Utah middle- and high-school students participating in school-wide antigen testing in January 2022 during omicron (BA.1) variant predominance, log binomial models were fit to estimate the protection of previous SARS-CoV-2 infection and coronavirus disease 2019 vaccination against SARS-CoV-2 infection.

RESULTS: Among 17910 students, median age was 16 years (range: 12–19), 16.7% had documented previous SARS-CoV-2 infection; 55.6% received 2 vaccine doses with 211 median days since the second dose; and 8.6% of students aged 16 to 19 years received 3 vaccine doses with 21 median days since the third dose. Protection from previous infection alone was 35.9% (95% confidence interval [CI]: 12.9%–52.8%) and 23.8% (95% CI: 2.1%–40.7%) for students aged 12 to 15 and 16 to 19 years, respectively. Protection from 2-dose hybrid immunity (previous SARS-CoV-2 infection and vaccination) with <180 days since the second dose was 58.7% (95% CI: 33.2%–74.4%) for students aged 12 to 15 and 54.7% (95% CI: 31.0%–70.3%) for students aged 16 to 19 years. Protection was highest (70.0%, 95% CI: 42.3%–84.5%) among students with 3-dose hybrid immunity, although confidence intervals overlap with 2-dose vaccination.

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Address correspondence to Olivia Almendares, MSPH, Coronavirus and Other Respiratory Viruses Division, Centers for Disease Control and Prevention, 1600 Clifton Rd NE, MS H24-9, Atlanta, GA 30329. gtt1@cdc.gov.

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CONCLUSIONS: The estimated protection against infection was strongest for those with hybrid immunity from previous infection and recent vaccination with a third dose.

Understanding the real-world impact of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) mitigation measures, particularly vaccination, in children and adolescents remains important. This is especially true in the context of variants with increased transmissibility in congregate settings, such as schools. Prevention strategies, including regular screening testing, physical distancing, and mask use, have been shown to decrease school-based SARS-CoV-2 transmission.[1,2] However, data on coronavirus disease 2019 (COVID-19) vaccine effectiveness (VE) in children and adolescents and the impact of vaccination on SARS-CoV-2 infection rates within school settings are limited.[3] In addition, understanding the impact of vaccine-derived immunity paired with infection-acquired immunity is important, given that currently published studies assessing VE against infection during the omicron variant (BA.1) wave in children and adolescents have excluded those with evidence of previous SARS-CoV-2 infection, leaving a gap in our understanding of hybrid immunity (previous SARS-CoV-2 infection paired with vaccination).

In December 2020, the US Advisory Committee on Immunization Practices (ACIP) recommended 2 doses of the BNT162b2/Pfizer-BioNTech (Comirnaty) COVID-19 vaccine for persons ≥16 years of age. In May 2021, ACIP extended this to include adolescents aged 12 to 15 years.[4–6] On November 21, 2021, a booster dose (post receipt of a second dose) was recommended for adults ≥18 years of age,[7] and this was extended to include adolescents 16 to 17 years of age on December 9, 2021.[8] Additionally, messenger ribonucleic acid (mRNA)-1273/Moderna (SpikeVax) was recommended for adults ≥18 years of age in December 2020; an mRNA-1273 booster dose was recommended for adults ≥18 years in November 2021.[9]

Children and adolescents had high rates of SARS-CoV-2 infection during the omicron (BA.1) wave in late 2021 and early 2022.[10,11] Notably, SARS-CoV-2 seroprevalence among adolescents aged 12 to 17 years in the United States increased from ~40% during September 2021 before omicron predominance to 74.2% during February 2022 (post omicron).[10] This provided an opportunity to characterize VE, the effectiveness of previous infection, and the effectiveness of hybrid immunity on reinfection in this population during the peak transmission of omicron BA.1 sub-lineage. The Utah Department of Health and Human Services (UDHHS) implemented a “Test to Stay” (TTS) strategy during the 2021 to 2022 school year to conduct school-wide SARS-CoV-2 testing for all students and staff, as outlined in Utah State Senate Bill 107.[12,13] In short, Senate Bill 107 recommended universal testing for all students attending at least some in-person learning in schools meeting the defined case threshold of 30 students (for schools with <1500 students) or 2% (for schools with ≥1500 students) of the school’s student body testing positive for SARS-CoV-2 within the previous 14 days.

