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# EFFECTIVENESS OF ADULT VACCINATION PROGRAMS IN REDUCING INFECTION BURDEN AMONG PATIENTS WITH DIABETES MELLITUS

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**ABSTRACT**
Adults with diabetes mellitus are more prone to infections and their complications and so vaccination is of great importance in preventing complications. A cross-sectional, survey-weighted study was performed of adults aged 18 years or older who were diagnosed with diabetes by their physician. Vaccination status against COVID-19 and influenza, pneumococcal, tetanus and shingles were measured. Outcomes were self-reported COVID-19 diagnosis, severe COVID-19, Long COVID, current post-COVID symptoms and general health status. Using weighted descriptive analyses and multivariable logistic regression, adjusted associations were estimated with demographic, behavioural, healthcare-access and clinical factors. Vaccination uptake for COVID-19 was high, but uptake for other recommended adult vaccines was not. Vaccinated adults reported less COVID-19 infection than unvaccinated adults, and their adjusted odds of COVID-19 infection were significantly lower. The adjusted associations between vaccination status and post-infection outcomes were not statistically significant, but the prevalence of severe symptoms, Long COVID and fair or poor general health were all lower among those vaccinated. The results are evidence for the uptake of an integrated health service provisioning of vaccination assessment, counselling and delivery within diabetes care. A limitation with the cross-sectional design and self-reported measures, however, is that they do not allow for causal interpretation. Longitudinal studies with accurate vaccination and clinical outcome records are necessary to establish effectiveness.

**KEYWORDS:** Adult vaccination; Diabetes mellitus; COVID-19; Infection burden; National Health Interview Survey

## INTRODUCTION

Hyperglycaemia, impaired neutrophil function, altered cytokine responses, vascular complications, and other chronic conditions increase the vulnerability of people with diabetes to infectious diseases and heighten clinical outcomes (Casqueiro et al., 2012). Diabetes has also been shown to contribute to respiratory, urinary, skin and systemic infections, and to disrupt glycaemic control and diabetes-related complications (Holt et al., 2024). Thus, infection prevention is an integral part of diabetes care. Vaccination is one of the most promising preventive interventions to reduce infection-related morbidity, hospitalization and death in high-risk adults. Despite efforts, however, there are ongoing challenges to adult immunisation programmes such as poor awareness, inadequate provider recommendations, missed vaccination opportunities, and fragmented healthcare delivery (Bridges et al., 2015).

Other factors to consider are reduced immunity, immunosenescence, and inadequate uptake and uptake of national immunisation guidelines, among others (de Gomensoro et al., 2018). However, there is significant evidence demonstrating the economic benefits of adult vaccination, especially for people with chronic conditions (Leidner et al., 2019). Influenza, pneumococcal, hepatitis B, COVID-19, tetanus, and shingles vaccines are recommended for adults with diabetes. Individuals with diabetes who have not received hepatitis B vaccine should be vaccinated as all adults without hepatitis B vaccination should be (Centers for Disease Control and Prevention [CDC], 2011).

In addition, current guidelines highlight age-appropriate, risk-based vaccination in diabetes management. (Kesavadev et al., 2024). Recent guidance calls for the assessment of vaccination status during all diabetes consultations ( Agarwal et al., 2025), and Indian evidence shows that it is important to have structured vaccination pathways in diabetes clinics and to improve healthcare professional education ( Kale et al., 2025). Experience in the management of chronic non-communicable diseases also shows that vaccination needs to be part of continual care and not as a one-off intervention (Vora et al., 2022). Influenza is a significant yet avoidable health threat to people with diabetes. Vaccination helps to prevent serious flu-related respiratory illness and diabetes-related complications (Goeijenbier et al., 2017). This was also found in a meta-analysis, which showed the link between diabetes and severe influenza, and the clinical benefits of influenza vaccines (Dicembrini et al., 2023).

