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Picturing prevention: Visualizing how vaccination profoundly protects your loved ones, you, and your community from hospitalization and death due to Covid- 19 using real-life data from 12 US states (January – July 2021)

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The views expressed in this paper are those of the author(s) and do not necessarily reflect those of the Harvard Center for Population and Development Studies.

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Author contributions: All four co-authors developed, approved, and take responsibility for the content of the Working Paper. NK initiated this project and drafted the working paper, as foreground to the scientific manuscript whose intellectual and empirical preparation JTC and CT are leading, building on this working paper; JTC and CT obtained the data, conducted the analyses, and developed the data visualizations and are equally first authors; and WPH contributed to conceptualizing this project and interpreting the data.

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Abstract

Visually depicting and contrasting the number and proportion of persons who become hospitalized with and die from COVID-19 among the fully vaccinated versus the unvaccinated populations offers a powerful argument for why getting vaccinated matters – to protect against preventable suffering due to COVID-19 among people’s loved ones, themselves personally, and their communities. Communicating this information clearly is an urgent task. In this brief report, we draw on publicly reported data available for 12 states (for January through July 2021) to illustrate the profoundly elevated risk of needless suffering and death among those who are not vaccinated vs. are fully vaccinated. We focus on the relative risk of hospitalization and death for the unvaccinated compared to the vaccinated to underscore the consequences of continued vaccine resistance and inequities in access. Varying by state, the unvaccinated are 5 to 133 times more likely to be hospitalized and 9 to 141 times more likely to die. This state variation likely reflects differences in age (among the total population as well as those vaccinated and not vaccinated), community health profiles, public health policies and investment, inequities in exposure to the virus that causes COVID-19, i.e., SARS-CoV-2 (e.g., among essential workers), and reasons for not being vaccinated (including lack of access, medical or religious exceptions, or ideological opposition). Considered together, these risks are on par with or vastly exceed the risk of lung cancer due to smoking or risk of injury or death in a car crash if not wearing a seat belt. We also provide a visual argument as to why focusing on the percentage of hospitalized or deceased persons diagnosed with COVID-19 who are vs. are not vaccinated is misleading, noting that once 100% of the population is vaccinated, all persons who contract or die from COVID-19 will have been vaccinated, but this number of persons will be tiny compared to the number who would have become ill or died had they not been vaccinated. Despite concerns about reduced vaccine efficacy associated with the rise of newer SARS-CoV-2 variants, data from these 12 states are consistent with continued vaccine efficacy. We will follow-up this brief visual paper with a more detailed and rich scientific manuscript that provides the mathematical, conceptual, and empirical foundations of our visual argument.

Visually depicting and contrasting the number and proportion of persons who become hospitalized with and who die from COVID-19 among the fully vaccinated versus the unvaccinated populations offers a powerful argument for why getting vaccinated matters – to protect against preventable suffering due to COVID-19 among people’s loved ones, themselves personally, and their communities. Communicating this information clearly is an urgent task.

In this brief report, we draw on publicly reported data available for 12 states (for January through July 2021) [1] to illustrate the profoundly elevated risk of needless suffering and death among those who are not vaccinated vs. are fully vaccinated. We also provide a visual argument as to why a focus on the percent of hospitalized or deceased persons diagnosed with COVID-19 who are vs. are not vaccinated is misleading, as some have observed [2], noting that once 100% of the population is vaccinated, all persons who contract or die from COVID-19 will have been vaccinated, but this number of persons will be tiny compared to the number who would have become ill or died had they not been vaccinated. We will follow-up this brief visual paper with a more detailed and rich scientific manuscript that provides the mathematical, conceptual, and empirical foundations of our visual argument [3].

For this brief report, we draw on publicly reported data that the Kaiser Family Foundation (KFF) has compiled on vaccination coverage and cases, hospitalizations, and deaths among vaccinated and unvaccinated individuals, available for a sub-set of 12 US states, whose data span from January through July 2021 [1]. For our analyses, we merged the KFF data [1] with state population estimates from 2019 [4]. We newly calculate risk ratios for hospitalization and death, comparing the unvaccinated to the fully vaccinated, as ratios of incidence rates per 100,000 person-weeks using person-time calculated from the daily counts of people fully vaccinated available at the CDC [5], as opposed to the cumulative number of fully vaccinated persons at the end of the data period [1]. We use these person-time denominators because the cumulative number of fully vaccinated persons at the end of the data period overstates the amount of person-time giving rise to vaccinated events, because vaccination rates have increased over time, and can thus lead to underestimation of the rate of hospitalization or death among vaccinated populations. We present visualizations of these data in **Figure 1**, and tabulate the relevant data in **Table 1**. To provide context, we also include corresponding state data from *America’s Health Rankings* on key health and health determinant data for 2020 [6].

The effect of vaccines on hospitalization or death due to COVID-19 is most often expressed as vaccine efficacy, i.e. a percent reduction in the risk of hospitalization or death for vaccinated compared with unvaccinated people. To communicate more clearly the dramatically higher risk of hospitalization or death for *unvaccinated* people, we focus in Table 1 on the relative risk of hospitalization or death for unvaccinated vs. vaccinated people, (RR_u) which is related to vaccine efficacy (VE) by

$$RR_u = \frac{1}{1 - VE}$$

Our central finding is that across the available states with data, persons who were unvaccinated were 5 to 133 times more likely to be hospitalized (median value for risk ratio: 26.25) and 9 to 141 times more likely to die of COVID-19 (median value for risk ratio: 25.9) compared to persons who were fully vaccinated. These relative risks are consistent with vaccine efficacies for hospitalization ranging from 80% to 99% and for deaths from 89% to 99%.

In this brief report, we do not explore the reasons for the variations in the risks of hospitalization and death, given vaccine status, across states. It is plausible, however, that they reflect state variation in age structure (of the total population, and also comparing those who are versus are not vaccinated), community health profiles and health inequities (including in relation to who died from COVID-19 between March and December 2020), state investment (or lack of investment) in public health, and

reasons for people not being vaccinated, ranging from lack of access to ideological opposition [7]. They may also reflect differences in behavior between vaccinated and unvaccinated populations, as well as continuing inequities in occupational risk of exposure to SARS-CoV-2, the virus that causes COVID-19, experienced by essential workers [7, 8]. We consider these issues in more detail in our scientific manuscript in preparation.

Here instead we wish to put the risk ratios we report in perspective. Stated succinctly, for risk of an outcome to be 25 or 100 times higher among people who have the adverse exposure (here, no vaccination) compared to those who are not exposed (here, those who are fully vaccinated) is huge. Consider the well-known case of smoking, a major cause of lung cancer: according to the CDC, “people who smoke cigarettes are 15 to 30 times more likely to get lung cancer or die from lung cancer than people who do not smoke” [9]. The risks of COVID-19 hospitalization and death among the unvaccinated compared to fully vaccinated range from being on par with to vastly exceeding these enormous relative risks for a major cause of death in the US. Consider too the case of seat-belts reducing risk of fatalities among persons in cars that have crashed: according to the US Department of Transportation’s National Traffic Highway Administration, “if you buckle up in the front seat of a passenger car, you can reduce your risk of fatal injury by 45% and moderate to critical injury by 50%”; if you are in a light truck, these respective risk reductions are by 60% and 65% [10]. These seat-belt protections, for a major cause of US injuries and deaths, are substantially lower than the 85 to 95% protection afforded by diverse COVID-19 vaccines against risk of hospitalization and death [1].

