

## **Inequities in COVID-19 vaccination rates among adolescents in Massachusetts: a cross-sectional study**

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**Summary:** In Massachusetts communities, lower income, early adolescent and adult vaccinations, and higher proportion of Black or Hispanic individuals correlated with lower adolescent vaccination rates later. Prior to the roll-out of COVID-19 vaccination programs, planners should lay groundwork targeting such communities.

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## **Abstract**

**Background:** The COVID-19 pandemic has disproportionately affected more socioeconomically disadvantaged persons and areas. We sought to determine how certain sociodemographic factors were correlated to adolescents' COVID-19 vaccination rates in towns and cities ("communities") in the Commonwealth of Massachusetts.

**Methods:** Data on COVID-19 vaccination rates were obtained over a 20-week period from March 30, 2021 to August 10, 2021. Communities' adolescent (ages 12-19) vaccination rates were compared across quintiles of community-level income, COVID-19 case rate, and proportion of non-Hispanic Black or Hispanic individuals. Other variables included population density and earlier COVID-19 vaccination rates of adolescents and adults, averaged from March 30 to May 11 to determine their effects on vaccination rates on August 10. Linear and logistic regression was used to estimate individual effects of variables on adolescent vaccination rates.

### **Results:**

Higher median household income, lower proportion of Black or Hispanic individuals, higher early adolescent COVID-19 vaccination rates, and higher early adult COVID-19 vaccination rates were associated with higher later adolescent COVID-19 vaccination rates. Income per \$10,000 (adjusted odds ratio=1.01 [95% confidence interval=1.01-1.02]), proportion of Hispanic individuals (1.33 [1.13-1.56]), early adolescent COVID-19 vaccination rates (5.28 [4.67-5.96]), and early adult COVID-19 vaccination rates (2.31 [2.02-2.64]) were associated with higher adolescent COVID-19 vaccination on August 10, while proportion of Black individuals approached significance (1.26 [0.98-1.61]).

**Conclusions:** Vaccination efforts for adolescents in Massachusetts should focus on boosting vaccination rates early in communities with the lowest incomes and greatest proportion of Hispanic individuals and consider targeting communities with a greater proportion of Black individuals.

**Keywords:** COVID-19; adolescents; Massachusetts; health disparities

**Abbreviations**

- COVID-19: coronavirus disease 2019
- US: United States
- SVI: Social Vulnerability Index
- MDPH: Massachusetts Department of Public Health

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## INTRODUCTION

As of January 20, 2022, 10.6 million US children tested positive for COVID-19, making vaccination of this population a crucial goal [1-2]. Among adults, COVID-19 has disproportionately affected lower-income communities that have also seen lower vaccination rates [3-4]. According to the Centers for Disease Control and Prevention, counties that rank high on the Social Vulnerability Index (SVI) have lower vaccination rates than counties that rank lower on this index. Median household income is one component of the SVI [5].

Herein, in Massachusetts towns and cities (communities), we examined the relationship between community level median household income, population density, race/ethnicity, COVID-19 case rates, early adolescent COVID-19 vaccination rates, and adult COVID-19 vaccination rates on rates of adolescent COVID-19 vaccination as of August 10, 2021. We anticipated that this analysis could uncover lessons to be learned for the rest of the country, where vaccination rates remain relatively low for 12- to 19-year-olds. This analysis could also deepen the understanding of structural barriers in vaccinating the 28 million children ages 5 to 11, an initiative which began nationally in early November 2021.

## METHODS

“Adolescents” were defined as individuals ages 12-19 years old and “adults” ages  $\geq 20$  years. COVID-19 vaccination rates were analyzed for adolescents receiving at least one dose and for adults fully vaccinating against COVID-19, which at the time of this investigation, meant receiving two COVID-19 vaccinations. At the inception of this investigation, many adolescents would have had the opportunity to be vaccinated only once whereas most adults would have had an opportunity for two shots.