Observational studies consistently demonstrate reduced hospitalisation rates in vaccinated people with diabetes: repeated seasonal vaccination offers ongoing protection in adults and the elderly (Looijmans-Van den Akker et al., 2006). Evidence from population also suggests lower risks of hospital admission or death in vaccinated adults with type 2 diabetes (Vamos et al., 2016), and higher vaccine coverage could yield large economic gains (Akın et al., 2016). However, influenza vaccine coverage is not at the recommended level (Mastrovito et al., 2024). Pneumococcal disease is also a significant clinical

problem in the elderly and those with chronic disease (Drijkoningen & Rohde, 2014). People living with diabetes are especially at risk due to comorbidities, antimicrobial resistance, and institutional exposures (Cheong & Song, 2024). In older adults with diabetes, pneumococcal polysaccharide vaccine has been effective (Kuo et al., 2016) and systematic reviews have shown reductions in hospitalisation and mortality (Del Riccio et al., 2023). A recent meta-analysis also revealed diabetes as a major risk factor for pneumococcal disease severity and confirmed the effectiveness of pneumococcal vaccines (Silverii et al., 2024).

Despite these advantages, vaccination rates have been sub-optimal, and immunity rates for older adults are affected by age, comorbidities and past vaccination status (Almasri & Holtzclaw, 2022). Recent U.S. data also reveal ongoing gaps in coverage, despite the presence of improvement strategies (Eiden et al., 2024). Limited knowledge, concerns regarding vaccine side effects, and inadequate provider recommendations are among the factors that hinder vaccine uptake among individuals with diabetes (Aldhahir et al., 2025). Randomized evidence has shown that structured, hospital-based programs can increase vaccination rates (Guerra et al., 2023), especially among older adults and high-risk adults (Pennisi et al., 2025). Finally, for diseases with a known safety profile for vaccines, narrative evidence also supports proactive vaccination approaches (Walewangko et al., 2025). Effective implementation, in general, and high immunization coverage rates can significantly reduce the burden of infectious diseases (Kashyap 2026).

The current study aims to examine vaccination uptake and beliefs around COVID-19, influenza, pneumococcal, tetanus, and shingles vaccines, especially as related to COVID-19 infection, severity of illness, post-COVID symptoms, health burden, and other factors. The goals are to estimate vaccination coverage; examine differences in outcomes associated with infection by vaccination status; and test for an independent association between vaccination and reduced burden of infection, after accounting for demographic, behavioural, health access, and clinical variables.

## 2. METHODOLOGY

### 2.1 Study Design and Data Source

The National Center for Health Statistics conducts the NHIS and is conducted on behalf of the civilian, noninstitutionalized adult population of the United States. The survey was conducted continuously from January to December, 2022, with geographically clustered sampling and computer-assisted interviews. It contained 27,651 Sample Adult interviews, one Sample Adult from each eligible household (National Center for Health Statistics, 2023). There are 637 variables in the Sample Adult file, such as health status, diabetes, immunisation, COVID-19 history, health service use, health behaviours, demographic characteristics, and survey design variables.

### 2.2 Study Population

The population targeted will be adults (age 18 +). Any respondents who report prediabetes, borderline diabetes, or that they are not sure if they have diabetes will be excluded. Other exclusions will pertain to respondents who do not have complete or clear information regarding vaccination status, COVID-19 infection history or to any other necessary design parameters. The final analytical sample size will be displayed in a participant-selection flow chart.

### 2.3 Exposure Assessment

The principal exposure will be adult vaccination, which will be largely achieved through COVID-19 vaccination given that there is a corresponding data on COVID-19 infection and outcomes. The respondents will be grouped into:

1. Unvaccinated-no reported COVID-19 vaccination.
2. Partially vaccinated-vaccinated but with an incomplete reported series.
3. Fully vaccinated completion of the primary vaccination series .
4. Additional-dose recipients-receipt of doses beyond the primary series, where the number of doses permits this classification.

There will be a primary comparison between ever vaccinated and unvaccinated using a binary comparison. A dose-response analysis will be performed as a secondary analysis based on the number of doses reported. The participation in the general vaccination programme of adults will also be described, based on available information on influenza, shingles and tetanus vaccination. There was dedicated immunisation content on the 2022 Sample Adult questionnaire on COVID-19, influenza, shingles, tetanus and HPV vaccination. An age eligible vaccine uptake score will be developed as a simple sum of the number of vaccines received.

### 2.4 Outcome Measures

The main outcome will be self-reported history of COVID-19 infection, which will be gathered through questions asking about the presence or absence of a COVID-19 diagnosis or test. The main analysis will be a comparison of the weighted prevalence of reported infection in vaccinated and unvaccinated adults with diabetes, and the adjusted odds of infection.