Recent attention has been focused on the possibility that the widely circulating and highly transmissible Delta variant (B.1.617.2) will result in reduced vaccine efficacy. For example, Lopez et al. [11] reported vaccine efficacy of the Pfizer vaccine of 88% against the Delta variant for symptomatic disease in the UK, though in a preprint from the same authors, Stowe et al. [12] reported continued vaccine efficacy of 96% against hospitalization for the Pfizer vaccine. The implied vaccine efficacy data we present in Table 1, based on data from the 12 states included, are consistent with these data. These observed state data thus continue to offer strong arguments for the continued protective effect of vaccination. We further note that the slightly lower effective efficacies we calculated for some states may not necessarily represent actual lower efficacies once age and other confounders are taken into account.

We close by showing, with **Figure 2**, that focusing on the percentage of vaccinated individuals among COVID-19 hospitalizations or deaths is severely misleading. This figure demonstrates that as the proportion of the population vaccinated in the population increases, so too will the proportion of persons who are vaccinated among those who are hospitalized with or die from COVID-19 [2]. This happens because as the percent of population that is vaccinated rises, cases will increasingly reflect the very rare event of breakthrough infections among these vaccinated persons. Yet, as shown by the data presented in **Figure 1** and **Table 1**, the number of affected persons will be miniscule compared to the counterfactual of the number who would have become ill or died had everyone remained unvaccinated. It is thus misplaced to direct attention, as media reports have repeatedly, to the percentage of cases and deaths that occur among persons who are vaccinated vs. unvaccinated [1,2]. COVID-19, currently tallying over 200 million cases and 4.3 million deaths worldwide, including over 616,000 deaths in the US [13], is not a disease that can be responsibly controlled without vaccination [14] or equity-oriented public health measures [8].

It thus is vital to focus on what matters: the enormously higher risk of being hospitalized or dying if one is not vaccinated vs. fully vaccinated, given that SARS-CoV-2 will continue to circulate in one’s community. In this spirit, we offer our preliminary figures as visual arguments, to spark public discussion and scientific discourse that is attuned to the preventable suffering that can and should be prevented.

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TABLES AND FIGURES

Table 1. Percent of population vaccinated, number of COVID-19 hospitalizations and deaths, by vaccine status, risk ratio of incidence for hospitalization and death due to COVID-19 comparing persons who are fully vaccinated versus unvaccinated, and implied vaccine efficacy, for 12 US states, January – July 2021, and selected state rankings from the America’s Health Ranking 2020 annual report.

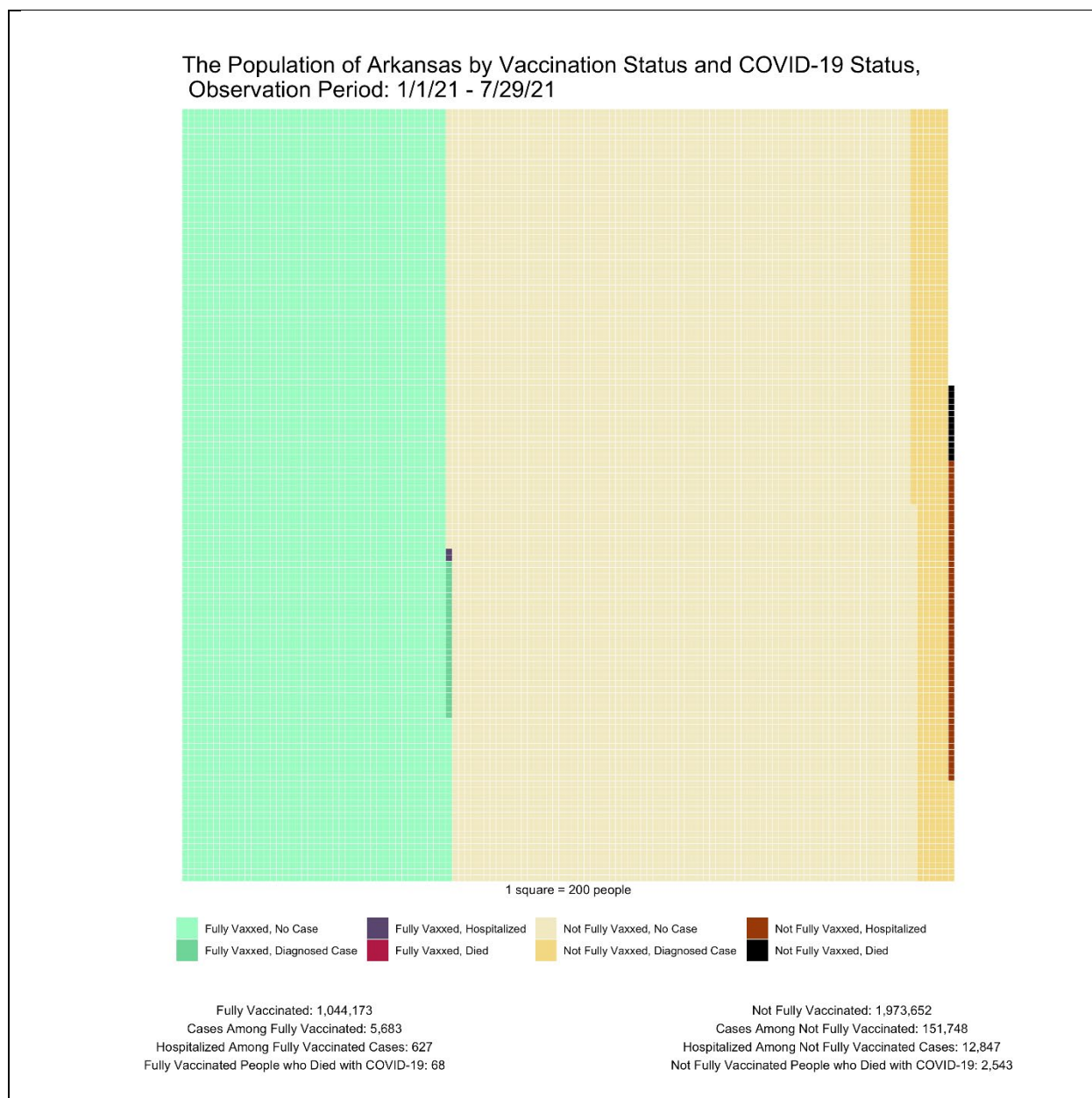
Figure 1. Visualization of the number of persons fully vaccinated and unvaccinated, and for each the number hospitalizations and deaths due to COVID-19, for 12 US states, January – July 2021.