We evaluated COVID-19 VE by leveraging existing SARS-CoV-2 school-based testing and vaccination data among middle- and high-school students aged 12 to 19 years. We aimed to estimate the effectiveness of 2 and 3 doses of an mRNA vaccine, with or without previous

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infection, against SARS-CoV-2 infection during a period of omicron (BA.1) predominance among students participating in TTS events in Utah schools.

METHODS

Study Population

During the 2021 to 2022 school year, Utah K-12 schools exceeding the case threshold defined above provided one-time SARS-CoV-2 school-based testing for students and staff. Data from students opting into TTS during the weeks of January 2 and 9, 2022, from 2 middle schools and 16 high schools across 5 counties in Utah were analyzed. The protocol for this evaluation was reviewed by the Centers for Disease Control and Prevention (CDC), determined to be non-research, and conducted consistent with applicable federal law and CDC policy as defined in 45 CRF 46.102(I)(2).[14]

Data Collection

Deidentified individual-level SARS-CoV-2 test results, test type, and week of test available from routine reporting during March 2020 through January 2022 to the UDHHS statewide public health surveillance system were used. Data included SARS-CoV-2 test results from middle- and high-school TTS events during the weeks of January 2 and January 9, 2022, and demographic and vaccination information including age (in years) at event onset, sex, race, ethnicity, and school type.

Given vaccination schedule recommendations, age was categorized as students aged 12 to 15 years and 16 to 19 years. Race and ethnicity were combined into 5 categories (Asian, non-Hispanic or Latino; Black or African American, non-Hispanic or Latino; other race, non-Hispanic or Latino; white, non-Hispanic or Latino, and Hispanic or Latino).

COVID-19 vaccination status, vaccine manufacturer for each dose received, and days since vaccine dose were identified from the Utah state immunization information system. Student vaccination status was categorized as (1) unvaccinated (no documented COVID-19 vaccine), (2) vaccinated with 2 doses of an mRNA vaccine, with ≥14 days from the second dose or <7 days from the third dose, or (3) vaccinated with 3 doses of an mRNA vaccine with ≥7 days from the third dose. We analyzed students with 2 or 3 vaccine doses separately, stratified by previous infection status and age group. Because of the limited sample size, 3-dose analyses were conducted for the 16 to 19 age group only. The time from the second vaccine dose to the TTS event for students with 2 vaccine doses was categorized as either <180 or ≥180 days for students with previous infection and as <120 or ≥120 days for students without previous infection. SARS-CoV-2 infection was defined as laboratory-confirmed positive by antigen or reverse transcriptase polymerase chain reaction (RT-PCR) test administered during a TTS event in January 2022 and previous SARS-CoV-2 infection as a positive SARS-CoV-2 antigen or RT-PCR test result reported to the UDHHS statewide surveillance system. Hybrid immunity was defined as students with previous SARS-CoV-2 infection paired with vaccination.

Students were excluded if they (1) were aged <12 years, (2) had a positive SARS-CoV-2 test within 90 days before the TTS test, (3) received a non-mRNA vaccine dose, only 1 mRNA

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dose, or second dose received <14 days before the TTS test, (4) received vaccine doses before the ACIP age-based recommendation, (5) were missing school type information, or (6) had a false-positive test (defined by UDHHS as a negative SARS-CoV-2 PCR result collected within 48 hours after a positive antigen test without other positive laboratory results).

Analysis

We used log binomial regression to estimate effectiveness against infection and VE by age groups as defined above.[15,16] Generalized estimating equations were used to account for clustering by school by using an exchangeable working correlation, binomial distribution, and log link to estimate the relative risk.[17] VE was calculated as (1 – relative risk) × 100. Possible confounders were systematically added to develop adjusted models, and final models were adjusted for race/ethnicity and sex covariates. We conducted stratified analyses to estimate VE against infection by time since the last dose and by previous infection. We also estimated the effectiveness of previous infection and hybrid immunity on reinfection.

