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Evaluation of a city-wide school-located influenza vaccination program in Oakland, California with respect to race and ethnicity: A matched cohort study

Anna T. Nguyen[a,b,*], **Benjamin F. Arnold**[c], **Chris J. Kennedy**[d], **Kunal Mishra**[a], **Nolan N. Pokpongkiat**[a], **Anmol Seth**[a], **Stephanie Djajadi**[a], **Kate Holbrook**[e,f], **Erica Pan**[e,g,h], **Pam D. Kirley**[i], **Tanya Libby**[i], **Alan E. Hubbard**[a], **Arthur Reingold**[a], **John M. Colford Jr.**[a], **Jade Benjamin-Chung**[a,b]

[a]Division of Epidemiology and Biostatistics, University of California, Berkeley, Berkeley, CA, United States

[b]Department of Epidemiology and Population Health, Stanford University, Stanford, CA, United States

[c]Francis I. Proctor Foundation, University of California, San Francisco, San Francisco, CA, United States

[d]Department of Biomedical Informatics, Harvard Medical School, Boston, MA, United States

[e]Division of Communicable Disease Control and Prevention, Alameda County Public Health Department, Oakland, CA, United States

[f]Department of Community Health Systems, School of Nursing, University of California, San Francisco, San Francisco, CA, United States

[g]California Department of Public Health, Richmond, CA, United States

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[*]Corresponding author at: 259 Campus Drive 19 HRP Redwood Building T152A, Stanford University, Stanford, CA 94305, United States. annatnguyen@stanford.edu (A.T. Nguyen).

CRediT authorship contribution statement

Anna T. Nguyen: Data curation, Formal analysis, Methodology, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. **Benjamin F. Arnold:** Conceptualization, Funding acquisition, Methodology, Writing – review & editing. **Chris J. Kennedy:** Formal analysis, Methodology, Software, Writing – review & editing. **Kunal Mishra:** Software, Writing – review & editing. **Nolan N. Pokpongkiat:** Software, Writing – review & editing. **Anmol Seth:** Software, Writing – review & editing. **Stephanie Djajadi:** Software, Writing – review & editing. **Kate Holbrook:** Investigation, Resources, Writing – review & editing. **Erica Pan:** Investigation, Resources, Writing – review & editing. **Pam D. Kirley:** Data curation, Investigation, Resources, Writing – review & editing. **Tanya Libby:** Data curation, Investigation, Resources, Writing – review & editing. **Alan E. Hubbard:** Conceptualization, Funding acquisition, Methodology, Writing – review & editing. **Arthur Reingold:** Conceptualization, Funding acquisition, Writing – review & editing. **John M. Colford:** Conceptualization, Funding acquisition, Writing – review & editing. **Jade Benjamin-Chung:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.vaccine.2021.11.073.

[h]Department of Pediatrics, Division of Infectious Diseases, University of California, San Francisco, San Francisco, CA, United States

[i]California Emerging Infections Program, Oakland, CA, United States

Abstract

Background: Increasing influenza vaccination coverage in school-aged children may substantially reduce community transmission. School-located influenza vaccinations (SLIV) aim to promote vaccinations by increasing accessibility, which may be especially beneficial to race/ethnicity groups that face high barriers to preventative care. Here, we evaluate the effectiveness of a city-wide SLIV program by race/ethnicity from 2014 to 2018.

Methods: We used multivariate matching to pair schools in the intervention district in Oakland, CA with schools in a comparison district in West Contra Costa County, CA. We distributed cross-sectional surveys to measure caregiver-reported student vaccination status and estimated differences in vaccination coverage levels and reasons for non-vaccination between districts stratifying by race/ethnicity. We estimated difference-in-differences (DID) of laboratory confirmed influenza hospitalization incidence between districts stratified by race/ethnicity using surveillance data.

Results: Differences in influenza vaccination coverage in the intervention vs. comparison district were larger among White (2017–18: 21.0% difference [95% CI: 9.7%, 32.3%]) and Hispanic/Latino (13.4% [8.8%, 18.0%]) students than Asian/Pacific Islander (API) (8.9% [1.3%, 16.5%]), Black (5.9% [−2.2%, 14.0%]), and multiracial (6.3% [−1.8%, 14.3%)) students. Concerns about vaccine effectiveness or safety were more common among Black and multiracial caregivers. Logistical barriers were less common in the intervention vs. comparison district, with the largest difference among White students. In both districts, hospitalizations in 2017–18 were higher in Blacks (Intervention: 111.5 hospitalizations per 100,00; Comparison: 134.1 per 100,000) vs. other races/ethnicities. All-age influenza hospitalization incidence was lower in the intervention site vs. comparison site among White/API individuals in 2016–17 (DID −25.14 per 100,000 [95% CI: −40.14, −10.14]) and 2017–18 (−36.6 per 100,000 [−52.7, −20.5]) and Black older adults in 2017–18 (−282.2 per 100,000 (−508.4, −56.1]), but not in other groups.

Conclusions: SLIV was associated with higher vaccination coverage and lower influenza hospitalization, but associations varied by race/ethnicity. SLIV alone may be insufficient to ensure equitable influenza outcomes.

Keywords

Influenza; Vaccinations; School-located influenza vaccinations; Schools; Vaccination coverage; Hospitalizations

1. Introduction

To reduce influenza transmission, the Advisory Committee on Immunization Practices (ACIP) recommends annual influenza vaccinations for all Americans over 6 months of age, with a target coverage level of 80% in non-institutionalized, non-elderly persons [1]. During recent influenza seasons, all racial/ethnic groups experienced low vaccination levels that fell short of this goal, with communities of color having the lowest coverage. While 49% of white adults received an influenza vaccine during the 2018–19 season, only 39% of Black adults, 37% Hispanic adults, and 44% of Asian adults were vaccinated [2].