Figure 2. Proportion of vaccinated among cases (y-axis) as function of vaccination coverage in the population (x-axis) and vaccine efficacy (VE).

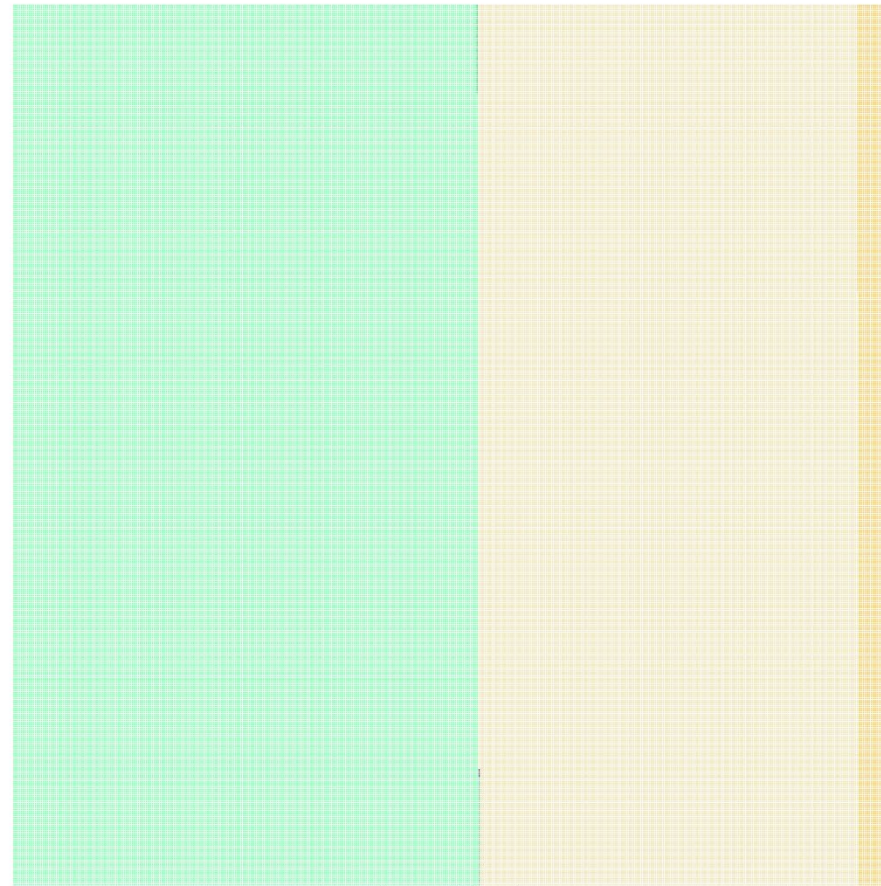
Table 1. Percent of population vaccinated, number of COVID-19 hospitalizations and deaths, by vaccine status, risk ratio of incidence for hospitalization and death due to COVID-19 comparing persons who are fully vaccinated versus unvaccinated, and implied vaccine efficacy, for 12 US states, January – July 2021, and selected state rankings from the America’s Health Ranking 2020 annual report.

State	COVID-19 data												America's Health Rankings: state rankings in 2020 (best = 1; worst = 50)				
	Dates data available	% fully vaccinated (as of end of data period)	Fully vaccinated (N) as of end of data period			Not vaccinated (N) as of end of data period			Risk ratio (RR): risk for unvaccinated versus fully vaccinated persons and implied vaccine efficacy (VE)				Social + economic factors	Physical environment	Clinical care	Behaviors	Health outcomes
			Total persons	COVID-19 hospitalizations	COVID-19 deaths	Total persons	COVID-19 hospitalizations	COVID-19 deaths	COVID-19 hospitalization		COVID-19 death						
									RR	VE	RR	VE					
Arkansas	1/1/21-7/29/21	34.6%	1,044,173	627	68	1,973,652	12,847	2,543	5.2	80.8%	9.4	89.4%	48	11	42	45	47
California	1/9/21-7/22/21	53.0%	20,927,113	934	93	18,515,110	117,244	38,061	43.2	97.7%	140.9	99.3%	27	49	23	14	5
District of Columbia	1/17/21-7/11/21	66.5%	469,462	13	4	235,287	2,672	292	96.4	99.0%	31.5	96.8%	n/a	n/a	n/a	n/a	n/a
Indiana	1/1/21-7/8/21	42.8%	2,883,877	132	46	3,848,342	21,053	4,528	42.6	97.7%	26.3	96.2%	32	27	38	36	36
Michigan	1/21/21-7/15/21	48.1%	4,800,032	529	217	5,186,825	40,220	7,861	23.5	95.7%	11.2	91.1%	44	41	15	35	40
Montana	2/15/21-7/20/21	43.9%	468,821	51	10	599,957	2,152	314	18.6	94.6%	10.3	90.3%	25	22	32	8	41
New Jersey	12/15/20-4/23/21	32.3%	2,873,499	30	7	6,008,691	40,738	7,546	132.6	99.2%	105.3	99.1%	3	50	26	11	4
New Mexico	1/1/21-6/1/21	48.0%	1,005,056	15	6	1,091,773	4,628	1,781	90.4	98.9%	86.9	98.8%	49	31	29	34	31
Tennessee	1/1/21-7/22/21	38.7%	2,642,790	204	31	4,190,384	21,578	5,817	27.7	96.4%	49.1	98.0%	40	17	44	42	44
Utah	1/16/21-7/19/21	45.2%	1,450,738	241	9	1,755,220	4,965	630	6.5	84.6%	21.4	95.3%	2	12	25	2	6
Virginia	1/21/21-7/18/21	53.5%	4,569,489	14	37	3,966,030	7,035	2,452	24.8	96.0%	25.5	96.1%	8	2	20	21	21
Washington	1/17/21-7/17/21	56.5%	4,302,519	228	48	3,312,374	10,073	2,201	18.1	94.5%	18.1	94.5%	4	16	14	6	13
Sources of data: references 1, 4-6 ; abbreviations: RR=risk ratio; VE=vaccine efficacy																	
Note:																	
(1) the risk ratios shown were calculated as ratios of incidence rates per 100,000 person-weeks using person-time calculated from the daily counts of people fully vaccinated from reference 5, not the cumulative Fully Vaccinated (N) total at the end of the data period (reference 1)																	
(2) although the District of Columbia is included in the America's Health Rankings report, its data are not assigned a state rank.																	

Figure 1. Visualization of the number of persons fully vaccinated and unvaccinated, and the number of hospitalizations and deaths due to COVID-19, for 12 US states, January – July 2021. [Source of data: reference 1].



