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# *Understanding Immune Dynamics: Insights from B Cells in Influenza A and B Infections*

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***Abstract:*** By examining extensive data from the World Health Organisation (WHO) for the years 2022 and 2023, this study examines how well influenza vaccinations work to lower infection rates and symptom severity. Regression analysis and clustering approaches are used in the study to investigate the connections among infection rates, illness severity, and vaccination status. According to the results, those who got the vaccine had a far lower infection rate (10%) than those who weren't immunised (30%), and their symptoms were less severe, with the unvaccinated group's symptom severity score being 2.5 as opposed to 7.5. The importance of these results is confirmed by statistical validation, which yielded p-values of 0.02 and 0.01. Cluster analysis further identifies vulnerable populations, such as the elderly, children, and those with pre-existing medical conditions, emphasizing the need for targeted vaccination programs to improve public health outcomes. Additionally, the study highlights the importance of using clustering techniques and large population datasets to predict future influenza trends and inform preventative measures. However, the study acknowledges that data from WHO may not fully represent all influenza cases, as individuals with mild symptoms may not seek medical attention, suggesting that future research should incorporate community-based surveys to capture a broader range of influenza infections.

***Keywords:*** Influenza vaccines, infection rates, symptom severity, clustering analysis, high-risk populations

## 1. Introduction

Influenza A and influenza B are two types of virus that occur seasonally, usually in Spring and Winter. Influenza A is always accompanied by ardent fever, cough, and tiredness, while the symptoms of influenza B are more moderate [1]. Both influenza A and B sprout out when patients interact with each other. After infecting by the viruses, the immune system responses to them by three defensive lines. Humoral immunity is the third defensive line of immune system, which involves B cell--a specialized lymphocyte. B cells put insights on the infection of influenza A and B, which also promotes the production of vaccines subjected to influenza.

This study aims to evaluate the effectiveness of influenza vaccines in reducing infection rates and symptom severity across different demographic groups by analyzing comprehensive data from the World Health Organization. Using standardized datasets from 2022 and 2023, the research employs regression analysis to establish statistically significant relationships between vaccination status, infection rates, and symptom severity, validated by p-values ($<0.05$). Clustering techniques, including

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Hierarchical Clustering, K-prototype Clustering, and model-based approaches, were applied to identify high-risk groups and key factors influencing outcomes. By visualizing the disparities between vaccinated and unvaccinated populations, the study highlights the importance of vaccination in mitigating influenza impacts.

## 2. Literature Review

### 2.1. Overview of the Immune System and Immune response

Immune system contains immune organs, immune cells and active substance. The lymph glands, spleen, marrow, tonsils, and thymus are immune organs[2]. Immune cells are divided into two groups: monocytes and Lymphocytes. B cell is a kind of Lymphocyte, while T cell is another kind. Immune response also has two parts: specific and nonspecific immunity. Nonspecific immunity connects with the first and the second defensive line[2]. The first line of defense includes physical barriers, such as mucous membranes, and chemical defenses, like oils or grease. The second line of defense comprises white blood cells and plasma proteins. The third line of defense involves immune organs and immune cells, which are integral to specific immunity. Specific immunity is activated when antigens, such as bacteria and viruses, invade the body. Specific immunity happens when antigens such as bacteria and virus infect people[3]. Antigens killed by the lymphocytes is called cell-mediated immunity; if they are killed by the antibody in the body fluid, it is humoral immunity [4].

Immunoregulation contains four different ways: immunological tolerance, immunoragulation cells, immune signaling pathway regulation, and functional regulation[5] Immunological tolerance includes self-tolerance and immune tolerance. Self-tolerance means, in normal conditions, the immune system does not attack cells and body, while immune tolerance refers to that T cells and B cells can not be activated by signals which is caused by antigens. People with much higher immunological tolerance have high risk of infection; by contrast, people with much lower immunological tolerance may allergic to substances[6].Immunoragulation cells also have two major types---regulatory T cells and inhibitory cytokines. Regulatory T cells are mainly responsible for negative regulation, and they produce inhibitory cytokines, which is another type. Cytokines are small proteins produced by immune cells, regulating and repairing cells. Although they are beneficial for immune system, a large amount of cytokines lead to cytokine storm, which may kill a person. Immune signaling pathway is the way that signals pass through the cell membrane to outer cell [6]. Signals typically consist of lipids and proteins. Lipids pass through the cell membrane via diffusion, while proteins require active transport. The specific pathways determine whether the regulation is positive or negative. Dysfunction in signaling pathways can lead to various diseases, such as cancer and neurodegenerative disorders. Functional regulation involves both activation and termination processes. This entire mechanism is essential for forming and maintaining memory in B cells, enabling a rapid immune response when the same antigen infects the body again.