We focused our analysis on Massachusetts for several reasons. COVID-19 vaccination data for adolescents were released weekly by the Massachusetts Department of Public Health (MDPH) for 335/351 towns and cities (henceforth termed “communities”) beginning March 30, 2021 and then specified by age (12-15, 16-19 years) beginning May 20 and ending August 10, 2021. Data discussed herein will generally refer to the combined vaccination data of adolescents (individuals ages 12-19 years old), although we do note vaccination rates of the 12–15- and 16–19-year-old subgroups in Table I. Additionally, the US Census utilizing American Community Survey data from 2014-2019 collected community-level data on income and race/ethnicity, while the MDPH collected community-level data on COVID-19 case rates since January 2020 [6-7].

Weekly COVID-19 vaccination rates were available for all 335 communities, which were subsequently divided into equal quintiles (67 communities in each income group) by consecutive decreasing income and another group of equal quintiles by consecutive decreasing COVID-19 case rate. Income Group 1, Income Group 2, Income Group 3, Income Group 4, and Income Group 5 had average weighted household incomes of: \$142,612, \$103,593, \$87,360, \$73,179, and \$53,840 respectively.

We also utilized these 10 groups, five based on income quintiles and another five based on case rate quintiles, to analyze differences in COVID-19 vaccination rates among adults. Similar to adolescents, COVID-19 vaccination rates for adults were analyzed between March 30, 2021 and August 10, 2021 for 335 communities in Massachusetts.

Case rate was defined as the number of COVID-19 cases from January 1, 2020 to April 30, 2021 divided by the community’s total population. Case Rate Group 1, Case Rate Group 2, Case Rate Group 3, Case Rate Group 4, and Case Rate Group 5 had average weighted case rates of: 11.86%, 7.95%, 6.26%, 4.87%, and 3.36% respectively.

We also analyzed adolescent COVID-19 vaccination rates based on race and ethnicity. Similar to income, 335 communities of Massachusetts with available adolescent COVID-19 vaccination data were split into equal quintiles based on the proportion of non-Hispanic Black individuals (“Black individuals”) or proportion of Hispanic individuals. These two race and ethnicity groups were analyzed independently because of the disproportionate impact of COVID-19 amongst these groups [8]. To obtain these quintiles, the proportions of Black individuals or the proportion of Hispanic individuals per community were ranked and separately divided into five equal quintiles by greatest to lowest proportion of Black individuals or Hispanic individuals. Communities within these quintiles were then aggregated to obtain an overall proportion of Black or Hispanic individuals per quintile. The COVID-19 vaccination rates of adolescents were then analyzed over the same 20-week period between March 30, 2021 and August 10, 2021. Proportion Black Group 1, Proportion Black Group 2, Proportion Black Group 3, Proportion Black Group 4, and Proportion Black Group 5 had proportions of Black individuals as: 12.7%, 2.7%, 1.5%, 0.7%, and 0.1%, and Proportion Hispanic Group 1, Proportion Hispanic Group 2, Proportion Hispanic Group 3, Proportion Hispanic Group 4, and Proportion Hispanic Group 5 had proportions of Hispanic individuals as: 19.9%, 5.0%, 3.3%, 2.3%, and 1.1%, respectively.

Statistical analyses were conducted in R-4.0.3, with significance determined at  $P < 0.05$  [9]. Chi square testing was used for comparing differences in weekly vaccination rates between income, case rate, and race/ethnicity groups; Mann-Kendall Trend Test for detecting trends in vaccination rates; and two-sample t-test to detect differences in increases in vaccination rates. Linear regression was also performed to determine how individual communities’ median income, population, race/ethnicity, COVID-19 case rates, and early COVID-19 vaccination rates of adolescents and adults (obtained as average COVID-19 vaccination rates between March 30, 2021 and May 11, 2021) were associated with

adolescent vaccination rates on August 10, 2021. Multivariable logistic regression analysis was performed and provided crude odds ratios (OR) and adjusted odds ratios (aOR) with corresponding 95% confidence intervals (95% CI) for each of the aforementioned variables.

## RESULTS

By August 10, 2021, across 335 Massachusetts communities, 63% of adolescents had received at least one dose, and 73% of adults were fully vaccinated (Table I).