The Population of California by Vaccination Status and COVID-19 Status,
Observation Period: 1/1/21 - 7/22/21



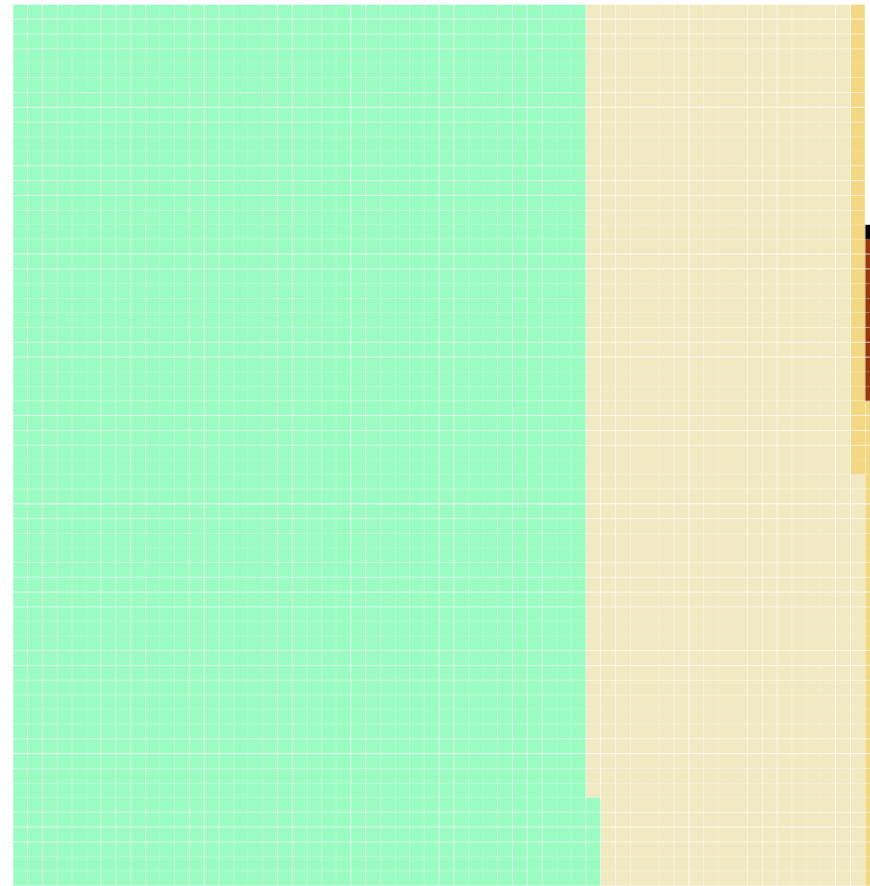
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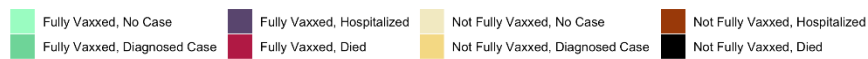
Fully Vaccinated: 20,927,113
Cases Among Fully Vaccinated: 21,083
Hospitalized Among Fully Vaccinated Cases: 934
Fully Vaccinated People who Died with COVID-19: 93

Not Fully Vaccinated: 18,585,110
Cases Among Not Fully Vaccinated: 1,537,902
Hospitalized Among Not Fully Vaccinated Cases: 117,244
Not Fully Vaccinated People who Died with COVID-19: 38,061

The Population of District of Columbia by Vaccination Status and COVID-19 Status,
Observation Period: 1/17/21 - 7/11/21



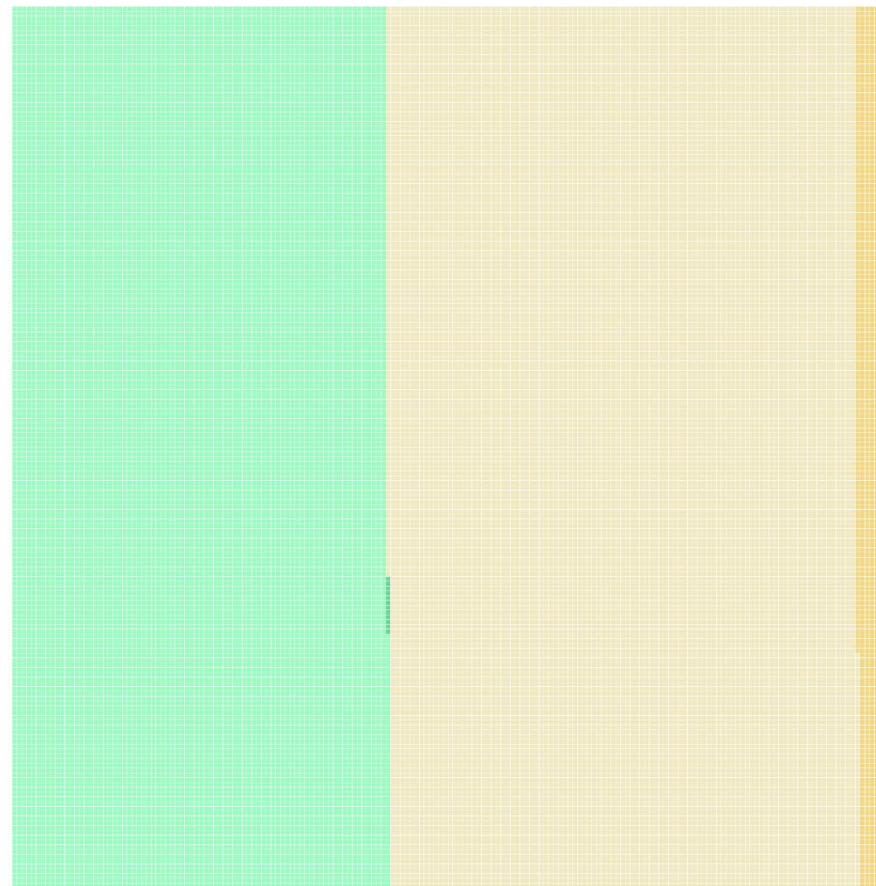
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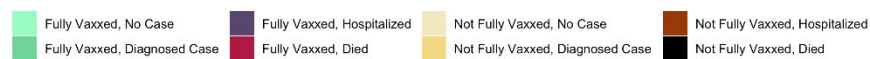
Fully Vaccinated: 469,462
Cases Among Fully Vaccinated: 200
Hospitalized Among Fully Vaccinated Cases: 13
Fully Vaccinated People who Died with COVID-19: 4

Not Fully Vaccinated: 236,287
Cases Among Not Fully Vaccinated: 15,718
Hospitalized Among Not Fully Vaccinated Cases: 2,672
Not Fully Vaccinated People who Died with COVID-19: 292

The Population of Indiana by Vaccination Status and COVID-19 Status,
Observation Period: 1/1/21 - 7/8/21