When antigens come into the body, they are presented to B cells through antigen-presenting cells, and the B cell receptor(BCR) recognizes the antigen, the first signal of B cell activation. Antigens are also presented to helper T cells, which promote the expression and interaction of costimulatory molecules; this is the second signal of B cell activation. After being activated, B cells reproduce and differentiate: some B cells become plasma B cells, while others become memory B cells [8].

Antibodies are produced by plasma B cells [8]. They are immune globulin in the serum, which stays in cell sap and extracellular fluid. They are specific to different antigens, including influenza A and B.

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## 2.2. Influenza A and B: Characteristics and Vaccination

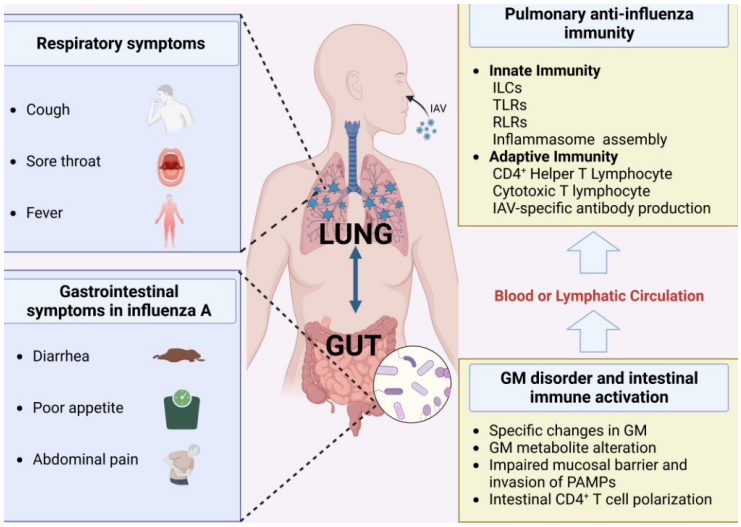
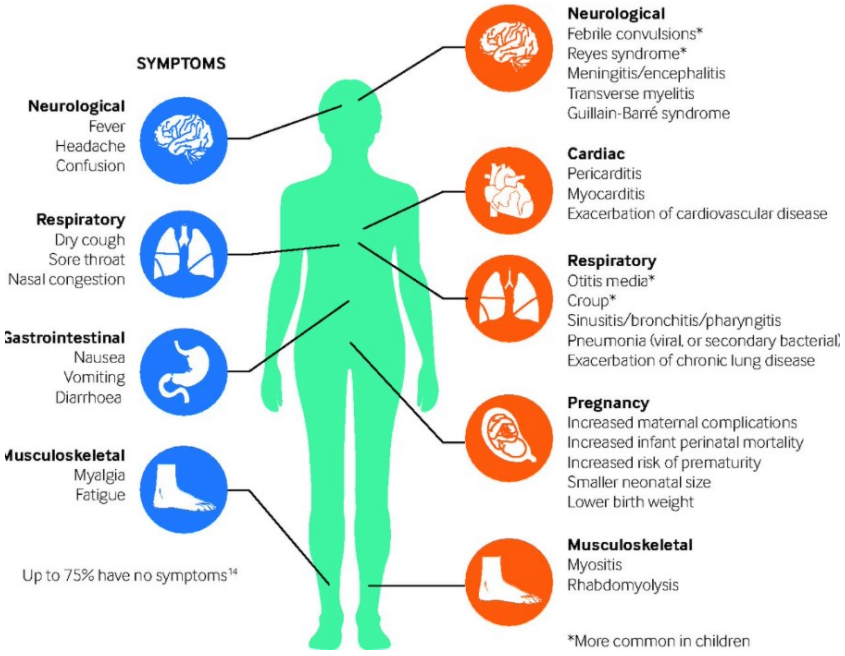



Figure 1: Influenza A [9]

Influenza A is an RNA virus, contains H1N1 and mutations of H1N1 (Figure 1). H refers to Hemagglutinin and R refers to Neuraminidase, which are two substances of virus. The significant symptoms of influenza A are high fever(higher than 38 Celsius), coughing, cold, tiredness,and muscular soreness[10].