Racial/ethnic disparities in vaccination coverage can be attributed to non-belief in the utility of vaccinations, institutionalized racism, and distrust of medical institutions that contribute to vaccine hesitancy among communities of color [3-7]. These inequities contribute to disproportionately high influenza morbidity rates among disadvantaged racial/ethnic groups, resulting in elevated rates of hospitalization and death. Prior research on the social determinants of influenza hospitalization showed that Black/African Americans and Hispanics had higher risks of hospitalization compared to Whites [8-10]. Differences in hospitalizations by race/ethnicity are linked to other socioeconomic risk factors which disproportionately impact communities of color, such as low household income or high residential density [8-10]. Increasing vaccination coverage among marginalized groups may reduce race/ethnicity inequities in influenza morbidity and mortality.

School-located influenza vaccination (SLIV) programs aim to increase vaccination coverage levels among young children by providing free vaccination in schools. SLIV has the potential to reduce barriers to vaccination that disproportionately impact communities of color. Prior community-based interventions increased influenza vaccination coverage among communities of color by reducing logistical barriers to vaccination through door-to-door and street-based immunizations [11]. By increasing vaccination coverage, SLIV may contribute to herd immunity and reduce influenza transmission community-wide, which may reduce racial/ethnic disparities in influenza [12,13]. Prior studies reported that SLIV programs were associated with increased influenza vaccination coverage [14-20] and decreased school absences [14-17,20-22] and student illness [14-17], but no studies have measured the differential impacts of large-scale SLIV interventions by race/ethnicity.

We previously reported results from an evaluation of a city-wide SLIV program delivered in elementary schools in Oakland, California from 2014 to 2018 [20]. We found that the intervention was associated with 7–11 percentage points higher vaccination coverage among school-aged children and 17 to 37 lower incidence of influenza hospitalizations per 100,000 during influenza seasons in which a moderately effective vaccine was being used. Here, we investigated whether SLIV effectiveness varied by race/ethnicity in a pre-specified subgroup analysis.

2. Material and methods

2.1. School-located influenza vaccination intervention

Starting in 2014, the Shoo the Flu program provided free influenza vaccinations to elementary school students city-wide in Oakland, California. The program aimed to increase vaccination coverage in children and contribute to herd protection in the surrounding community. The intervention was offered to all public elementary schools, charter schools, and preschools, as well as private schools, in the city of Oakland.

All students at participating schools were eligible to be vaccinated, regardless of their insurance status. During the 2014–2018 seasons, Shoo the Flu served between 95 and 139 schools and vaccinated between 7,502 and 10,106 students (22–28% of eligible students) each year. Caregivers provided written consent for each student vaccination. Additional program details are reported elsewhere [20].

In the 2014–15 and 2015–16 seasons, the program primarily provided live attenuated influenza vaccines (LAIV), with inactivated injectable influenza vaccine (IIV) available to students with contraindications. In LAIV seasons, the vaccine had relatively low effectiveness against the predominant circulating strain [23]. As a result, in 2016–17 and 2017–18, only the IIV was offered, consistent with Advisory Committee on Immunization Practices (ACIP) recommendations, and the vaccine was moderately effective against the predominant strain of the influenza virus [23].

2.2. Study design

We employed a matched cohort design to evaluate the effect of the intervention on vaccination coverage and influenza hospitalization. We focused our study on public elementary schools in Oakland Unified School District (OUSD, the intervention district). At the start of the intervention period, there were 50 district-run elementary schools serving 19,987 students and 6 district authorized charter schools serving 4,192 students. We excluded private and non-district charter schools because pre-intervention data on school characteristics was not available for them.

We selected West Contra Costa Unified School District (WCCUD) as the comparison district, as it resulted in the closest school pair matches based on pre-intervention student characteristics. Additional details on the matching procedure are described in Supplement 1.

2.3. Outcomes and data sources

We evaluated the association between SLIV and (1) influenza vaccination coverage among school-aged children and (2) community-wide lab-confirmed influenza hospitalization.

2.3.1. Pre-Intervention district comparison—To compare population characteristics between the comparison and intervention districts, we obtained pre-intervention data on socioeconomic status, school enrollment, and race/ethnicity from the three-year 2013 American Community Survey (ACS).

2.3.2. Vaccination coverage—To measure influenza vaccination coverage in the study population, we distributed two cross-sectional surveys in 22 matched school pairs [20]. A survey administered in March 2017 measured vaccination history for the 2014–17 seasons and a survey conducted in March 2018 measured vaccination history for the 2017–18 season.

In the 2017 survey 2,246 of the 8,121 distributed surveys were returned in the intervention district and 3,824 of the 10,056 distributed surveys were returned in the comparison district. In the 2018 survey 2,421 of the 10,110 distributed surveys were returned in the intervention district and 4,086 of the 11,820 distributed surveys were returned in the comparison district.

The surveys were conducted independently from the intervention. All students in participating schools were invited to participate in the surveys, regardless of their vaccination status or participation in the SLIV program. We distributed anonymous surveys to students at schools for their caregivers to report influenza vaccination status, vaccine type, and location of vaccination. Caregivers of unvaccinated students reported the reason for non-receipt of vaccine.

Caregivers self-identified by selecting from the following student races/ethnicities: White, Black or African American, Hispanic or Latino, Asian, Native Hawaiian or Pacific Islander, or American Indian or Alaska Native.

2.3.3. Laboratory-confirmed influenza hospitalization—To measure potential herd effects of SLIV, we analyzed laboratory-confirmed influenza hospitalization data among all ages in the school district catchment sites. We obtained data from the California Emerging Infections Program (CEIP) in zip codes that fell within the boundaries of the intervention or comparison districts. CEIP surveillance data tracks race-specific hospitalizations for the White, Black/African American, Hispanic, Asian/Pacific Islander, Multiracial, and American Indian/Alaska Native populations. We calculated the cumulative incidence of hospitalization each season using age-, race-, and ethnicity-specific population estimates from the 2010 Census.