A 2-sided $P < .05$ was considered statistically significant. All analyses were conducted by using SAS software, version 9.4 (SAS Institute Inc, Cary, NC).

RESULTS

Overall Description

A total of 19 932 students participated in TTS during January 2022 (Fig 1). Of these, 17 910 students were included in the final analysis (Fig 1). We excluded 2022 students; >85% were excluded because of having a laboratory-confirmed SARS-CoV-2 infection in the 90 days before the TTS event ($n = 1030$) or for only having 1 dose of mRNA vaccine or a second dose received <14 days before the TTS test ($n = 697$; Fig 1).

The median age was 16 years (range: 12–19 years); 64.0% were aged 16 to 19 years (Table 1). Almost one-half (49.1%) were female, three-quarters (74.9%) identified as white race, non-Hispanic or Latino ethnicity, and 14.8% identified as Hispanic or Latino (Table 1). Sixteen percent of students had documented previous SARS-CoV-2 infection (excluding infections 90 days before the TTS test). Students aged 16 to 19 years had higher previous positivity (18.5%) compared with 12- to 15-year-old students (13.6%; Table 1). Overall, 88.0% of previous SARS-CoV-2 infections occurred during the prealpha/alpha variant predominant period (March 2020–June 2021; Supplemental Fig 3). Overall SARS-CoV-2 positivity was 14.4% during a school TTS event in January 2022 (Table 1). Antigen tests were the primary testing method during school TTS events, accounting for 99.8% of tests performed (Table 1). Additionally, the overall attack rate across all schools was 8.7% (Supplemental Table 3).

Vaccination Status

Unvaccinated students accounted for 35.8% overall, whereas 55.6% received 2 doses of an mRNA vaccine (Table 1). Vaccination status by age group was similar, although students aged 12 to 15 years had a slightly higher proportion of unvaccinated (38.9%) compared with

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students aged 16 to 19 years (34.1%). Additionally, 13.4% of students aged 16 to 19 years received 3 doses of an mRNA vaccine (Table 1). The median interval between the receipt of a second dose and the TTS test was 211 days (range: 14–387 days), overall, and was similar by age group. Most students with 2 doses received the second dose ≥180 days before their SARS-CoV-2 TTS test (67.8%), although the proportion of students aged 16 to 19 years receiving a second dose ≥180 days before was higher (70.5%) compared with students aged 12 to 15 years (63.8%). Students aged 16 to 19 years who had received their third dose had a median of 21 days (range: 7–54) before their SARS-CoV-2 TTS test (Table 1).

Effectiveness of Vaccination and Protection Through Infection, Hybrid Immunity

Compared with unvaccinated students with no previous SARS-CoV-2 infection, 2-dose VE without previous infection was not significant for students aged 12 to 15 years. However, when stratified by time, 2-dose VE without previous infection was 30.9% (95% confidence interval [CI]: 7.9%–48.1%) in the <120 days since the second vaccine dose (Fig 2). Protection against infection for those with previous infection only was 35.9% (95% CI: 12.9%–52.8%). In the same age group, the effectiveness of hybrid immunity among students with 2 vaccine doses was 55.0% (95% CI: 36.5%–68.2%) and was similar across time since vaccination with effectiveness of 58.7% (95% CI: 33.2%–74.4%) in the <180 days since second dose and 51.1% (95% CI: 21.2%–69.6%) ≥180 days since second dose (Fig 2).

When compared with unvaccinated students aged 16 to 19 years without previous SARS-CoV-2 infection, protection against infection was highest for those with hybrid immunity and 3 vaccine doses, from 24.2% (95% CI: 3.8%–40.3%) for 2-dose hybrid immunity to 70.0% (95% CI: 42.3%– 84.5%) for 3-dose hybrid immunity (Fig 2). When stratified by time, protection of 2-dose hybrid immunity was 54.7% (95% CI: 31.0%–70.3%) when <180 days since the second dose and was not significant after 180 days. Among those with no previous infection, 2 doses were not protective, regardless of stratification by the time since the last dose (Fig 2).