*Adolescent COVID-19 vaccination rates by income:* From March 30 to August 10, 2021, adolescents' COVID-19 vaccination rates were lower every week in communities with lower income versus those with higher income ( $P<0.001$ ) (Figure 1). From March 30 to August 10, 2021, the rate of adolescent COVID-19 vaccinations increased from 2% to 50% for the lowest income communities compared with 5% to 86% in the highest income communities as of August 10. In particular, within two weeks of adolescent data being released, on April 13, 2021, only 5% of adolescents ages 16-19 were vaccinated in the 67 lowest income communities versus 14% in the 67 highest income communities. After six weeks, on May 11, 2021, only 16% of adolescents in the 67 lowest income communities versus 35% in the 67 highest income communities had been vaccinated. By August 10, 2021, nearly 71,000 more adolescents from the 67 lowest income communities would need to be vaccinated against COVID-19 to improve from the average rate of 50% to an equivalent 86% of adolescents vaccinated in the 67 highest income communities.

*Adult COVID-19 vaccination rates by income:* Similar to the trends found for income and adolescent vaccination rates, adults in the lowest income communities had the lowest COVID-19 vaccination rates throughout the entire period (March 30 to August 10, 2021) compared to quintiles of other communities with higher incomes ( $P<0.001$ ). By August 10, 151 communities had adult COVID-19 vaccination rates below the state-wide average; of

these 151 communities, 109/151 (72.2%) also had adolescent COVID-19 vaccination rates below the state-wide average.

*Adolescent and adult COVID-19 vaccination rates by case rates:* COVID-19 vaccinations were lower among adolescents in communities most impacted by COVID-19 compared to those communities less impacted, particularly those communities in the quintile with the lowest case rates of COVID-19 (54% rate of vaccinations for communities with highest COVID-19 case rates vs. 82% for lowest COVID-19 case rates) ( $P<0.001$ ). A similar pattern was seen for adults, whose COVID-19 vaccination rates were lowest in the highest vs. lowest quintiles of COVID-19 case rates (69% vs. 75% of adults fully vaccinated,  $P<0.001$ ). Trend analysis revealed that vaccinations increased across all communities regardless of income or case rate from March 2021 to August 2021 ( $P<0.001$ ).

*Adolescent COVID-19 vaccination rates by race/ethnicity:* The proportion of adolescents vaccinated against COVID-19 in the 67 communities with the greatest proportion of Black or Hispanic individuals consistently had the lowest COVID-19 vaccination rates throughout the study's timeframe ( $P<0.001$ ) (Figures 2-3). In particular, by August 10, 2021, although vaccination rates were approximately equal amongst the four quintiles of communities with the lowest proportion of Black (ranging from 68% to 73%) or Hispanic individuals (69% to 76%), only 55% and 54% of adolescents in the quintile of communities with the highest proportion of Black or Hispanic individuals, respectively, were vaccinated against COVID-19. Adolescent COVID-19 vaccination rates among Black or Hispanic individuals also increased more slowly (from 3% to 55% and 3% to 54%, respectively) than that of non-Hispanic White (5% to 71%) and Asian (4% to 67%) individuals ( $P<0.001$ ).

In the linear regression, with the community as the unit of analysis, median income ( $\beta=0.011$ ), proportion of Hispanic individuals ( $\beta=0.28$ ), average adolescent COVID-19

vaccination rates prior to May 12, 2021 ( $\beta=1.66$ ), and average adult COVID-19 vaccination rates prior to May 12, 2021 ( $\beta=0.84$ ) were associated with higher COVID-19 vaccination rates among adolescents ages 12-19 years old on August 10, 2021 ( $P<0.001$ ). Proportion of Black individuals approached significance ( $\beta=0.23$ ,  $P=0.07$ ), while case rate ( $\beta=0.32$ ,  $P=0.20$ ) and population per 1,000 individuals ( $\beta=-0.0001$ ,  $P=0.28$ ) were not significant.