We restricted analyses to influenza seasons using a prespecified, data-driven definition based on local transmission patterns. We set a 2.5% threshold for the percentage of medical visits for influenza-like illness in a week, as reported by the California Department of Public Health (CDPH), to mark the start and end of an influenza season. Each year, the season started when there were two consecutive weeks that exceeded the threshold and ended when there were two consecutive weeks that dropped below the threshold.

2.4. Statistical analysis

Analyses were conducted in R (version 4.0.2). The pre-analysis plan, selected datasets, and replication scripts are available through the Open Science Framework (https://osf.io/v6djf/).

2.4.1. Reasons for vaccine non-receipt—The 2017–18 survey included questions about reasons for non-receipt of influenza vaccine and classified each reason into the following categories: 1) logistics, 2) non-belief, 3) barriers specific to SLIV (intervention site only) (Supplement 2). We combined concerns of effectiveness ("I don't believe in [the vaccine]") and concerns of safety ("I believe [the vaccine] might make my child sick") into the broader "non-belief" category. We estimated the school-level prevalence of each category and summarized characteristics in schools with prevalence above and below the median prevalence in each district. We fit bivariate log-linear Poisson models to estimate the association between an indicator of whether the school fell above or below the median prevalence for the specified reason for non-receipt and school-level characteristics [24].

2.4.2. Influenza vaccination coverage—We used linear regression models to estimate differences in influenza vaccination coverage between the intervention and comparison districts within each racial/ethnicity group, adjusting for caregiver education level. To account for clustering within matched school pairs we calculated robust sandwich standard errors, which require no assumptions about the nature of correlation within school pairs [25].

We pre-specified subgroup analyses by race and ethnicity. Post-hoc we excluded American Indian/Alaska Native students from the stratified analyses because the group was very small (N < 20 per site per year). We excluded survey responses that did not specify a student's race/ethnicity (2017: Intervention N = 60 (2.67%), Comparison N = 90 (2.35%); 2018: Intervention N = 63 (2.60%), Comparison N = 90 (2.20%)),

2.4.3. Laboratory-confirmed influenza hospitalization—To estimate incidence ratios, we fit log-linear modified Poisson models with an offset for population size [24]. To account for pre-intervention differences in influenza hospitalization incidence between districts, we estimated the difference-in-differences (DID) in cumulative incidences per 100,000 individuals. We defined DIDs as the difference in pre-intervention (2011–2013) and intervention period (2014–2018) incidence differences in each site. Pre-intervention trends were similar between sites [20].

We pre-specified stratification by age groups (non-elementary school aged individuals (<= 4 years, >13 years) and older adults (>=65 years)). Because the number of elementary school aged children who were hospitalized for influenza was small, there was inadequate statistical power to estimate associations separately for this age group.

After examining the survey data, we combined White and Asian/Pacific Islander racial categories due to low incidence among Asian/Pacific Islanders. We excluded Multiracial and American Indian/Alaska Native groups from the analysis due to rare outcomes We excluded hospitalization records that did not report race/ethnicity.

2.5. Ethical statement

This study was reviewed and approved by the Committee for the Protection of Human Subjects at the University of California, Berkeley (Protocols # 2014-01-5960 and 2016-12-9406).

During the two years of piloting, we requested written documentation of informed consent from all caregivers for the completion of the vaccination coverage survey. The complex nature of the consent forms contributed to low response rates, preventing us from reaching a sufficiently large sample size to detect differences in vaccine coverage. During the primary study period, we obtained a waiver of documented informed consent.

3. Results

Prior to the intervention, the intervention and comparison districts had generally similar demographic characteristics (Table 1). However, relative to the comparison district, the intervention districts had a higher proportion of Black/African American residents (Intervention: 26%, Comparison: 17%), but a lower proportion of White (Intervention: 41%, Comparison: 48%), Asian (Intervention: 16%, Comparison: 19%), and Hispanic/Latino

(Intervention: 26%, Comparison: 33%) residents. The intervention district had a lower median household income than the comparison district, but a higher proportion of residents holding a bachelor's degree or above.

3.1. Vaccination coverage

The race/ethnicity distributions of respondents were similar to the overall distributions in the sampled schools (Fig. 1), except for Black/African American students, who were underrepresented in both districts (Intervention: 33% in target population versus 16% in survey; Comparison: 19% in target population versus 10% in survey). The distributions of student race/ethnicity as reported in caregiver surveys are described in Table 2. In both districts, most multi-racial students identified as part Black/African American (2017: Intervention 39%, Comparison 26%) or Asian/Pacific Islander (2017: Intervention 37%, Comparison 35%) (Table S1).

Vaccination coverage levels varied by race/ethnicity, when controlled for highest caregiver education (Fig. 2). In all seasons, we observed lower vaccine coverage among Black/African American and multiple race students across both districts. During the 2017–18 season, 46% (95% CI 30%, 64%) of Black/African American students were vaccinated, compared to 74% (95% CI 65%, 80%) of Asian/Pacific Islander and 67% (95% CI 48%, 82%) of White students in the intervention district. In the comparison district, 40% (95% CI 24%, 59%) of Black/African American students were vaccinated, compared to 65% (95% CI 57%, 72%) of Asian/Pacific Islander and 46% (95% CI 28%, 66%) of White students.

