

Does Herd Immunity Reduce the Risk of Contracting COVID-19?

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Abstract

Herd immunity is often considered a measure to protect a whole community or population from disease if the vaccination threshold is met. Using the demographic and COVID-19 infection data from the state of Pennsylvania, United States, the study aimed to determine if herd immunity by vaccination is an effective way to reduce the spread of the COVID-19 virus. The Pennsylvania counties were split into two groups based on qualification of herd immunity: counties that met the COVID-19 herd immunization rate of 70% and counties that did not. The ANOVA test was used to analyze the difference between the groups with and without herd immunity by the COVID-19 vaccine. The results demonstrated that there was no significant statistical difference between counties that did achieve and those that did not achieve the herd immunity threshold for the COVID-19 vaccine. On the other hand, it was observed that there had been a significant decrease in positive cases between 2020 and 2023. This decline can be attributed to the overall protection by the vaccination and adaptability to the disease, not specifically due to herd immunity alone. Ultimately, these outcomes suggest that herd immunity cannot reduce the risk of contracting COVID-19. Increased efforts to get vaccinated should be implemented to protect the general community and a wider scope of age.

Keywords

COVID-19, Herd Immunity, Vaccine

1. Introduction

The COVID-19 pandemic, which originated in December 2019, largely impacted the global population with its contagious and infectious behavior through airborne particles and droplets. Since then, there have already been over one million deaths in the United States of America [1]. The disease is caused by the virus SARS-CoV-2,

which has severe effects on the respiratory system. The symptoms, regardless of age or gender, range from mild to severe signs of illness, including fever, chills, sore throat, and even death [2]. Patients with pre-existing medical conditions, specifically cancer and lung diseases, have increased vulnerability to severe complications. Treatments during the beginning focused on the quarantine of affected individuals and their recovery throughout several weeks. Symptoms can also be reduced through over-the-counter medication and certain antiviral prescriptions [3]. Proper hygienic care and up-to-date vaccinations are current solutions that can provide COVID-19 relief and prevention.

The most applicable option to prevent the spread of COVID-19 is through vaccinations. The COVID-19 vaccine was developed and made available to the public in late 2020. During the first phases of the Pfizer-BioNTech COVID-19 Vaccine, the vaccinations were only given to individuals who were at least 16 years old. The FDA administration approved the administration of giving two doses of the vaccine, three weeks apart [4]. The Moderna vaccine's approval followed shortly after, except it was only approved for those 18 and older. In August of 2021, the Pfizer-BioNTech COVID-19 Vaccine was passed to be distributed to children between the ages of 12 - 15; a third dose was also an option for those interested. In June 2022, the Moderna vaccine was recommended by the FDA for infants between the ages of 6 months and 5 years old [5].

With more vaccination efforts, many are wondering whether herd immunity will be effective on the COVID-19 virus. The level of immunity in a community, at which termination of transmission can usually be assured, is known as herd immunity [6]. This has been considered as a threshold that defines when a whole community is protected, including the individuals within the community who have not been vaccinated. The percentage of people who need to be immune to achieve herd immunity varies with each disease depending on the immunity variance and how contagious the disease is [7]. Although the concept of herd immunity for COVID-19 has not been fully established yet, there are many health organizations and research institutes that have attempted to determine the implications of herd immunity on the prevention of the virus transmission. While no guideline has been published by the World Health Organization (WHO) yet, it generally supports achieving herd immunity through vaccination [8]. In 2021, its COVAX Allocation Mechanism, the Independent Allocation Validation Group, was calling for the "achievement of 70% coverage with COVID-19 vaccines in all countries as a global imperative" to end the pandemic [9]. In a separate study, it was estimated that a vaccination rate of 50% - 70%, dependent on the age groups, was required to achieve herd immunity [10]. Similarly, according to a study conducted by Johns Hopkins University, for a community to reach herd immunity against COVID-19, it was suggested that 70% or more of the population would need to be vaccinated [11].

Therefore, the present study aims to evaluate whether the suggested vaccination rate of 70% or above to reach herd immunity can reduce the risk of COVID-19 infection. The hypothesis is that communities that have reached the threshold of

70% vaccination rate should have lower positive COVID-19 cases than the ones that do not meet the threshold.

2. Materials and Methods

2.1. Data

The population and demographic information of the state of Pennsylvania came from the United States Census Bureau surveys in 2020 and 2023 [12]. The COVID-19 vaccination data and the number of total confirmed positive cases in each county in Pennsylvania were obtained from the Pennsylvania Department of Health COVID-19 aggregate cases archive database, which was updated on June 29, 2023 [13]. Pennsylvania had a population of almost 13 million in 2022. Therefore, the sample size used was much larger than strictly necessary to detect clinically significant differences.