**Secondary indicators of infection burden will include:**

- perceived severity of COVID-19 symptoms
- symptoms lasting three months or longer
- current Long COVID or post-COVID symptoms
- poor or fair general health
- activity or functional limitation and
- healthcare utilisation indicators, where available.

The 2022 NHIS introduced measures of prolonged and current post-COVID symptoms in addition to diagnosis, testing and perceived symptom severity. Among respondents reporting prior COVID-19 infection, separate models will examine whether vaccination is associated with lower odds of severe symptoms and Long COVID.

### 2.5 Covariates and Potential Confounders

The following items will be included as covariates: age, sex, race/ethnicity, education, income/poverty, insurance, region, urban–rural residence, smoking, BMI, physical activity, access to healthcare, interview quarter, use of insulin, hypertension, hypercholesterolaemia, cardiovascular disease, asthma, COPD, cancer, kidney disease, and immunosuppression. Physician-diagnosed chronic conditions will be used to create a multimorbidity score. Primary infection models will not include variables that could be a result of the infection (e.g., poor health, activity limitation) to reduce overadjustment.

### 2.6 Data Management

Vaccination dates will undergo screening for implausible date, as it is noted that the 2022 COVID-19 vaccination dates have not been reasonableness edited. For the main model, since the proportion of missingness is small, complete case will be used. If the missingness in the important covariates is above 5%, multiple imputation by chained equations will be employed, with survey weights and/or outcome values not being imputed as appropriate.

### 2.7 Statistical Analysis

The complex NHIS design will be accounted for in analyses due to the use of weight (WTFA_A), stratification (PSTRAT) and sampling (PPSU). Weighted proportions with 95% CIs will describe adults with diabetes. Rao–Scott chi-square and survey-adjusted tests will compare categorical and continuous variables. Survey-weighted models will estimate the crude and adjusted ORs for infection, severity, and Long COVID: Model 1 (unadjusted), Model 2 (sociodemographic adjusted), and Model 3 (behavioural, access-related, and clinical factors adjusted). Predicted probabilities, average marginal effects, IPTW propensity-score sensitivity analysis, and standardised mean differences (<0.10 acceptable) will be reported. Subgroups and interactions will be examined for age, sex, insulin use, multimorbidity, and immunosuppression. Significance will be determined by FDR correction and $p<0.05$.

### 2.8 Ethical Considerations

The NHIS public-use data are anonymized and are for statistical research. The secondary analysis will not be considered an activity involving direct contact with participants and will generally be considered non-human-subject research as per institutional requirements. Due to the cross-sectional nature of the design, the interpretation of the "effectiveness" will not be as a cause-and-effect relationship, but rather as an estimated association.

## 3. RESULTS

### 3.1 Participant Characteristics

The prevalence of COVID-19 vaccination among adults with diabetes was 84.7%. The weighted mean age of the vaccinated participants was greater than the unvaccinated participants (62.7 years vs 57.7 years, respectively). Frequently, the participants who were vaccinated also had a greater percentage of health-insurance coverage and lower prevalence for current smoking, obesity and chronic obstructive pulmonary disease. Table 1 presents demographic and clinical data of adults with diabetes based on their COVID-19 vaccination status. The participants who were vaccinated tended to be older, have health insurance, and to not report smoking, obesity, COPD, or having been diagnosed with COVID-19 nor fair or poor health.

**Table 1. Characteristics of adults with diabetes according to COVID-19 vaccination status**

| Characteristic | Unvaccinated, n = 414 | Vaccinated, n = 2,482 |
|---|---|---|
| Age, weighted mean, years | 57.7 | 62.7 |
| Female, weighted % | 46.9 | 49.2 |
| Health-insurance coverage, weighted % | 91.9 | 96.6 |
| Insulin use, weighted % | 29.1 | 31.4 |
| Obesity, weighted % | 61.2 | 54.9 |
| Current cigarette smoking, weighted % | 22.0 | 10.7 |
| Hypertension, weighted % | 77.0 | 72.7 |
| Coronary heart disease, weighted % | 16.0 | 16.1 |
| Chronic obstructive pulmonary disease, weighted % | 14.1 | 9.6 |
| History of cancer, weighted % | 15.8 | 17.0 |
| Self-reported COVID-19 diagnosis, weighted % | 41.6 | 27.9 |
| Fair or poor general health, weighted % | 49.6 | 39.4 |

Note: Percentages are weighted using WTFA_A. Unweighted denominators vary slightly because of missing responses.