In the comparison district, we saw a drop in vaccination coverage during the 2016–17 season, when only IIV was offered after two years when LAIV was ineffective (Fig. 2, Fig. S1). This decline occurred in all race/ethnicity groups, with Black/African American students facing the largest drop. In the intervention district, coverage levels were sustained for all groups other than Black/African Americans. In the intervention district, among vaccinated students, the percent of students receiving a vaccine at a school increased slightly over time and was similar across race/ethnicity groups (Fig. S1). Among White, Hispanic/Latino, and Asian/Pacific Islander students the percent of students receiving a vaccine at a doctor/-clinic remained consistent throughout the study period, suggesting that the increase in school-located vaccinations is associated with students who would not be vaccinated elsewhere due to logistical barriers. Concordance of caregiver-reported vaccination status in surveys with overlapping recall periods was over 70% (see additional details in Supplement 3).

Associations between SLIV and vaccine coverage varied between racial/ethnic groups (Fig. 3, Table S2). In the first two seasons of SLIV there were no differences in vaccine coverage for any group, apart from Asian/Pacific Islanders. In the 2016–17 season, there were increases in vaccine coverage in all groups other than multiple race students. We observed higher coverage levels in the intervention district relative to the comparison district among Black/African American (9% higher in intervention versus comparison; 95% CI 2%, 17%), Hispanic/Latino students (11%; 95% CI 5%, 17%),White (7%; 95% CI −1%, 14%), and Asian/Pacific Islander (5%; 95% CI 0%, 9%) students.

In the 2017–18 season, we observed significantly higher influenza vaccine coverage levels among Asian/Pacific Islander (9%; 95% CI 1%, 16%), Hispanic/Latino (13%; 95% CI 9%, 18%), and White (21%; 95% CI 10%, 32%) students in the intervention district relative to the comparison district. Vaccine coverage was higher among Black/African American (6%; 95% CI −2%, 14%) and multiple race (6%; 95% CI −2%, 14%) students, with more vaccinated students in the intervention district.

3.2. Reason for vaccine non-receipt

Among caregivers of students who were not vaccinated for influenza, those of Black/African American students and multiple race students were more likely to cite non-belief as a reason for vaccine non-receipt. (Fig. 4) Frequency of non-belief was slightly lower in the intervention district (Black/African American: 68.5%, Multiple: 72.9%) than in the comparison district (Black/African American: 85.1%, Multiple: 76.6%)Among caregivers citing reasons of non-receipt relating to non-belief, we found that concerns of safety were more common than concerns of effectiveness in both the intervention (Safety: 57.0%, Effectiveness: 30.4%, N = 405) and comparison (Safety: 57.9%, Effectiveness: 27.1%, N = 963) districts (Table S3).

Caregivers of White, Hispanic/Latino, and Asian/Pacific Islander students in the intervention district less commonly reported logistical barriers to vaccination (White: 25.6%, Hispanic/Latino: 24.6%, Asian/Pacific Islander: 30.1%). These barriers were reported more often in the comparison district in these groups (White: 44.60%, Hispanic/Latino: 38.6%, Asian/Pacific Islander: 39.5%).

SLIV-specific concerns were most common among Asian/Pacific Islander (29.5%) and Hispanic/Latino (28.2%) students in the intervention district.

Schools with a prevalence of non-belief in influenza vaccination above the district median had a higher percentage of White, Black/African American, and multiple race students and a lower percentage of English learners and students eligible for free lunch in both districts (Table S4). Schools with a prevalence of logistical barriers above the district median had a higher percentage of English learners and students eligible for free lunch in both districts, and a higher percentage of Hispanic/Latino students in the comparison district.

3.3. Laboratory-confirmed influenza hospitalization

The incidence of influenza hospitalizations varied by race/ethnicity (Figure S2). These differences were most pronounced during the 2016–17 and 2017–18 seasons, which had more higher rates of influenza. In both seasons, the incidence of all-age, older adult, and non-elementary hospitalization for influenza in each district was highest among Black/African Americans. In 2017–18, the cumulative incidence of hospitalizations among Black/African Americans in the intervention district (111 per 100,000) was about three times higher than the cumulative incidence among White and Asian/Pacific Islanders (36 per 100,000). Similarly, the cumulative incidence among Black/African Americans in the comparison district (134 per 100,000) was nearly twice as high as the cumulative incidence among Whites and Asian/Pacific Islanders (73 per 100,000). The cumulative incidence of influenza hospitalizations of Hispanics was relatively low, at 32 hospitalizations per 100,000 in the intervention district and 43 per 100,000 in the comparison district.

Associations between SLIV and influenza hospitalizations varied by race/ethnicity (Fig. 5, Fig. S3). We observed fewer all-age influenza hospitalizations in the intervention district among Whites and Asian/Pacific Islanders in the 2016–17 season (DID of −25.1 per 100,000 between intervention and comparison districts; 95% CI −40.1, −10.1) and in the 2017–18 (−36.6; 95% CI −52.7, −20.5) season, the seasons when the influenza vaccine was moderately effective. Among older adults, we found large, protective DIDs among Whites and Asian/Pacific Islanders in the 2016–17 (−116.1; 95% CI −205.7–26.5) and 2017–18 (−133.9; 95% CI −225.5, −42.2) seasons and among Black/African Americans during the 2017–18 (−282.3; 95% CI −508.4, −56.1) season. Hispanics experienced a smaller DID in all-age hospitalizations (2017–18: −12.1; 95% CI −31.5, 7.4), but the incidence of influenza hospitalizations was lower in the intervention district relative to the comparison district.

4. Discussion

We assessed the variation in the impact of a city-wide SLIV program on influenza vaccine coverage and influenza-related hospitalizations by race and ethnicity. We found associations between SLIV and higher vaccine coverage among elementary school children in all racial/ethnic groups during the 2016–17 and 2017–18 seasons, when there was a moderately effective vaccine and larger seasonal epidemics. However, influenza vaccine coverage remained lower among Black/African American students compared to other groups. Associations between SLIV and higher vaccination coverage were largest among Hispanic/Latino and White students.