For students aged 16 to 19 years receiving 3 doses without previous infection, VE was 44.2% (95% CI: 33.4%–53.3%). Overall, protection was highest (70.0%, 95% CI: 42.3%–84.5%) among students with 3-dose hybrid immunity, although confidence intervals overlapped with the estimate for 3 doses without previous infection (Fig 2).

Vaccine Effectiveness by Previous SARS-CoV-2 Infection

Among students aged 16 to 19 years, analysis stratified by the presence of previous infection revealed that the effectiveness for students with 3 doses was higher among those with previous infection (63.6%, 95% CI: 30.1%–81.1%) compared with those without (44.2%, 95% CI: 33.4%–53.3%), but confidence intervals overlapped (Table 2). No protection was noted among students aged 16 to 19 years with or without previous infection for 2 doses (Table 2).

DISCUSSION

In the context of a surge in SARS-CoV-2 infections due to the emergence of omicron BA.1 sub-lineage, we evaluated 2- and 3-dose VE and protection from previous infection in a

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population of almost 18 000 students who underwent school-based testing as part of a local TTS strategy to keep schools open. Our findings reveal that point estimates for infection paired with vaccination (ie, hybrid immunity) were higher than either previous infection or vaccination alone against presumed omicron (BA.1) infection, but confidence intervals often overlapped. Among students aged 16 to 19 years, point estimates for 2-dose hybrid immunity were significantly higher than 2 doses of vaccine alone. However, in the same age group, only the estimate for 3-dose hybrid immunity was higher than vaccine or previous infection only. Regardless of previous infection status, VE was higher for students with a recent vaccination with a third dose compared with 2-dose VE among students aged 16 to 19 years.

Our findings align with other studies revealing that hybrid immunity improves the overall protection and duration of protection against omicron (BA.1)[18–20] and our estimates for 3-dose VE are comparable with studies assessing VE against omicron (BA.1) infection in similar age groups. The authors of at least 3 studies found BNT162b2 2-dose VE against infection for persons aged 12 and older ranging from 40% to 59% for those without previous infection.[21–23] The authors of at least 1 study noted significantly higher 2-dose mRNA VE against omicron infection for previously infected compared with noninfected (68% vs 42%, respectively) in persons 12 years of age and older.[18] Studies not excluding persons with previous infection revealed a 2-dose mRNA VE against omicron infection from 51% to 78% in adolescents 12 to 17 years of age, although both studies revealed declines in VE against infection as time since the second dose increased.[24–26]

Among students aged 16 to 19 years with 2-dose hybrid immunity, protection against infection <180 days since vaccination was moderate yet not significant after 180 days. In the same age group, 2 doses with no previous infection were not protective against infection. In contrast, 2 doses, <120 days since vaccination, and with no previous infection were moderately effective for students aged 12 to 15 years. The differences in protection between age groups may be due to changes in risky behavior after vaccination, given comparable median days since the second dose for both age groups. Age-group differences may be explained by risk compensation (ie, a tendency to adjust behavior given perceived risk), potentially leading to riskier behavior. Risk compensation is more likely to occur when people are both highly motivated to take on risky behavior and it is within their control to do so.[27] There are likely important differences in the opportunities for independent decision-making for students aged 16 to 19 years compared with those aged 12 to 15 years. This, paired with the demonstrated efficacy reported postclinical trials for COVID-19 mRNA vaccines,[28] may have led to further reduced adherence to other precautions, such as mask-wearing, physical distancing, and increased participation in higher-risk behaviors among those vaccinated with 2 doses.

Although 3 doses among students aged 16 to 19 years were moderately effective (44.2%), protection increased to 70% among students with 3-dose hybrid immunity, although confidence intervals overlap. The addition of a third dose increased protection regardless of previous infection status, highlighting the importance of booster doses. In assessing the effect of previous infection on VE, students aged 16 to 19 years with previous infection had better protection with 2 and 3 doses compared with those without previous infection. The

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rates of past infection and vaccination likely affected the overall observed school attack rates during the omicron (BA.1) surge. These observations suggest that, absent infection-induced and vaccine-induced immunity, the school-level impact of the BA.1 surge on students may have been much worse.