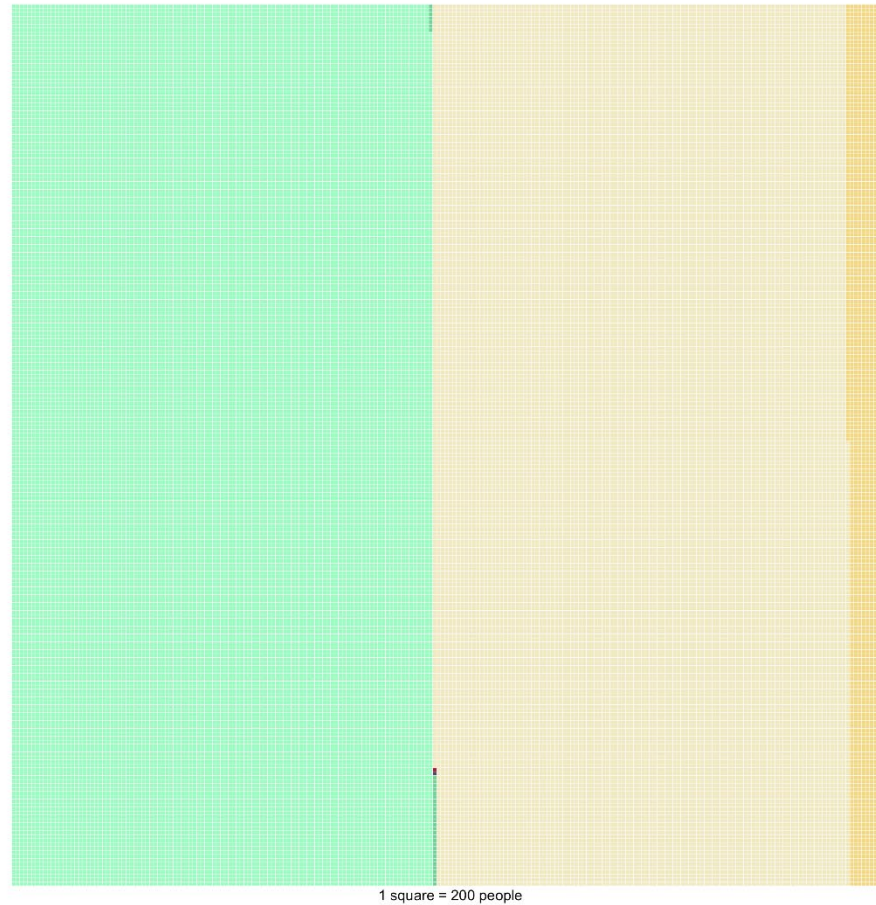
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Fully Vaccinated: 2,883,877
Cases Among Fully Vaccinated: 2,720
Hospitalized Among Fully Vaccinated Cases: 132
Fully Vaccinated People who Died with COVID-19: 46

Not Fully Vaccinated: 3,848,342
Cases Among Not Fully Vaccinated: 245,110
Hospitalized Among Not Fully Vaccinated Cases: 21,053
Not Fully Vaccinated People who Died with COVID-19: 4,528

The Population of Michigan by Vaccination Status and COVID-19 Status,
Observation Period: 1/1/21 - 7/15/21

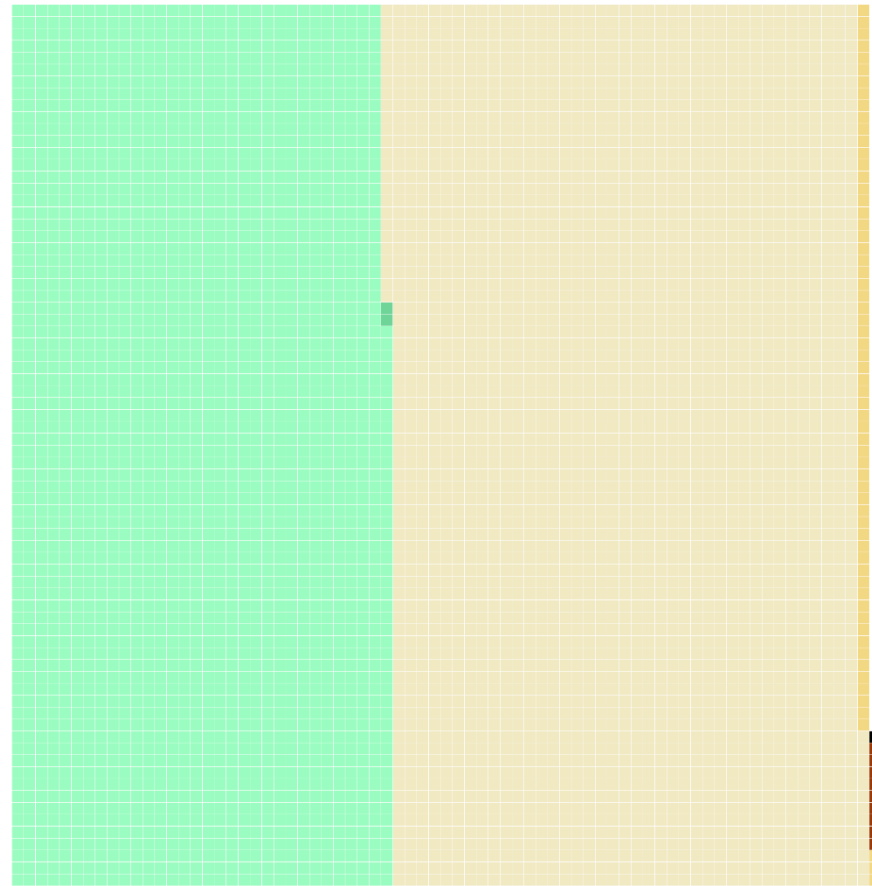


■ Fully Vaxxed, No Case	■ Fully Vaxxed, Hospitalized	■ Not Fully Vaxxed, No Case	■ Not Fully Vaxxed, Hospitalized
■ Fully Vaxxed, Diagnosed Case	■ Fully Vaxxed, Died	■ Not Fully Vaxxed, Diagnosed Case	■ Not Fully Vaxxed, Died

Fully Vaccinated: 4,800,032
 Cases Among Fully Vaccinated: 7,696
 Hospitalized Among Fully Vaccinated Cases: 529
 Fully Vaccinated People who Died with COVID-19: 217

Not Fully Vaccinated: 5,186,825
 Cases Among Not Fully Vaccinated: 466,171
 Hospitalized Among Not Fully Vaccinated Cases: 40,220
 Not Fully Vaccinated People who Died with COVID-19: 7,861

The Population of Montana by Vaccination Status and COVID-19 Status,
Observation Period: 2/15/21 - 7/20/21