2.2. Statistical Analysis

The data analysis was divided into two phases. In the first phase, COVID-19 test-positive cases for each Pennsylvania county were calculated and grouped per the herd immunity thresholds. To reach COVID-19 herd immunity, vaccination must be >70% for COVID-19. Therefore, the data were classified and divided into two groups. The first group consists of the counties that reached herd immunity rate, the other group below 70%. The statistical differences between the means of the two groups were analyzed by the Analysis of Variance (ANOVA) test. The ANOVA test compares variance between groups to determine whether statistically significant differences exist between their means. A p-value greater than 0.05 means that the deviation from the null hypothesis is not statistically significant, and the null hypothesis is not rejected.

3. Results

3.1. COVID-19 Positive Cases in Pennsylvania

The population of Pennsylvania in the year 2020 was estimated to be around 13 million. Amongst the 67 counties, the counties with the highest population were Allegheny and Philadelphia because they included the major cities, Pittsburgh and Philadelphia, respectively. The ranges of COVID-19 positive rates by county are between 2.49% to 7.53% in 2020, and 0.63% and 1.71% between January to May 2023 (Figure 1). This suggests that COVID-19 vaccination and other measures, such as social distancing, have significantly reduced COVID-19 infection rates and have a substantial impact on mitigating its related outbreaks.

3.2. Relationship between COVID Vaccination and COVID-19 Infection

The COVID vaccination rate by county was between 31% and 81% in 2023, with an average of $46.7\% \pm 3.2\%$ (Figure 2). Out of 67 counties, only 10 reached a COVID-19 vaccination rate of 70% and above in 2023. A common similarity between the

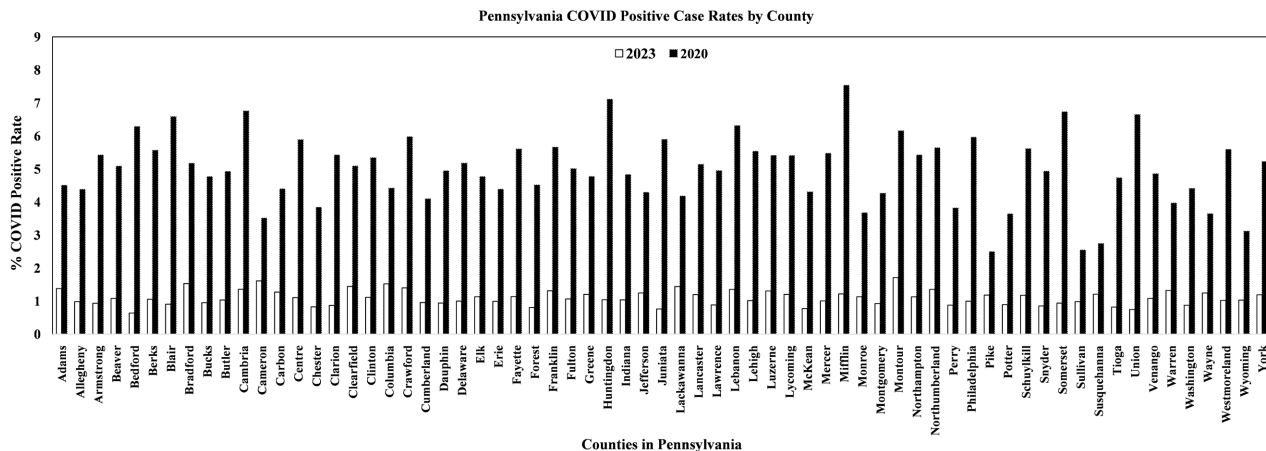


Figure 1. The positive cases of each county in Pennsylvania in 2020 and 2023.