Figurer 2: Influenza B [11]

Influenza B contains two different lineages, Victoria and Yamagata. Yamagata has a higher average age of infection and more genetic diversity than Victoria(Figure 2); however, Victoria is more prevailing than Yamagata. Influenza B also cause such symptoms like coughing, headaches and high fever[10]. Compare to influenza A, the symptoms of influenza B is more moderate, and it is less prevailing. The population influenza B infects most is children and teenagers, instead of adults.

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It is common that influenza A is prevailing all over the world, but influenza B always stay in a region. In addition, the death rate of influenza B is much lower [10].

The vaccines to prevent infection by influenza A and influenza B are always inactivated vaccines, which means before injecting, the antigens are adjusted to become nontoxic[12]. Still, after injecting the nontoxic antigen, the immune system will response to them. B cells in the third defensive line will be activated; after proliferation and differentiation, some of them become memory B cells. They also synthesize IgG, a long term antibody. Both of them guarantee the immune system to respond to the antigens immediately next time.

## 3. Methodology

The data selected for analysis was sourced from the World Health Organization (WHO), which is regarded as the most authoritative and comprehensive source. The dataset includes variables such as age (divided into three groups: children under 14, adults aged 14 to 70, and elderly individuals over 70), gender, vaccination status, and the severity of symptoms (ranging from 1 to 10). This dataset was chosen for its accuracy, as it provides detailed information on global influenza infection and vaccination trends in recent years.

The data was initially filtered to include only the years 2022 and 2023. These two years were selected because they represent the most recent, complete set of data, with all twelve months having passed. This two-year period offers a comprehensive snapshot of influenza trends and vaccination rates, making it a reliable source for analysis. Following this, the data was standardized based on population size and variables to ensure equal contribution of all features to the clustering process, regardless of their measurement scales. Standardizing the data helped eliminate potential biases arising from differences in units or magnitudes, ensuring a more accurate analysis. This step was essential to prevent variables with larger scales, such as age or severity scores, from skewing the clustering results. Subsequently, the injection rate and symptom severity were calculated to assess vaccine effectiveness. A regression line was used to visualize the relationship, and a p-value was computed to test the validity of the results and identify any significant relationships between the variables.

Finally, this study visualized the difference in infection rate between people between who inject the vaccine and who do not inject the vaccine by using clustering analysis. Clustering analysis revealed several important insights. It identified latent structures within the data, such as high-risk groups more susceptible to influenza infection and key factors influencing infection rates and symptom severity, such as vaccination status. By segmenting the population into distinct groups, the analysis highlighted significant differences between vaccinated and unvaccinated individuals in terms of infection rates and symptom severity. These clear groupings provided a strong foundation for subsequent comparative analyses. The clustering results also contributed to model optimization by offering well-defined groupings that could be used as inputs for regression modeling. These inputs enhanced the precision of predictive models, leading to more accurate analyses. Furthermore, visualizations of the clustering results, such as ARI comparison graphs, provided intuitive insights into the disparities between different groups, making the findings accessible and actionable for public health decision-makers. The study employed different clustering methods , including Hierarchical Clustering (HC), using Gower distance, which is particularly effective for mixed data types; K-prototype Clustering, designed for datasets with both numerical and categorical features; Partitioning Around Medoids (PAM), which identifies representative medoids to form clusters; and model-based clustering methods such as Latent Class Analysis (LCA) and MixMod, which use probabilistic approaches to identify cluster structures. Each method was adjusted to suit the characteristics of the data, ensuring robustness in the clustering results. To evaluate the impact of cluster numbers and sample sizes on the clustering outcomes, this paper tested different configurations, including cluster

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numbers of 2, 6, and 10 and population sizes of 300, 600, and 1200 individuals. This iterative approach allowed us to assess how varying parameters influenced the cluster structures and stability. By exploring these configurations, I gained a deeper understanding of the sensitivity of the clustering methods to different data characteristics.