1 square = 200 people

Fully Vaxxed, No Case

Fully Vaxxed, Hospitalized

Not Fully Vaxxed, No Case

Not Fully Vaxxed, Hospitalized

Fully Vaxxed, Diagnosed Case

Fully Vaxxed, Died

Not Fully Vaxxed, Diagnosed Case

Not Fully Vaxxed, Died

Fully Vaccinated: 468,821

Cases Among Fully Vaccinated: 500

Hospitalized Among Fully Vaccinated Cases: 51

Fully Vaccinated People who Died with COVID-19: 10

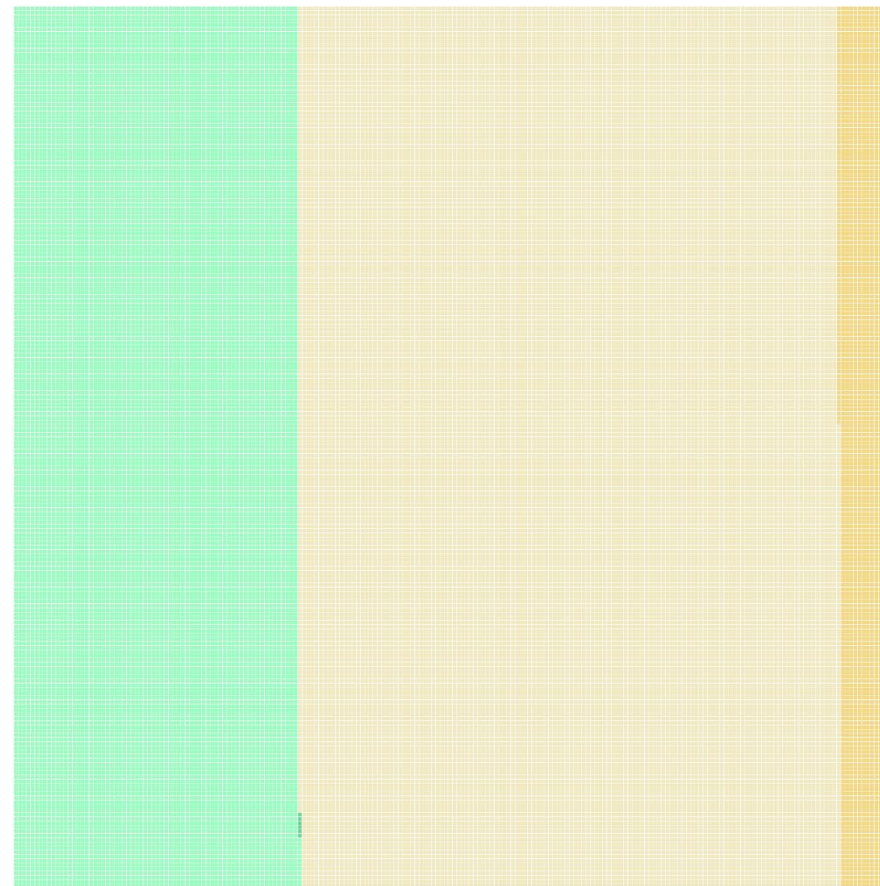
Not Fully Vaccinated: 599,957

Cases Among Not Fully Vaccinated: 15,120

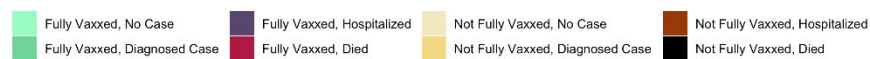
Hospitalized Among Not Fully Vaccinated Cases: 2,152

Not Fully Vaccinated People who Died with COVID-19: 314

The Population of New Jersey by Vaccination Status and COVID-19 Status,
Observation Period: 12/15/20 - 4/23/21



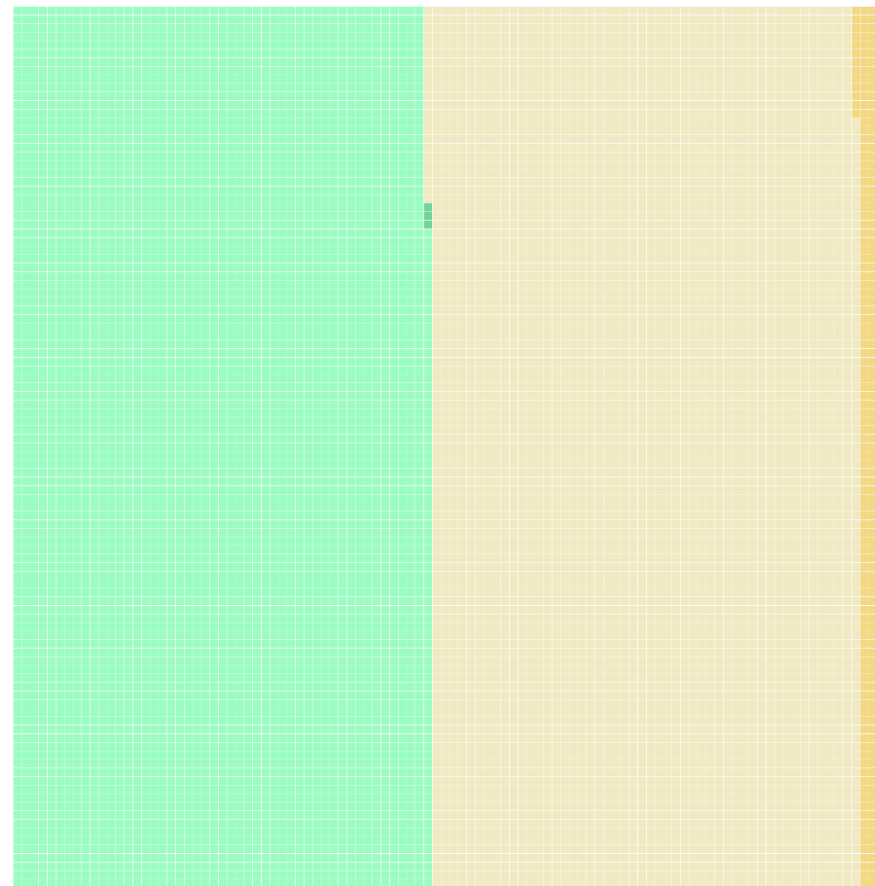
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Fully Vaccinated: 2,873,499
Cases Among Fully Vaccinated: 1,319
Hospitalized Among Fully Vaccinated Cases: 30
Fully Vaccinated People who Died with COVID-19: 7

Not Fully Vaccinated: 6,008,691
Cases Among Not Fully Vaccinated: 546,095
Hospitalized Among Not Fully Vaccinated Cases: 40,738
Not Fully Vaccinated People who Died with COVID-19: 7,546

The Population of New Mexico by Vaccination Status and COVID-19 Status,
Observation Period: 1/1/21 - 6/1/21