Among unvaccinated students, fewer caregivers reported logistical barriers in the intervention district than in the comparison district across all racial/ethnic groups. Nonbelief in the influenza vaccine was over twice as common as reported logistical barriers in all groups and was most common among Black/African American and White caregivers.

SLIV was associated with fewer influenza hospitalizations among Whites and Asian/Pacific Islanders in years when the influenza vaccine was moderately effective. Despite associations between SLIV and higher vaccine coverage in Black/African American over two seasons, we observed protective associations with influenza hospitalizations only in this group in older adults in one season.

SLIV has the potential to increase equity of vaccine coverage by reducing logistical barriers to vaccination that are more common in communities of color [3,26]. Prior studies attributed low influenza vaccine coverage among Hispanics/Latinos to limited accessibility and affordability [3,27,28]. In our study, logistical barriers were reported more common by caregivers of children in comparison district schools, where more students were English Learners or qualified for free lunch (a proxy for lower socioeconomic status). This was not the case in the intervention district and may suggest that SLIV helped reduce logistical barriers to influenza vaccination for students in schools with lower socioeconomic status. However, 22% of caregivers of unvaccinated students in the intervention district still reported logistical barriers. Taken together, these findings suggest that intervention reduced, but did not eliminate logistical barriers to vaccination.

In both districts, nonbelief in influenza vaccination was a more common reason students were not vaccinated than logistical barriers; however, non-belief was slightly less common in the intervention district. Nonbelief was common across all racial/ethnic groups but was most common among Black/African American, multiracial, and White caregivers. Non-belief stems from beliefs and historical contexts that vary by race/ethnicity. Among Black/African Americans, current institutional racism, as well as discrimination, exploitation, and abuse in medical practice and research contributes to distrust of medical institutions and vaccine hesitancy [6,29-32]. Vaccine hesitant White populations tend to be affluent, have low perceived severity of influenza, and experience lower incidence of severe influenza morbidity [33,34]. In groups with greater vaccine hesitancy, variation in the effectiveness of influenza vaccines between seasons may have a stronger impact on coverage. For example, we observed a larger decline in vaccination coverage in 2016–17, when only IIV was offered after two years when LAIV was ineffective, among Black/African American students compared to other groups.

Our findings highlight a challenge to SLIV programs: increasing access to influenza vaccinations though school-based programs by itself does not address vaccine hesitancy. To achieve equitable improvements in influenza vaccine coverage, SLIV programs may need to be tailored to address concerns and beliefs of specific school communities. In prior studies, targeted, culturally-sensitive outreach campaigns that addressed the specific concerns and needs of communities and that empowered them to make informed health decisions on their own terms were more successful in increasing vaccination rates across groups [11,35-37].

Prior studies have found that groups with higher influenza vaccine coverage have fewer influenza hospitalizations [20,38]. However, in our study, even though SLIV was associated with higher vaccination coverage in Black/African Americans, the incidence of influenza related hospitalizations remained higher than that of other groups. Similarly, for Hispanics/Latinos, improvements in vaccination coverage did not translate to lower influenza hospitalization. Increases in vaccine coverage among this group in the SLIV site were smaller relative to increases for Whites and may not have been large enough to translate to lower rates of influenza hospitalization in these groups. Structural racism contributes to persistent barriers to vaccination and access to medical care in Black and Hispanic/Latino communities [39-41], and may be associated higher prevalence of comorbid conditions in these groups, which may have resulted in the disparities in the impact of SLIV on influenza hospitalization [42].

SLIV shows promise for the delivery of other vaccines, such as SARS-CoV-2 vaccines. Black, Hispanic/Latinos, and American Indians/Alaska Natives were more likely to experience severe COVID-19 illness than Whites and faced structural barriers to vaccination during early SARS-CoV-2 vaccination efforts [43-45]. Vaccinating children will be crucial in protecting communities from COVID-19 outbreaks. Once SARS-CoV-2 vaccines receive approval for use in children, SLIV may be effective at increasing vaccine coverage levels and increasing equity of vaccination coverage.

4.1. Limitations

Our study is subject to several limitations. Student influenza vaccination history was reported by caretakers and may be subject to poor recall. Measurements during the 2014–15 and 2015–16 influenza seasons had longer recall periods and may be more prone to error. There may have been differential accuracy of recall between the intervention and comparison districts because the presence of SLIV could have improved caregivers' ability to correctly remember their child's vaccination history However, in our assessment of the consistency of caregiver-reported vaccination in surveys with overlapping recall periods, concordance levels were high and similar between districts.

Additionally, we did not have access to personal identifiers in any dataset, so we could not directly link individual vaccination status with laboratory-confirmed influenza hospitalization. However, Since the intervention was delivered at the city-level, our goal was to estimate community-wide rather than individual-level associations, and our results capture associations among both vaccinated and unvaccinated individuals.

Similar to other epidemiologic studies of vaccination, we saw higher levels of non-response among Black/African American students [46,47]. If those who did not respond to the survey were also less likely to have been vaccinated, our results may have underestimated the true disparities in vaccination between Black/African American students and other racial/ethnic groups. However, we previously standardized vaccine coverage models by school-district race distributions and did not find evidence of selection bias [20]. In addition, our estimates of overall vaccine coverage were consistent with national and state data reported by the United States Centers for Disease Control and Prevention [48,49].

Differences in race/ethnicity classification between data sources may impact the interpretability of our results. In the caregiver surveys, we conflated race and ethnicity such that "Hispanic/Latino" was treated as an independent group from "White", "Black/African American" and "Asian/Pacific Islander". The CEIP and United States Census Bureau separately records race and Hispanic ethnicity. As a result, the "Hispanic/Latino" population we describe in the vaccine coverage analysis is not the same as CEIP or Census designations.