For example, a community with a median household income of \$104,000, would have an 11% higher adolescent vaccination rate than a community with a median income of \$87,360. After adjusting for other predictors for adolescent COVID-19 vaccination, income per \$10,000 (aOR=1.01 [95% CI=1.01-1.02]), proportion of Hispanic individuals (1.33 [1.13-1.56]), early adolescent COVID-19 vaccination rates (5.28 [4.67-5.96]), and early adult COVID-19 vaccination rates (2.31 [2.02-2.64]) were associated with increased adolescent COVID-19 vaccination rates on August 10<sup>th</sup>, while proportion of Black individuals approached significance (1.257 [0.980-1.613]). (Table II). There was no independent effect of population or total population case rate on adolescent COVID-19 vaccination rates.

## DISCUSSION

With the national rollout of the COVID-19 vaccine for children ages 5-11 currently ongoing, it is important to draw lessons from the earlier, separate rollouts for 12-15- and 16-19-year-olds. Among noteworthy findings, we found that communities with higher COVID-19 vaccination rates for adolescents and adults soon after the vaccine became available had adolescent COVID-19 vaccination rates that were greater many months later. Therefore, prior to the actual roll-out of a COVID-19 vaccination program, planners should lay the groundwork in communities with lower income and higher proportion of Hispanic and Black individuals [10].

Childhood vaccination rates in Massachusetts are some of the highest in the country. For the 2020-2021 school year 93.8% of children had received all the required vaccinations prior to kindergarten entry and 88.2% prior to 7<sup>th</sup> grade entry [11-12]. One vaccine that is typically associated with decreased vaccination rates is the human papilloma virus (HPV) [13]. In this study, as of August 2021, rates of COVID-19 vaccinations of adolescents (63%) lagged behind vaccination rates in 2020 of individuals ages 13-17 years old who had completed the HPV series (73%) [14]. Similar to our findings, vaccination rates tend to lag in communities of decreased socioeconomic status and in Black children, making these communities important targets [13].

There are limitations to this study. Our analysis is limited to one state, and we do not have information on all potential confounding factors, such as family size. More generally, this analysis was based on community-level data, and we do not have the actual measures for each adolescent in the community; information that is not available from the Department of Public Health. Thus, in our ecologic analysis, there may have been some error in estimating the effects of measures on COVID-19 vaccination rates.

It is also worth noting that approval for the Pfizer-BioNTech COVID-19 vaccine for 16-to-19-year-olds began in December 2020 and was available as of April 19, 2021; the vaccine became available for 12-to-15-year-olds on May 10, 2021. However, because adolescents with co-morbidities were able to get the vaccine at the same time as adults, the MDPH began reporting vaccinations for children ages 0 to 19 in March 2021. We noted that disparities in vaccine utilization by income of the community were apparent soon after the “age by community-specific rates” were first reported for adolescents.

Concentrating efforts in low-income communities represent opportunities to increase COVID-19 vaccination equity for adolescents. Vaccines were available during this period in

Massachusetts in physician offices, pharmacies, community hospitals, and through Boards of Health. We propose a broader multi-pronged plan of vaccinating parents and caretakers against COVID-19, providing adequate COVID-19 vaccine supply to physicians including pediatricians and family physicians, employing vaccinated teen ambassadors to counter disinformation, promoting a TV/radio/social media campaign directed to hesitant parents, employing more pop-up clinics where teens congregate such as recreational sites, and using open school buildings to deepen the penetration of adolescent COVID-19 vaccinations. Such initiatives must focus on the thousands of unvaccinated adolescents in the 67 lowest income communities and now the 400,400 children in Massachusetts ages 5 to 19 who have yet to be vaccinated [15].

Lessons learned from this attempt to successfully vaccinate adolescents may provide valuable lessons for vaccinating the next wave of younger children. In particular, federal agencies and state planners must embark on a broad-scale public service campaign highlighting parents, pediatricians, and the aforementioned sub-groups to motivate the nearly two-thirds of parents who have initial hesitancy about vaccinating against COVID-19 their children ages 5 to 11 [16]. There has been much confusion over current messaging about COVID-19 vaccine safety and efficacy. However, the data are clear that regardless of age and medical history, the risk of severe adverse effects from COVID-19 vaccination, particularly for those ages five and older, is always lower than complications from the virus itself. The messaging needs to be simple, clear, and widespread such that nearly all parents will want to choose vaccination for their child.