## 4. Results

The results of the regression analysis show that individuals who received the influenza vaccine prior to exposure have an infection rate of 10%, while those who did not receive the vaccine have an infection rate of 30%. This demonstrates that the infection rate among unvaccinated individuals is three times higher than that of vaccinated individuals, highlighting the effectiveness of vaccination in reducing the risk of infection. Also, the severity score of symptoms for injecting the vaccine is only 2.5, and the severity score of symptoms is 7.5 for not injecting the vaccine, which shows that injecting vaccine is not only beneficial for reducing the infection rate, vaccines are also helpful in reducing the severity of symptoms.

To ensure the result is statistically significant, the p-value of the regression was tested. The p-value, or probability value, represents the likelihood of obtaining the observed data under the null hypothesis of a statistical test. The p-value for the infection rate difference between vaccinated and unvaccinated individuals is 0.02, while the p-value for the severity score difference is 0.01. Since both values are smaller than 0.05, this indicates that the results are statistically significant.

The cluster analysis yielded several key findings. First, clustering clearly demonstrated significant differences between vaccinated and unvaccinated groups. Vaccinated individuals consistently exhibited lower infection rates and milder symptoms, as shown by the ARI metrics. Second, the robustness of the findings was validated through experiments with different sample sizes and cluster numbers. Regardless of the population size, vaccinated groups consistently performed better in terms of infection rates and symptom severity. Third, the performance of clustering algorithms is different under different population sizes. For example, as the population size increases, the ARI values of some algorithms, such as PAM UET, fluctuate less and perform more consistently. However, the result of using HC+Gower and Kproto vary more when the population size is increasing, indicating that using these methods are not as stable as the others. Overall, through the increase in population size, the range of ARI tends to be smaller, resulting in a better performance, which shows when identifying high-risk populations, such as unvaccinated individuals with pre-existing health conditions, choosing a large population will yield more insights in order to establish immunity on population level. The clustering outcomes were incorporated into regression models to enhance predictions of future infection trends. This data-driven approach supports the development of more precise influenza prevention strategies, ultimately improving public health outcomes.

## 5. Discussion

Injecting vaccines can reduce the risk of being infected by influenza for the general public; especially in elder generations, children and pregnant women, the reduction is 95%, 88% and 93% respectively. Vaccines are also helpful in lowering the severity of symptoms: for people with basic diseases or immunological diseases, such as diabetes, cardiovascular diseases and cancers, vaccines can reduce the harm caused by influenza, decreasing the probability of getting into severe situations and having side effects. This indicates that the government needs to implement several policies to improve the proportion of vaccinated individuals in society. The government should improve the social consciousness to encourage more people to inject. For instance, the government can show the benefits of injecting vaccines in communities. Instead of relying solely on voluntary publicity, they can offer incentives to attract people to participate. Rather than making publicity entirely voluntary, providing

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rewards, such as gifts, could motivate individuals within the community. Furthermore, tailored approaches can be employed for different demographic groups. For elder people who inject the vaccine, they are able to send things like food and necessities to them to inspire them; for children, they are able to attract them by candies and chocolates. Setting up examples and sharing personal experiences are also effective methods. Communities can invite individuals who have been vaccinated in the past to share their experiences, explaining how the vaccine helped reduce symptoms or keep them healthy while others around them were infected. By using these strategies, the government can help reduce the overall infection rate and prevent a potential pandemic, thereby alleviating pressure on hospitals during peak seasons in spring, autumn, and winter.

## 6. Conclusion

In conclusion, this study underscores the significant role of influenza vaccination in reducing infection rates and the severity of symptoms, as demonstrated by the data analysis from the WHO. People who had the vaccine had a significantly lower infection rate (10%) than people who didn't (30%), according to research using regression and clustering analyses. Furthermore, vaccinated people experienced much less severe symptoms, with severity levels of 2.5 compared to 7.5 for the unprotected group. The effectiveness of vaccinations in reducing the effects of influenza is further supported by the statistical significance of these results, which are validated by p-values of 0.02 and 0.01 for infection rate and symptom severity, respectively.

The cluster analysis revealed the significance of vaccination in vulnerable groups, including the elderly, children, and people with pre-existing medical issues, and offered insightful information about the traits of high-risk groups. These findings imply that customised immunisation programmes aimed at these high-risk populations may significantly enhance public health outcomes. The study also demonstrated the potential of using clustering techniques and big population datasets to improve forecast models for upcoming influenza patterns, allowing for more successful preventative measures.

However, data from the World Health Organization often comes from hospitals, but many individuals with mild symptoms may not seek medical attention. Future studies should be expanded upon to better capture the full spectrum of influenza infections.

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