Changes in health care utilization over time could have influenced estimates for the incidence of influenza hospitalization [50]. In this study, the first year of the intervention coincided with expanded coverage of preventative care under the Affordable Care Act. However, the matched cohort design and DID analysis controlled for time-invariant confounding variables, and it is unlikely that policy changes impacted the two study districts differently.

5. Conclusion

After four years of implementation, SLIV was associated with higher influenza vaccine coverage in school age students during seasons with a moderately effective vaccine, but racial/ethnic disparities in vaccine coverage were present with the largest differences observed among White and Hispanic/Latino students. Associations between SLIV and lower rates of influenza hospitalizations varied by race and ethnicity but were not consistent with the relative improvements in vaccination coverage by race and ethnicity. We did not observe associations between SLIV and reductions in the incidence of all-age hospitalization despite higher vaccine coverage among the Black/African American and Hispanic/Latino communities, although reductions in the incidence of hospitalizations among Black/African American older adults were observed in the 2017–18 season. Future SLIV programs may benefit from tailored campaigns to address race/ethnicity-specific beliefs, concerns, and structural factors that contribute to lower vaccine coverage.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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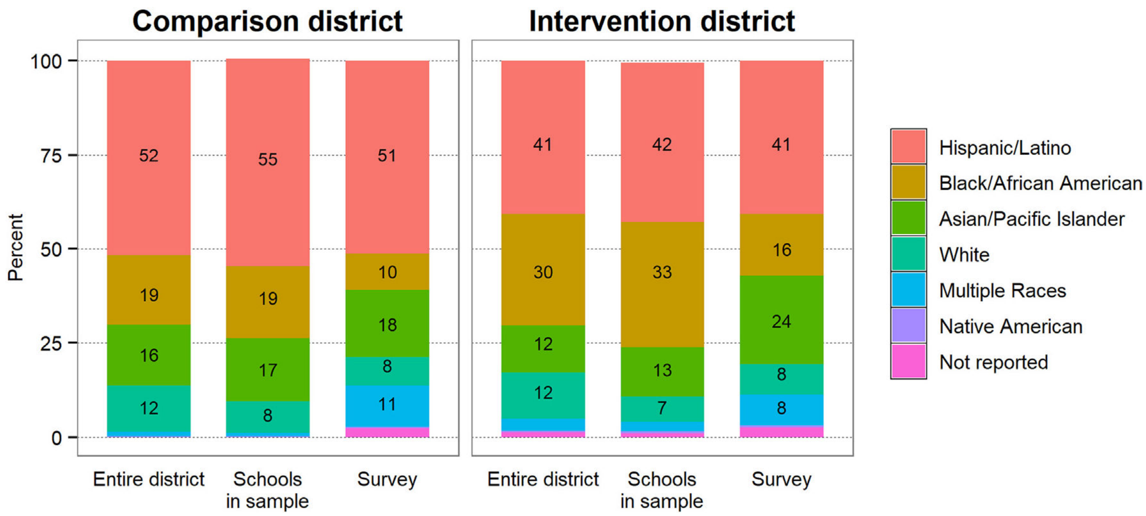

Fig. 1.

Distribution of student race/ethnicity among school district, sampled schools, and survey respondents. Distribution of student race/ethnicity across the district, sampled schools, and survey responses in each school district in March 2017.

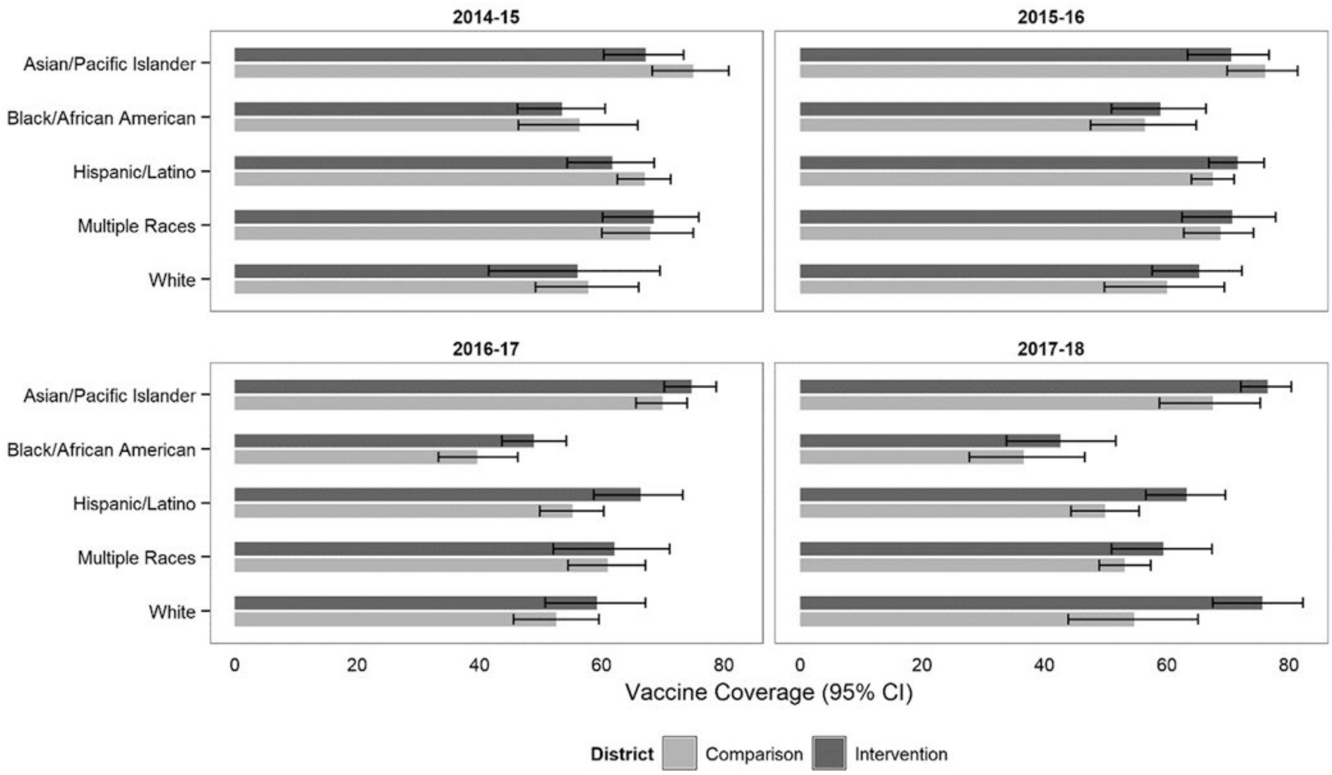

Fig. 2.