This analysis is subject to several limitations. First, we were unable to evaluate VE for 12- to 15-year-olds receiving 3 doses of an mRNA vaccine because of a low sample size, given the short time window between the recommendation of a third dose for this age group and the TTS events analyzed. Second, we were unable to distinguish between students vaccinated with a third dose because of a risk-based indication (ie, immunocompromising status), which may lead to an underestimated VE. Third, most schools used antigen tests during TTS events because of ease of use and rapid results turn-around. Antigen test sensitivity for SARS-CoV-2 is generally lower compared with nucleic acid amplification tests, increasing the potential for false-negatives and the misclassification of outcomes, which may impact estimated effects. Fourth, this analysis was based on data from a single state; there may be individual-level (socioeconomic, behavioral) or state-level characteristics (variations in mandates of mitigation measures) that differ across the country. In addition, race/ethnicity was included in adjusted models, although race/ethnicity is likely a proxy for other unmeasured social/behavioral drivers of risk. Fifth, for children with hybrid immunity, we stratified by time since vaccination rather than time since last exposure (vaccine or past infection). Thus, students who were vaccinated a long time before, but had a more recent infection, may not be comparable to those who were vaccinated at the same time but were infected before vaccination because the time from the last exposure to an immunity-producing event (vaccination or infection) will differ. Sixth, previous infection status may be misclassified if it was not captured by the state surveillance system (eg, positive on an at-home antigen test and not reported). Finally, individual students/parents could opt out of TTS testing, and during the time period for this analysis, the participation of students in TTS events was 71% median (range: 48%–90%) across all schools. We were unable to assess the differences between those opting in compared with those opting out of TTS testing, and students opting in may have higher risk tolerance of SARS-CoV-2 exposure. These factors limit the generalizability of the findings.

The continual circulation of SARS-CoV-2 in the United States in the context of the reduction of other prevention measures highlights the importance of vaccination to protect both individuals and communities. Although protection with primary series vaccination against infection for previously SARS-CoV-2 naïve students was not found, our results reveal that protection against infection increased for those with hybrid immunity or with the addition of a third vaccine dose in the absence of infection-induced immunity. We were unable to measure protection against other severe outcomes of SARS-CoV-2 infection, such as hospitalization, yet current evidence suggests that VE remains strong against these severe outcomes.[24–26,29] Real-world VE estimates can guide the prioritization of resources and help focus messaging needed, particularly at the state and local levels to protect against the risk of infection.

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CONCLUSIONS

As this investigation illustrates, these real-world, programmatic data from school-based testing were useful to reveal the relative effectiveness of past infection and/or vaccination in preventing infections in child and adolescent populations. Age-stratified VE estimates for child and adolescent populations are more challenging to obtain throughout other postmarketing platforms. These estimates are especially important in the context of school or other congregate settings, in which transmission risk may be high but other prevention measures can be difficult to implement on a large scale. Further studies are needed to assess both the impact of additional boosters in children and adolescents, considering infection-induced immunity with emerging variants, as well as the impact of vaccination on the reduction of other indirect effects of symptomatic SARS-CoV-2, such as school absenteeism and family economic burden.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Ms Almendares and Ms Ruffin conceptualized and designed the study, conducted analyses, drafted the initial manuscript, and critically reviewed and revised the manuscript; Ms Collingwood and Ms Dash collected data and critically reviewed and revised the manuscript; Drs Avrich Ciesla and Wiegand critically reviewed and revised the manuscript; Drs Nolen, Lanier, Tate, and Kirking conceptualized and designed the study and critically reviewed and revised the manuscript; and all authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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ABBREVIATIONS

ACIP	Advisory Committee on Immunization Practices
CDC	Centers for Disease Control and Prevention
CI	confidence interval
COVID-19	coronavirus disease 2019
mRNA	messenger ribonucleic acid
RT-PCR	reverse transcriptase polymerase chain reaction
SARS-CoV-2	severe acute respiratory syndrome coronavirus 2
TTS	Test to Stay

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UDHHS	Utah Department of Health and Human Services
VE	vaccine effectiveness

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WHAT'S KNOWN ON THIS SUBJECT:

Waning immunity from coronavirus disease 2019 vaccines against infection has been documented; however, protection of hybrid immunity against infection is not well-described. During omicron BA.1 emergence, the rates of infection among children and adolescents increased substantially, leading to widespread seroprevalence.