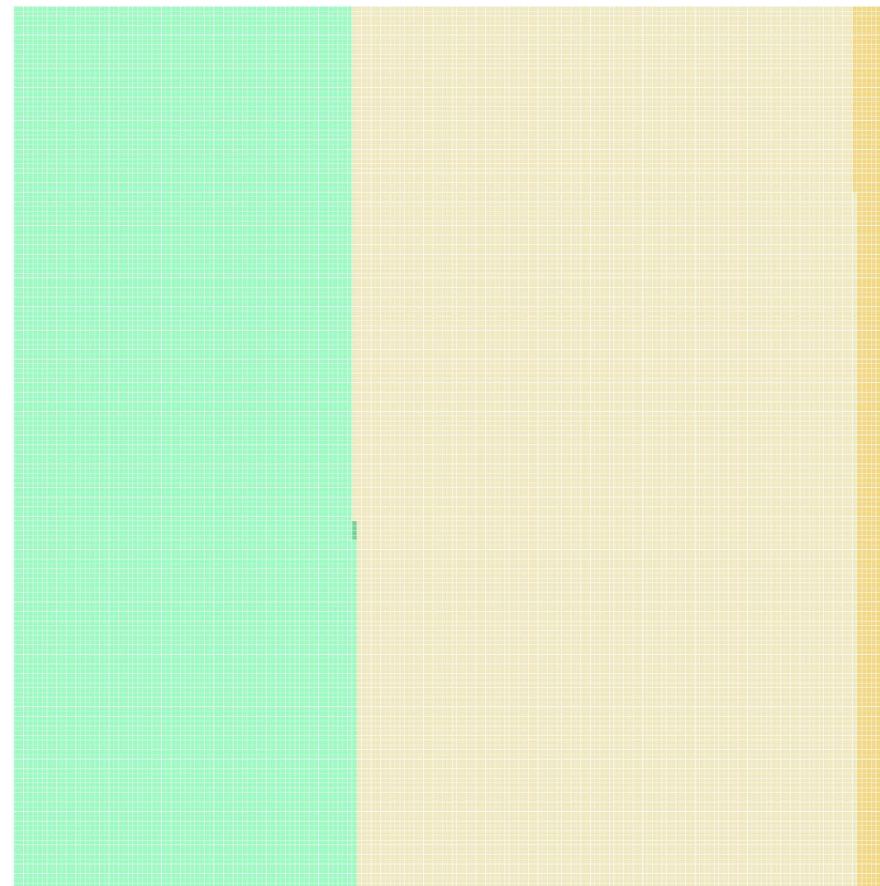


■ Fully Vaxxed, No Case	■ Fully Vaxxed, Hospitalized	■ Not Fully Vaxxed, No Case	■ Not Fully Vaxxed, Hospitalized
■ Fully Vaxxed, Diagnosed Case	■ Fully Vaxxed, Died	■ Not Fully Vaxxed, Diagnosed Case	■ Not Fully Vaxxed, Died

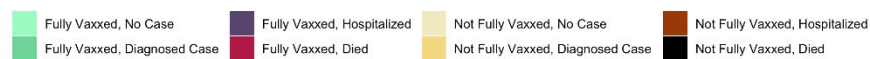
Fully Vaccinated: 1,005,056
 Cases Among Fully Vaccinated: 696
 Hospitalized Among Fully Vaccinated Cases: 15
 Fully Vaccinated People who Died with COVID-19: 6

Not Fully Vaccinated: 1,091,773
 Cases Among Not Fully Vaccinated: 59,591
 Hospitalized Among Not Fully Vaccinated Cases: 4,628
 Not Fully Vaccinated People who Died with COVID-19: 1,781

The Population of Tennessee by Vaccination Status and COVID-19 Status,
Observation Period: 1/1/21 - 7/22/21



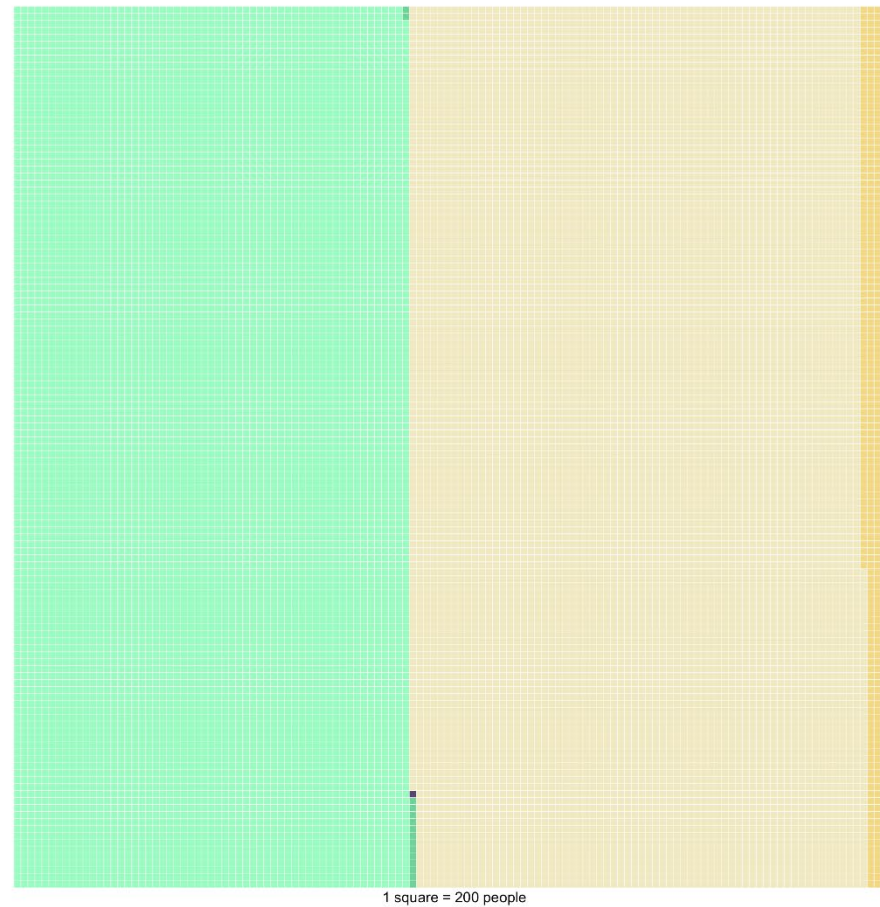
1 square = 200 people



Fully Vaccinated: 2,642,790
Cases Among Fully Vaccinated: 1,035
Hospitalized Among Fully Vaccinated Cases: 204
Fully Vaccinated People who Died with COVID-19: 31

Not Fully Vaccinated: 4,190,384
Cases Among Not Fully Vaccinated: 291,467
Hospitalized Among Not Fully Vaccinated Cases: 21,578
Not Fully Vaccinated People who Died with COVID-19: 5,817

The Population of Utah by Vaccination Status and COVID-19 Status,
Observation Period: 1/16/21 - 7/19/21