Vaccination coverage levels by race among students in the comparison and intervention districts. Percent of students vaccinated in the intervention district and percent of students vaccinated in the comparison district, adjusted for highest parental education level. Estimates calculated from caregiver surveys in March 2017 (for the 2014–15, 2015–16, 2017–18 seasons) and March 2018 (for the 2017–18 season). Standard errors calculated with respect to school-level clustering.

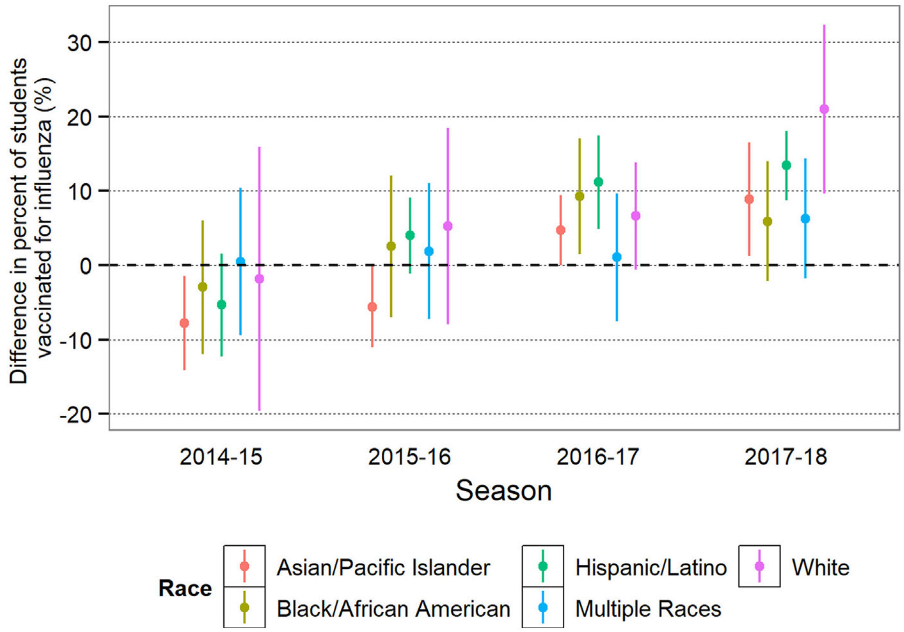

Fig. 3.

Differences in vaccination coverage among students enrolled in the intervention versus comparison district between 2014 and 2018. Difference in the percent of students vaccinated in the intervention district and percent of students vaccinated in the comparison district, adjusted for highest parental education level. Estimates calculated from caregiver surveys in March 2017 (for the 2014–15, 2015–16, 2017–18 seasons) and March 2018 (for the 2017–18 season). Standard errors calculated with respect to school-level clustering.

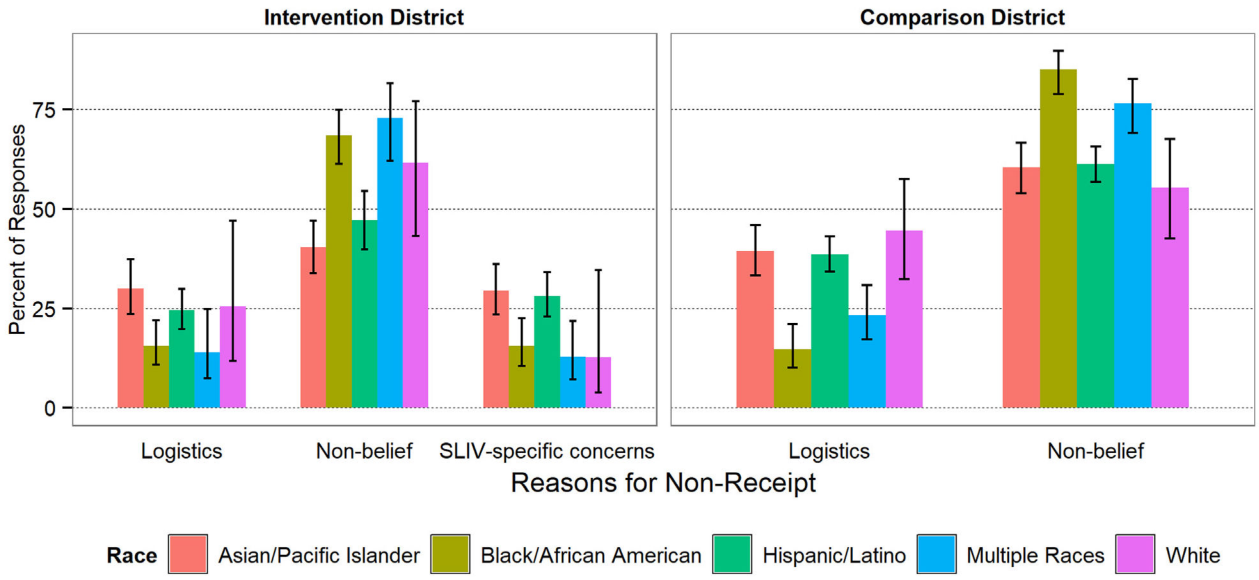

Fig. 4.