WHAT THIS STUDY ADDS:

In this study, we evaluate the protection of coronavirus disease 2019 vaccination and previous SARS-CoV-2 infection among students attending school: a congregate setting with limited data. Protection against SARS-CoV-2 infection was strongest among those recently vaccinated and with hybrid immunity.

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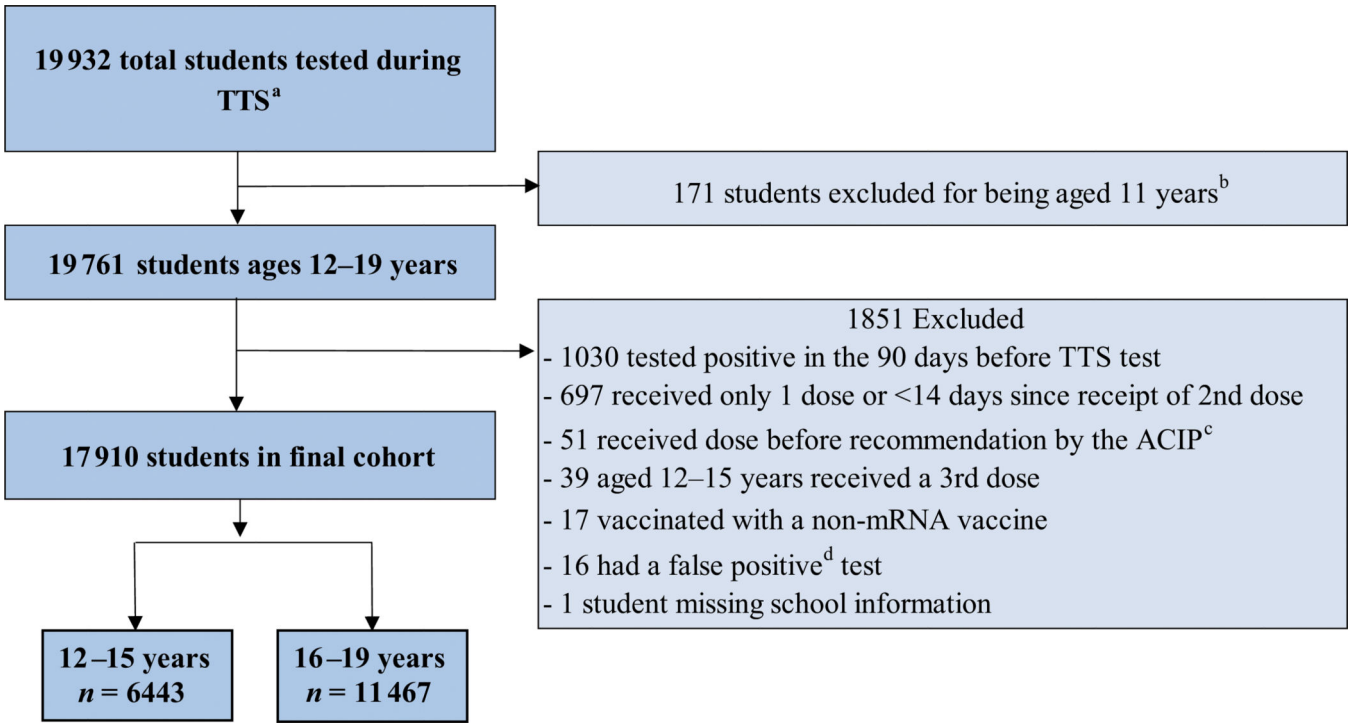

FIGURE 1.

Inclusions and exclusions of a retrospective cohort analysis of middle- and high-school students participating in school SARS-CoV-2 TTS events, Utah, January 2022.

[a] Indicates the SARS-CoV-2 testing program implemented by K-12 schools in Utah whereby school-wide testing events for SARS-CoV-2 testing events for SARS-CoV-2 took place once the defined outbreak threshold was met, per Utah Senate Bill 107: https://le.utah.gov/~2021/bills/static/SB0107.html

[b] Students aged 11 years were excluded because of receiving a differing dose of the mRNA vaccine.