In conclusion, as vaccination efforts in Massachusetts increase for both adolescents and children in the 5 to 11 year old age group, such multi-pronged efforts should focus on promoting positive messages about vaccines and providing multiple access points as early as possible in communities with the lowest incomes, while also consider targeting communities with a greater proportion of Hispanic and Black individuals. Similar campaigns can also target these communities prior to the rollout of vaccinations for children less than 5 years old. Such efforts may contribute to increased vaccination equity between towns and cities with differing sociodemographic factors.

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## Tables and Figures

Table I. Average demographics and adolescent/adult vaccination rates in 335 communities (towns/cities) of Massachusetts

<b>Average socioeconomic demographics and vaccination rates per town/city (community)<sup>a</sup></b>	<b>n (%)</b>
<b>Communities</b>	335
<b>Race/Ethnicity</b>	
Non-Hispanic White	14,560 (72%)
Hispanic	2,407 (12%)
Non-Hispanic Black	1,408 (6.9%)
Asian	1,338 (6.6%)
Other	638 (3.1%)
<b>Average state-wide income<sup>b</sup></b>	\$86,431
Income Group 1	\$142,612
Income Group 2	\$103,593
Income Group 3	\$87,360
Income Group 4	\$73,179
Income Group 5	\$53,840
<b>Coronavirus disease-19 case rate<sup>c</sup></b>	9.0%
Case Rate Group 1	11.9%
Case Rate Group 2	8.0%
Case Rate Group 3	6.3%

Case Rate Group 4	4.9%
Case Rate Group 5	3.4%
<b>Population by age</b>	
Overall per community	20,352
12-15 years	959 (4.7%)
16-19 years	1,122 (5.5%)
12-19 years	2,081 (10.2%)
≥20 years	16,000 (78.6%)
<b>Average state-wide vaccination rates on May 11, 2021<sup>d</sup></b>	
Adolescents (12-19 years) receiving at least one dose of the COVID-19 vaccine	551 (10.4%)
Adults (≥20 years) receiving two doses of the COVID-19 vaccine	8,583 (53.6%)
<b>Average state-wide vaccination rates on August 10, 2021<sup>e</sup></b>	
12-15 years	653 (62.0%)
16-19 years	784 (64.1%)
Adolescents (12-19 years)	1,311 (63.0%)
Adults (≥20 years)	11,603 (72.5%)

<sup>a</sup>Socio-economic demographics and vaccination rates are weighted by population per town/city (community) then subsequently averaged to obtain a state-wide average.

<sup>b</sup>335 communities of Massachusetts were analyzed in equal quintiles of 67 communities based solely on income level

<sup>c</sup>335 communities of Massachusetts were analyzed in equal quintiles of 67 communities based solely on highest to lowest COVID-19 rates from January 1, 2020 to April 30, 2021

<sup>d</sup>Adolescent vaccinations refer to 12–19-year-old individuals who received at least one dose of the COVID-19 vaccination. Adult vaccinations refer to  $\geq 20$ -year-old individuals who have received two doses against COVID-19. Numerical averages refer to state-wide average of vaccinated persons across communities, while percentages refer to proportion of total state-wide adolescent or adult population that was vaccinated.

<sup>e</sup>Delineations between 12-15 years and 16-19 years were made in data sets released by the Massachusetts Department of Public Health on May 12<sup>th</sup>, 2021 and afterwards.

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Table II: Effects of unadjusted and adjusted variables on adolescent vaccination rates in week of August 10, 2021

<u>Main Effects:</u>	<u>Income<sup>a</sup></u>	<u>Total population<sup>b</sup></u>	<u>Proportion of non-Hispanic Black individuals (%)</u>	<u>Proportion of Hispanic individuals (%)</u>	<u>Case rate (%)</u>	<u>Early adolescent vaccination rate (%)</u>	<u>Early adult vaccination rate (%)</u>
Unadjusted OR (95% CI):	<b>1.026 (1.018-1.034)<sup>d</sup></b>	<b>0.991 (0.985-0.997)</b>	0.600 (0.339-1.062)	<b>0.587 (0.433-0.796)</b>	0.072 (0.032-1.161)	<b>7.289 (6.353-8.363)</b>	<b>4.850 (3.970-4.850)</b>
Following adjustment with co-variables:							
+Income <sup>a</sup>	-	<b>0.993 (0.988-0.999)</b>	0.840 (0.485-1.453)	0.771 (0.568-1.046)	<b>0.122 (0.055-0.270)</b>	<b>6.623 (5.840-7.510)</b>	<b>5.148 (4.116-6.439)</b>
+Total population <sup>b</sup>	<b>1.025 (1.017-1.032)</b>	-	1.143 (0.626-	0.859 (0.622-1.186)	<b>0.138 (0.060-</b>	<b>6.676 (5.876-7.584)</b>	<b>5.052 (4.036-6.325)</b>