Caregiver-reported reasons for non-receipt of influenza vaccination among students during the 2017–18 season. Estimated percent of caregivers of non-vaccinated children that responded with the specified reason for non-receipt within each racial/ethnic group, calculated from survey data filled out by student caregivers in March 2018 (for the 2017–18 season). Questions corresponding to each category listed in Supplement 9.

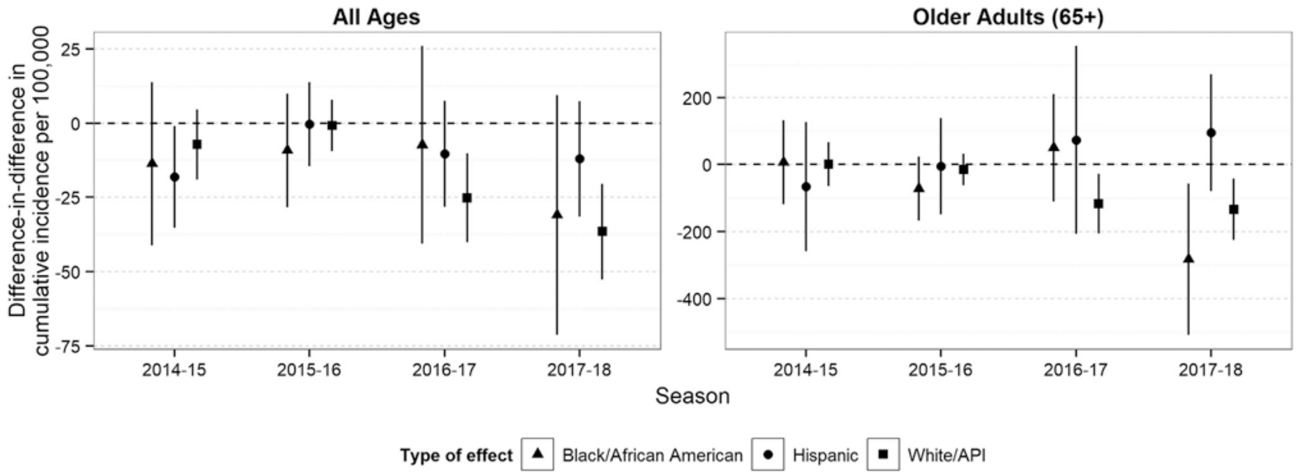

Fig. 5.

Difference-in-differences in the cumulative incidence of influenza-related hospitalizations per 100,000 in the intervention district versus comparison district, by age group and race. Difference in the difference in cumulative incidence per 100,000 of hospitalization between the intervention season and pre-intervention period in the intervention district versus the difference in cumulative incidence of hospitalization between the intervention season and pre-intervention period in the comparison district. Estimates calculated from influenza surveillance data provided by the California Emerging Infections Program.

Table 1

Pre-intervention characteristics of the intervention (Oakland, California) and comparison (West Contra Costa County, CA) district catchment areas for the three-year period between 2011 and 2013.

Characteristic	Intervention (95% CI)	Comparison (95% CI)
Median household income (dollars)	51,849 (50460, 53238)	61,596 (59662, 63530)
Households below the poverty level (%)	21 (20, 22)	15 (13, 16)
Highest education level (%)		
Less than high school	16 (15, 18)	14 (12, 17)
High school graduate	24 (21, 26)	30 (25, 34)
Some college or Associate’s	46 (43, 48)	50 (46, 55)
Bachelor’s degree or higher	15 (12, 17)	6 (4, 8)
Children attending kindergarten in private versus public schools (%)		
Public kindergarten	87 (81, 92)	86 (80, 92)
Private kindergarten	13 (8, 19)	14 (8, 20)
Children attending grade 1–4 in private versus public schools (%)		
Public grades 1–4	89 (86, 92)	84 (79, 88)
Private grades 1–4	11 (8, 14)	16 (12, 21)
Children attending grade 5–8 in private versus public schools (%)		
Public grades 5–8	89 (86, 91)	87 (83, 91)
Private grades 5–8	11 (9, 14)	13 (9, 17)
Race (%)		
White	41 (40, 42)	48 (47, 50)
Black or African American	26 (25, 27)	17 (16, 18)
Asian	16 (16, 17)	19 (18, 20)
Other race	9 (8, 10)	8 (7, 9)
Native Hawaiian and Other Pacific Islander	1 (0, 1)	0 (0, 1)
Two or more races	6 (6, 7)	6 (5, 7)
Hispanic or Latino ethnicity	26 (25, 27)	33 (32, 35)

Table reproduced from Benjamin-Chung et al (2020).[20] Data source: 2013 American Community Survey for the 3-year period between 2011 and 2013.

Table 2

Distribution of student race/ethnicity reported on caregiver surveys.

	2017				2018			
	Intervention		Comparison		Intervention		Comparison	
Race/Ethnicity	**N**	**Percent**	**N**	**Percent**	**N**	**Percent**	**N**	**Percent**
White	180	8.0	292	7.6	188	7.8	324	7.9
Black/African American	367	16.3	371	9.7	398	16.4	402	9.8
Hispanic/Latino	916	40.8	1961	51.3	869	35.9	2055	50.3
Asian/Pacific Islander	529	23.6	678	17.7	643	26.6	737	18.0
Native American	11	0.5	17	0.4	17	0.7	24	0.6
Multiple Races	183	8.2	415	10.9	243	10.0	454	11.1
Missing	60	2.7	90	2.4	63	2.6	90	2.2

Distribution of student race/ethnicity among survey responses in each school district, as reported by caregivers in March 2017 and March 2018. Distribution of race/ethnicity among multiple race students is reported in Table S1 in the supplemental materials.