[c] The committee that develops vaccine recommendations within the United States.

[d] False positives were defined as a RT-PCR negative test result collected within 48 hours following an antigen positive test and no other positive labs.

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Vaccination/Infection Status (Days Since Last Dose)	Total	Cases	Days Since Previous Infection, Median (Range)	Days Since Last Dose, Median (Range)	Adjusted Effectiveness Infection/Vaccination % (95% CI)[a]
Aged 12-15 years					
Unvaccinated (nPI[b])	2138	307	--	--	Ref
Previous infection only	361	33	357 (91-651)	--	**35.9 (12.9 to 52.8)**
2 doses, nPI	3422	532	--	206 (14-236)	-10.2 (-26.3 to 3.8)
(14-119)	373	36	--	83 (14-119)	**30.9 (7.9 to 48.1)**
2 doses, HI[c]	513	34	378 (91-644)	182 (14-225)	**55.0 (36.5 to 68.2)**
(14-179)	252	15	378 (98-602)	136 (14-179)	**58.7 (33.2 to 74.4)**
(180-225)	261	19	385 (91-644)	213 (180-225)	**51.1 (21.2 to 69.6)**
Aged 16-19 years					
Unvaccinated (nPI)	3139	429	--	--	Ref
Previous infection only	766	79	371 (91-644)	--	**23.8 (2.1 to 40.7)**
2 doses, nPI	4882	933	--	218 (14-387)	**-40.6 (-57.6 to -25.5)**
(14-119)	491	78	--	90 (14-119)	-14.7 (-31.6 to -0.1)
2 doses, HI	1135	120	385 (91-630)	215 (14-379)	**24.2 (3.8 to 40.3)**
(14-179)	382	24	371 (98-609)	130 (14-179)	**54.7 (31.0 to 70.3)**
(180-379)	753	96	392 (91-630)	237 (180-379)	8.2 (-15.8 to 27.2)
3 doses, nPI	1323	99	--	21 (7-54)	**44.2 (33.4 to 53.3)**
3 doses, HI	215	9	392 (98-644)	21 (7-52)	**70.0 (42.3 to 84.5)**

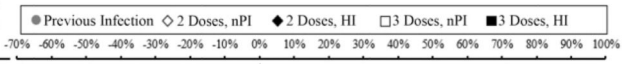

FIGURE 2.

Adjusted effectiveness of previous SARS-CoV-2 infection and mRNA vaccination against SARS-CoV-2 infection during omicron (BA.1) sub-lineage predominance by age groups (12–15 and 16–19 years), Utah, January 2022.

[a] All models adjusted for race/ethnicity and sex.

[b] Indicates no evidence of a prior SARS-CoV-2 infection.

[c] Indicates a confirmed prior SARS-CoV-2 positive test.

nPl, no prior infection; HI, hybrid immunity

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TABLE 1

Characteristics of Middle- and High-School Students Participating in a School-Based TTS[a] Event, January 2022

	n **(%)**		
Characteristics	**Total students, *n* = 17 910**	**12–15 y, *n* = 6443**	**16–19 y, *n* = 11 467**
Median age (range)	16 (12–19)	15 (12–15)	17 (16–19)
School			
High school	16 991 (94.9)	5524 (85.7)	11 467 (100.0)
Middle school	919 (5.1)	919 (14.3)	—[*]
Sex			
Male	9094 (50.8)	3238 (50.3)	5856 (51.1)
Female	8800 (49.1)	3196 (49.6)	5604 (48.9)
Unknown	16 (0.1)	9 (0.1)	7 (0.1)
Race and ethnicity[b]			
White, non-Hispanic or Latino	13 414 (74.9)	4694 (72.9)	8720 (76.0)
Hispanic or Latino	2647 (14.8)	1041 (16.2)	1606 (14.0)
Other Race, non-Hispanic or Latino[c]	843 (4.7)	332 (5.2)	511 (4.5)
Asian, non-Hispanic or Latino	655 (3.7)	238 (3.7)	417 (3.6)
Black/African American, non-Hispanic or Latino	351 (2.0)	138 (2.1)	213 (1.9)
Known previously COVID-19-positive[d]	2990 (16.7)	874 (13.6)	2116 (18.5)
Median previous SARS-CoV-2 infections (range)	1 (1–3)	1 (1–3)	1 (1–3)
Positive SARS-CoV-2 result, during TTS[e]	2578 (14.4)	909 (14.1)	1669 (14.6)
SARS-CoV-2 test type (TTS testing)			
Antigen	17 874 (99.8)	6437 (99.9)	11 437 (99.7)
RT-PCR	36 (0.2)	6 (0.1)	30 (0.3)
Vaccination characteristics			
Unvaccinated	6414 (35.8)	2504 (38.9)	3910 (34.1)
Vaccinated with mRNA, by no. of doses			
2 doses[f]	9958 (55.6)	3939 (61.1)	6019 (52.5)