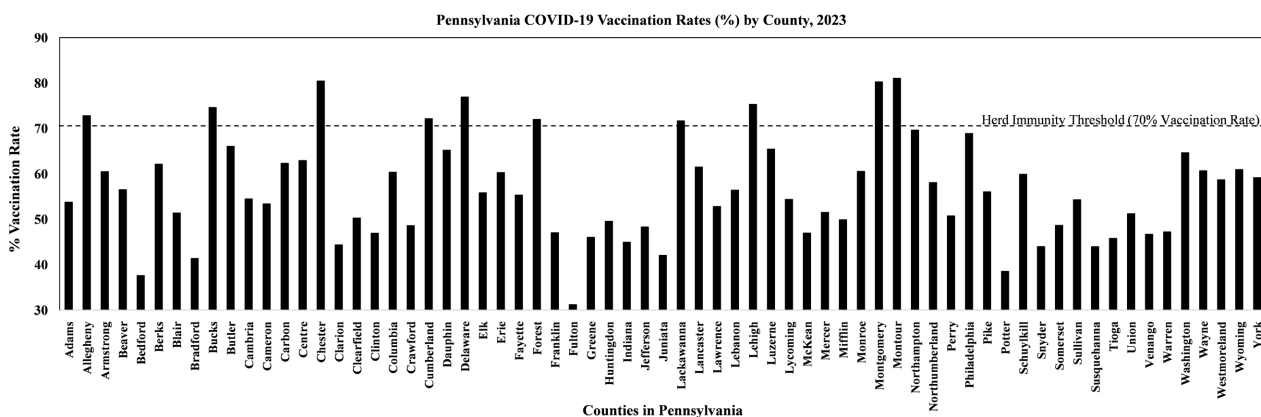


Figure 2. The vaccination rate (%) of each county in Pennsylvania in 2020 and 2023.

counties that are supposed to reach herd immunity is that they typically have larger populations, and most are considered large central metro or large fringe metro regions. However, the average COVID test positive rate of these counties with higher vaccination rates was 1.06%, very close to that of the rest of the counties. The p-value of this ANOVA test is 0.55, therefore, there is no significant statistical difference in COVID-19 infection rate between the counties that are supposed to reach herd immunity and those not (Table 1). Hence, this suggests that threshold of 70% vaccination rate or above, which is supposed to result in herd immunity, does not lower the risk of COVID-19 infection.

Table 1. The ANOVA test results with the p-value conclude that there is no significant difference between the two groups.

	COVID-19 vaccination rate (Mean, %)	COVID-19 positive case rate (Mean, %)	ANOVA (p-value)
Counties above 70% herd immunity threshold	75.72 ± 3.74	1.06 ± 0.29	0.55
Counties below 70% herd immunity threshold	53.43 ± 8.32	1.11 ± 0.21	

4. Discussion

The COVID-19 pandemic has caused a significant global health crisis, which has also undermined the economic and social well-being of individuals and communities. The rapid development and introduction of the COVID-19 vaccine to the public since late 2020 have significantly mitigated infection rates, hospitalizations, and deaths. These consequences were demonstrated by the state of Pennsylvania, which has seen a five-time decrease in COVID-19-positive cases from 2020 to the middle of 2023. On the other hand, herd immunity makes it hard for a disease to spread through a group of people, including those who haven't or can't get a vaccine. It is effective in some diseases, such as measles. Therefore, many public health agencies and organizations promote and support achieving herd immunity through vaccination, including COVID-19.

This study aimed to focus on the localized demographic of the Pennsylvania population by accounting for the herd immunity of the COVID-19 vaccine amidst the counties. Overall, the average COVID vaccination rate of all the counties together was only 56.7%, meaning the population as a whole in Pennsylvania did not pass the threshold for herd immunization. However, out of 67 counties, 10 counties reached >70% vaccination rate. According to the recommendations by the previous studies and health organizations, these counties, therefore, should have reached herd immunity against COVID-19. By comparing the COVID-19 positive rates between these 10 counties and the rest, it was found that there was no significant correlation between herd immunity and the risk of contracting COVID. Therefore, this study showed that herd immunity is unlikely to reach.

In the case of COVID-19, there may be several reasons that limit the reduction in COVID-19 infection through herd immunity. This is partly because COVID-19 has had many variants in a short time. The effectiveness of the vaccines is therefore reduced because it cannot keep up with the numerous changes the virus undergoes. Another reason is that many people with the disease do not show any visible symptoms, which complicates the number of people who have contracted it. Even if herd immunity was achieved, people with symptoms that are not visible are not accounted for. Specific to this case study, population movement and level of social interaction in Pennsylvania could have also been a large factor. Although the United States was in quarantine for the majority of 2020, there were also many cases where people had to interact with others between counties or states. The migration and contact of people from different regions can lead to cross-contamination of the disease. Previous studies assumed the threshold of herd immunity under the guise of unvaried, mixed populations [14]-[16]. However, there are many factors that impact herd immunity levels: the age structure of the demographic, the vulnerability to infection by age or other medical conditions, the order of vaccinated individuals, and diverse contract structures. Additionally, there is evidence from research and laboratory studies that indicate that the immunity protection lasts several months, leading to varied or partial defense against transmission and risk [17].

On the other hand, between 2020 and 2023, the decline in positive cases indicates that even without herd immunity, the counties can recover from COVID-19, suggesting that vaccination remains an effective method to reduce COVID-19 infection among the individuals. Other possible safety and precautionary measures such as hygiene practices, social distancing, quarantine control, and proper mask-wearing also contribute to limiting and preventing further spread of the disease.

5. Conclusion

In conclusion, based on the current evidence, reaching vaccine-induced herd immunity is still challenging. Nonetheless, vaccination, along with other precautionary measures, will still dramatically reduce COVID-19 infection.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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