			2.088)		<b>0.316)</b>		
+Proportion of non-Hispanic Black individuals (%)	<b>1.025 (1.017-1.033)</b>	<b>0.993 (0.986-0.999)</b>	-	0.850 (0.614-1.177)	<b>0.114 (0.049-0.269)</b>	<b>6.696 (5.897-7.604)</b>	<b>5.070 (4.049-6.347)</b>
+Proportion of Hispanic individuals (%)	<b>1.024 (1.016-1.032)</b>	0.993 (0.987-1.000)	1.181 (0.644-2.166)	-	<b>0.057 (0.020-0.161)</b>	<b>6.919 (6.096-7.854)</b>	<b>5.140 (4.095-6.452)</b>
+COVID-19 case rate (%)	<b>1.023 (1.015-1.031)</b>	0.994 (0.988-1.000)	1.735 (0.956-3.150)	<b>1.556 (1.063-2.277)</b>	-	<b>7.296 (6.371-8.354)</b>	<b>4.872 (3.922-6.053)</b>
+Early adolescent vaccination rate (%) <sup>c</sup>	<b>1.019 (1.015-1.024)</b>	0.999 (0.995-1.002)	1.180 (0.869-1.601)	1.163 (0.957-1.414)	<b>1.863 (1.036-3.350)</b>	-	<b>2.307 (2.016-2.641)</b>
+Early adult vaccination rate (%)	<b>1.013 (1.009-1.016)<sup>e</sup></b>	0.999 (0.996-1.001)	1.257 (0.980-1.613)	<b>1.327 (1.130-1.558)</b>	1.371 (0.847-2.219)	<b>5.278 (4.670-5.965)</b>	-

OR= odds ratio; CI=confidence intervals;

<sup>a</sup> Income is measured per \$10,000

<sup>b</sup> Population is measured per 10,000

<sup>c</sup> Early adolescent vaccination rates were measured as average vaccination rates of adolescents between March 30 and May 11, 2021

<sup>d</sup> Significant values are bolded and determined as  $P < 0.05$

<sup>e</sup> Each covariate was added in sequential order of co-variables listed on the left-side of Table II. For example, the adjusted odds ratio of income on adolescent vaccination rates after adjusting for total population, proportion of non-Hispanic Black individuals, proportion of Hispanic individuals, COVID-19 case rate, early pediatric vaccination rates, and early adult vaccination rates was significant at aOR=1.013 (95% CI=1.009-1.016).

**Figure legends:**

**Figure 1.** Weekly adolescent vaccination rates by average weighted income. “Adolescent” was defined as individuals ages 12-19 years old. Data reflect those adolescents receiving one or more doses of the COVID-19 vaccine. Income Group 1, Income Group 2, Income Group 3, Income Group 4, and Income Group 5 had average weighted incomes of: \$142,612, \$103,593, \$87,360, \$73,179, and \$53,840 respectively.

**Figure 2.** Weekly Massachusetts adolescent vaccination rates by non-Hispanic Black race. “Adolescent” was defined as individuals 12-19 years. Data reflect those adolescents receiving one or more doses of the COVID-19 vaccine. Proportion Black Group 1, Proportion Black Group 2, Proportion Black Group 3, Proportion Black Group 4, and Proportion Black Group 5 had proportions of Black individuals compared to the entire quintile’s population as: 12.7%, 2.7%, 1.5%, 0.7%, and 0.1% respectively

**Figure 3.** Weekly Massachusetts adolescent vaccination rates by Hispanic ethnicity. “Adolescent” was defined as individuals 12-19 years. Data reflect those adolescents receiving one or more doses of the COVID-19 vaccine. Proportion Hispanic Group 1, Proportion Hispanic Group 2, Proportion Hispanic Group 3, Proportion Hispanic Group 4, and Proportion Hispanic Group 5 had proportion of Hispanic individuals compared to the entire quintile’s population as: 19.9%, 5.0%, 3.3%, 2.3%, and 1.1% respectively.