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	***n* (%)**		
Characteristics	**Total students, *n* = 17 910**	**12–15 y, *n* = 6443**	**16–19 y, *n* = 11 467**
Median d since most recent dose (range)	211 (14–387)	204 (14–236)	218 (14–387)
Interval range, d			
14–179	3203 (32.2)	1427 (36.2)	1776 (29.5)
180–387	6755 (67.8)	2512 (63.8)	4243 (70.5)
3 doses[g]	1538 (8.6)	—[*]	1538 (13.4)
Median d since most recent dose (range)	21 (7–54)	—[*]	21 (7–54)

[a] TTS indicates the test performed during a SARS-CoV-2 school-wide cross-sectional testing event after meeting the required threshold, per Utah Senate Bill 107 (https://le.utah.gov/~2021/bills/static/SB0107.html).

[b] Race and ethnicity were combined following the "Method A" approach, prioritizing Hispanic or Latino ethnicity and assuming non-Hispanic ethnicity when ethnicity data were unknown or missing (see https://www.cdc.gov/mmwr/volumes/70/wr/mm7032a2.htm).

[c] Other, non-Hispanic races include American Indian/Alaska Native, Native Hawaiian/Pacific Islander, "Other race" or multiple races selected, and unknown race.

[d] Excludes those with a positive SARS-CoV-2 test during the 90 days before their TTS event.

[e] TTS indicates the test was performed during a SARS-CoV-2 school-wide testing event.

[f] All students received the BNT162b2 (PfizerBioNTech) vaccine, except 10 students aged ≥18, who received 2 doses of mRNA-1273; excludes students with a second dose in the 14 days before the TTS test and any non-mRNA vaccine doses received (including mixed series).

[g] Includes 47 (0.3%) students who received a mixed mRNA vaccine series (ie, 2 doses of BNT162b2, third dose with mRNA-1273 or vice versa); excludes those who received a third dose in the 6 days before their TTS test; unable to decipher between third dose or boosted.

[*] Data not applicable for the particular characteristic and age group.

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TABLE 2

COVID-19 Vaccine Effectiveness by Previous SARS-CoV-2 Infection Status for High School Students Aged 16 to 19 Years Participating in a TTS Event, Utah, January 2022

Vaccination/Infection Status	Total	Cases	Days Since Last Dose, Median (range)	Adjusted VE % (95% CI)[a]
No previous infection				
Unvaccinated (nPI[b])	3139	429	—*	Ref
2 doses, nPI[b]	4882	933	218 (14–387)	−40.6 (−57.6 to −25.5)
3 doses, nPI[b]	1323	99	21 (7–54)	44.2 (33.4 to 53.3)
Previous infection				
Unvaccinated (previous infection)	766	79	—*	Ref
2 doses, HI[c]	1135	120	215 (14–379)	1.0 (−19.0 to 17.6)
3 doses, HI[c]	215	9	21 (7–52)	63.6 (30.1 to 81.1)

HI, hybrid immunity; nPI, no previous infection.

[a]All models adjusted for race/ethnicity and sex.

[b]Indicates no evidence of a previous SARS-CoV-2 infection.

[c]Indicates a confirmed previous SARS-CoV-2-positive test.

*Data not applicable for those with unvaccinated status.