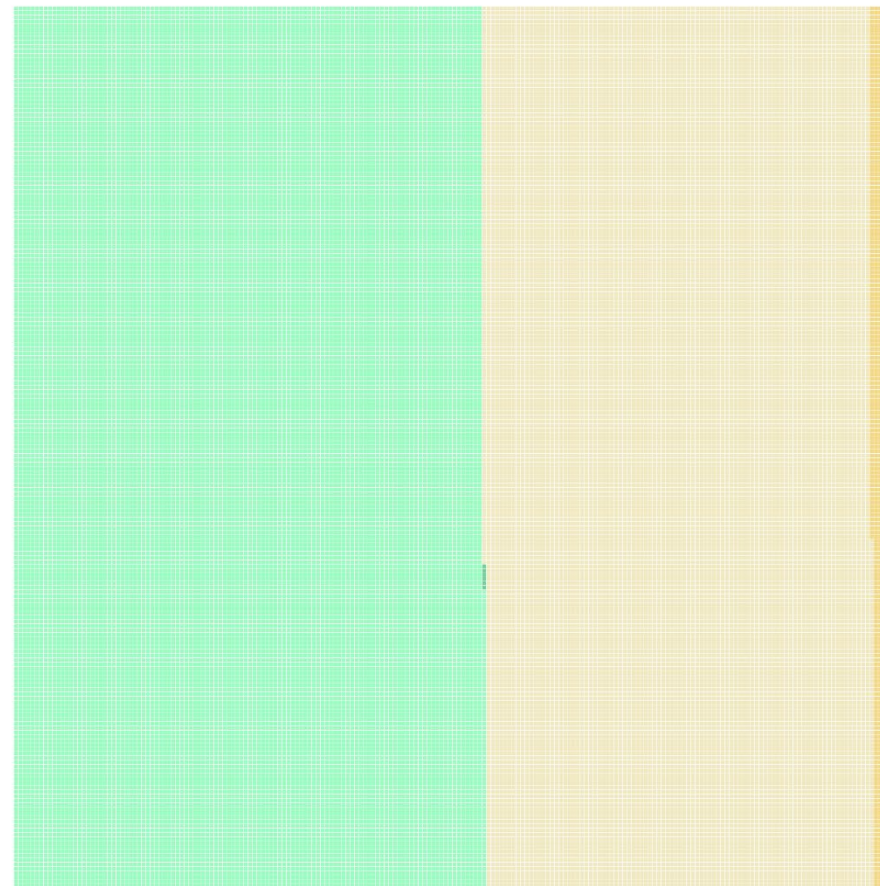


■ Fully Vaxxed, No Case	■ Fully Vaxxed, Hospitalized	■ Not Fully Vaxxed, No Case	■ Not Fully Vaxxed, Hospitalized
■ Fully Vaxxed, Diagnosed Case	■ Fully Vaxxed, Died	■ Not Fully Vaxxed, Diagnosed Case	■ Not Fully Vaxxed, Died

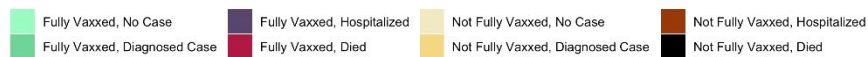
Fully Vaccinated: 1,450,738
 Cases Among Fully Vaccinated: 3,251
 Hospitalized Among Fully Vaccinated Cases: 241
 Fully Vaccinated People who Died with COVID-19: 9

Not Fully Vaccinated: 1,755,220
 Cases Among Not Fully Vaccinated: 97,684
 Hospitalized Among Not Fully Vaccinated Cases: 4,965
 Not Fully Vaccinated People who Died with COVID-19: 630

The Population of Virginia by Vaccination Status and COVID-19 Status,
Observation Period: 1/21/21 - 7/18/21



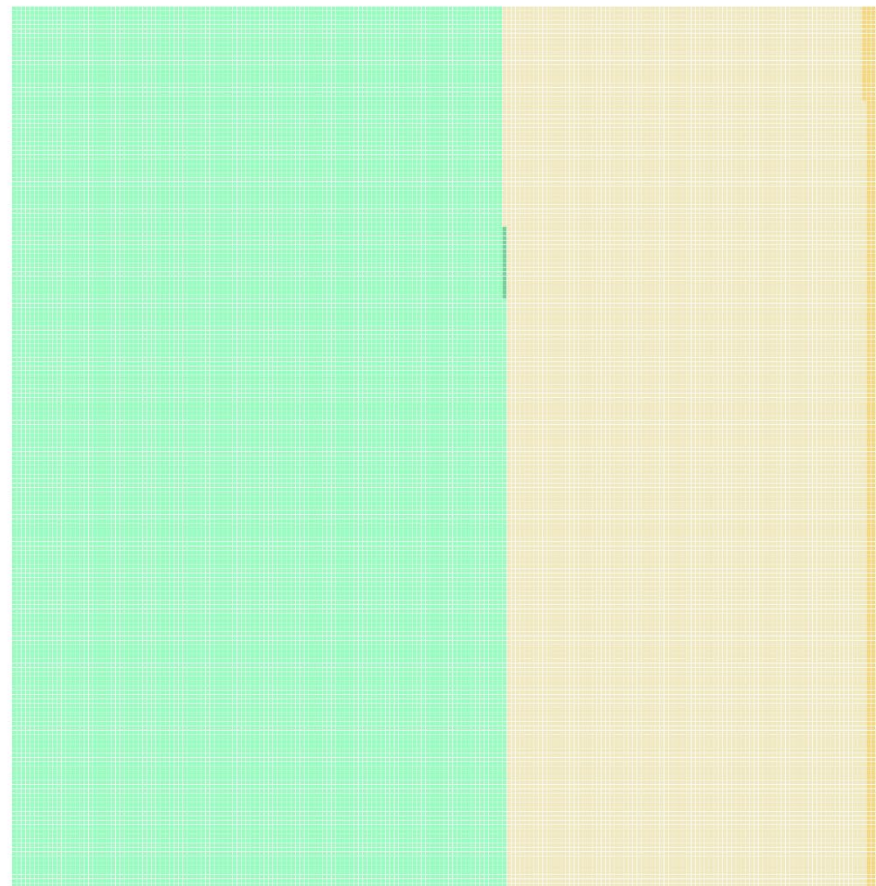
1 square = 200 people



Fully Vaccinated: 4,569,489
Cases Among Fully Vaccinated: 1,377
Hospitalized Among Fully Vaccinated Cases: 114
Fully Vaccinated People who Died with COVID-19: 37

Not Fully Vaccinated: 3,966,030
Cases Among Not Fully Vaccinated: 197,379
Hospitalized Among Not Fully Vaccinated Cases: 7,035
Not Fully Vaccinated People who Died with COVID-19: 2,452

The Population of Washington by Vaccination Status and COVID-19 Status,
Observation Period: 1/17/21 - 7/17/21



1 square = 200 people



Fully Vaccinated: 4,302,519
Cases Among Fully Vaccinated: 3,446
Hospitalized Among Fully Vaccinated Cases: 228
Fully Vaccinated People who Died with COVID-19: 48

Not Fully Vaccinated: 3,312,374
Cases Among Not Fully Vaccinated: 170,651
Hospitalized Among Not Fully Vaccinated Cases: 10,073
Not Fully Vaccinated People who Died with COVID-19: 2,201

Figure 2. Proportion of vaccinated among cases (y-axis) as function of vaccination coverage in the population (x-axis) and vaccine efficacy (VE)