Figure 1

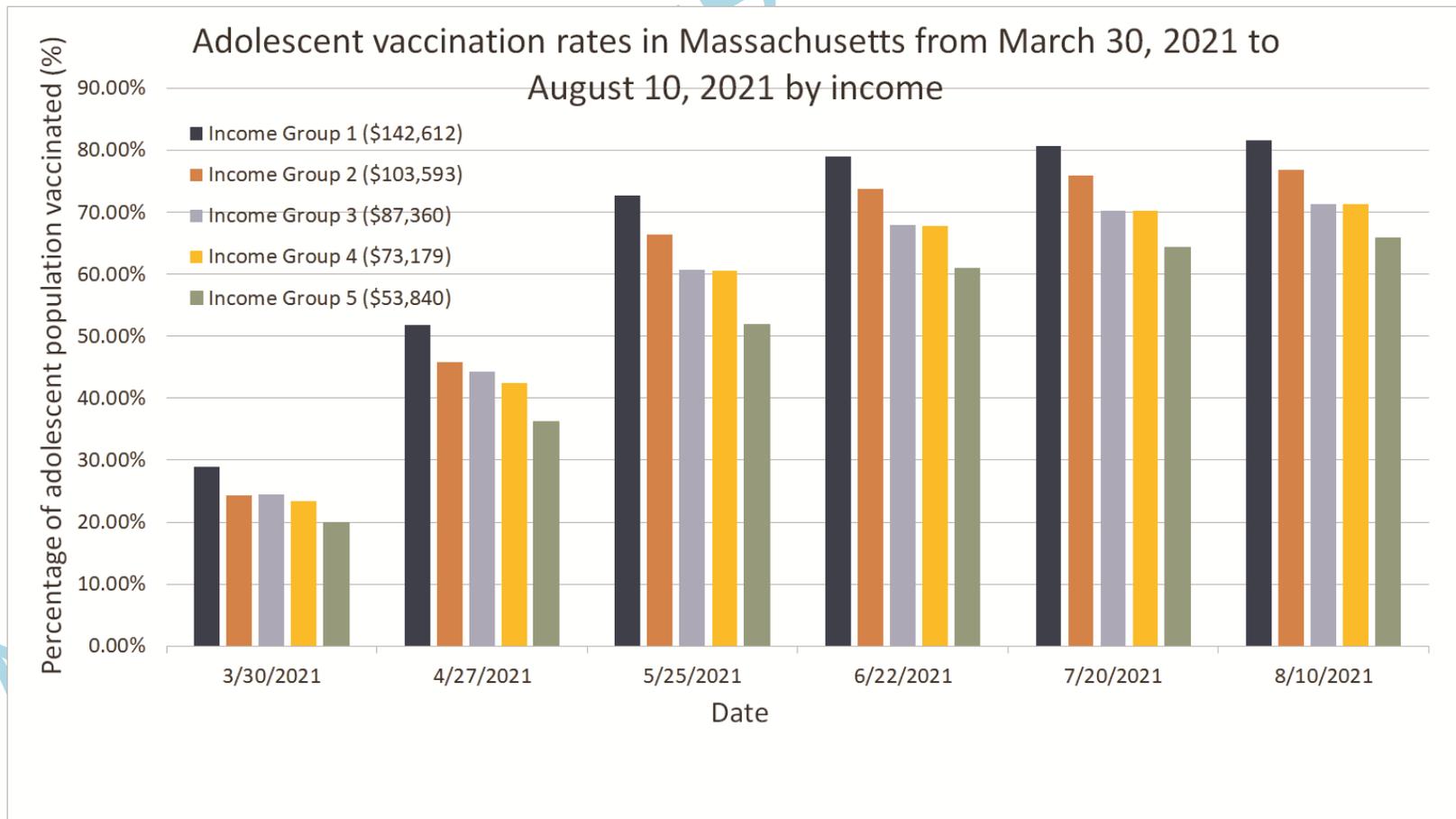


Figure 2

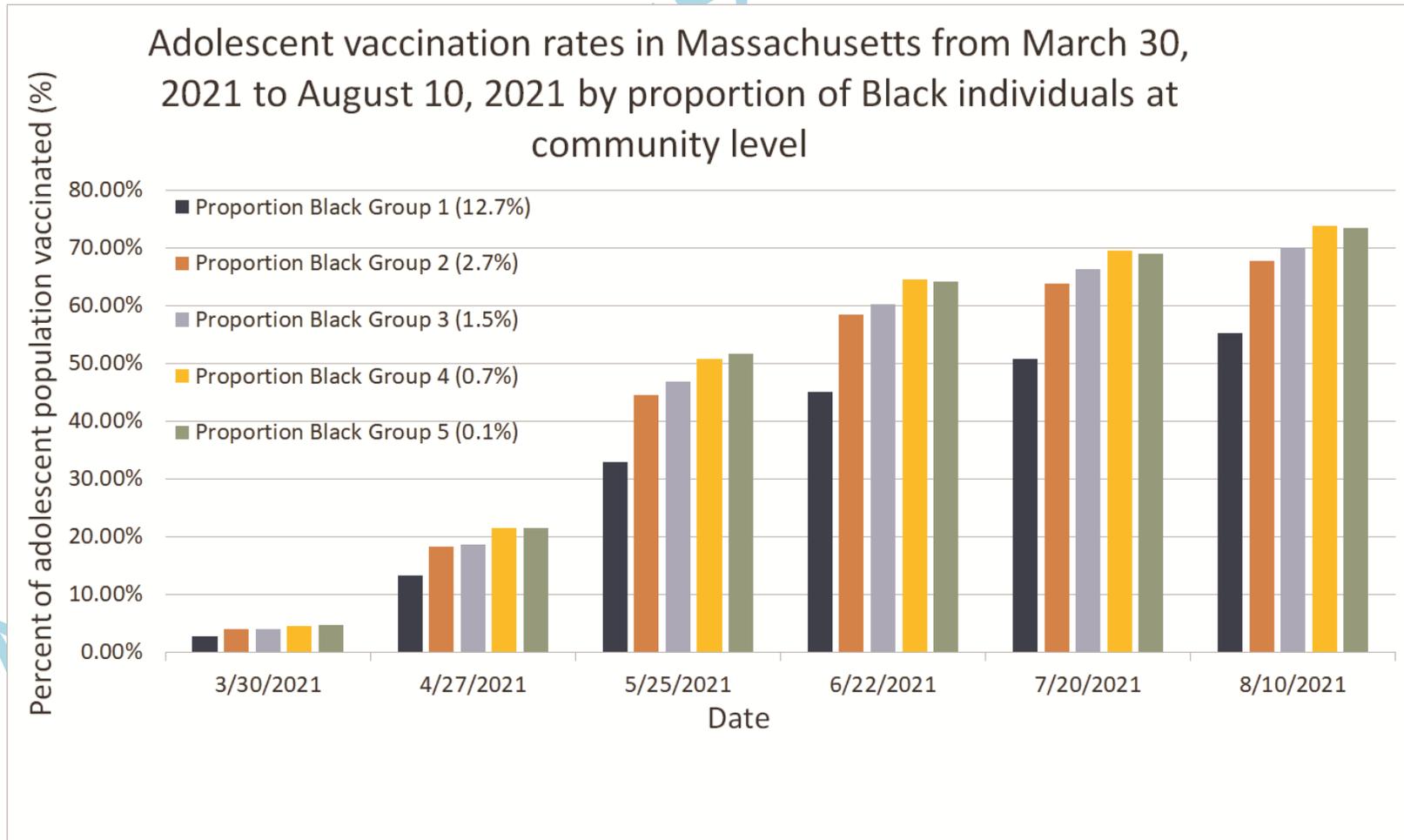


Figure 3