### 3.2 Adult Vaccination Coverage

The coverage of Covid-19 vaccination is the highest of the vaccinations evaluated. About 84.7% of all adults with diabetes said they had one or more doses of COVID-19 vaccination. Influenza vaccination uptake was 64.3%, pneumococcal vaccination uptake was 68.8% among those who were asked the question and tetanus vaccination uptake was 58.7%, with 36.6% taking up shingles vaccination in the preceding year. Table 2 shows the percentage of adults with diabetes who received the recommended vaccines, along with weights for each vaccine. COVID-19 vaccination had the highest uptake

rates, while the lowest rates of vaccination were observed for shingles vaccination. Figure 1 displays the weighted percent of adults with diabetes that have received COVID-19, influenza, pneumococcal, tetanus, and shingles vaccinations.

**Table 2. Weighted vaccination uptake among adults with diabetes**

| Vaccination indicator | Valid unweighted n | Weighted uptake, % |
|---|---|---|
| COVID-19 vaccination | 2,896 | 84.7 |
| Influenza vaccination in past 12 months | 2,895 | 64.3 |
| Pneumococcal vaccination | 1,470 | 68.8 |
| Tetanus-containing vaccination | 2,739 | 58.7 |
| Shingles vaccination | 2,564 | 36.6 |

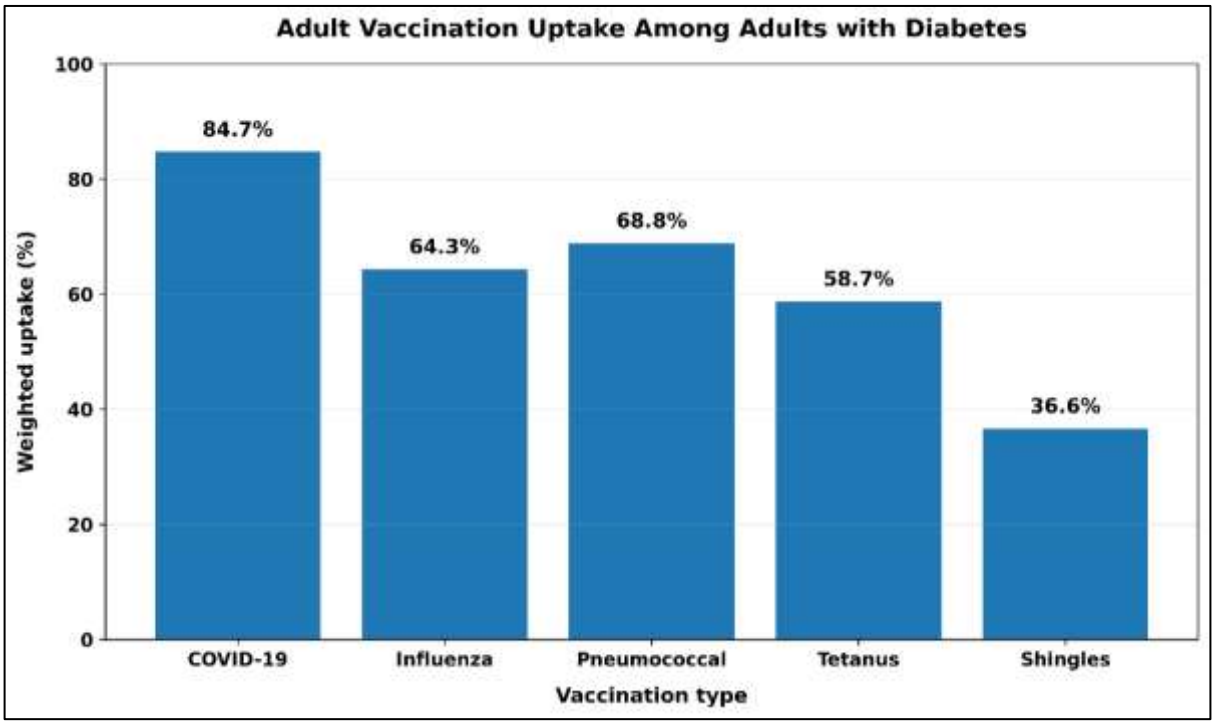


**Figure 1. Adult vaccination uptake among adults with diabetes**

### 3.3 COVID-19 Infection Burden According to Vaccination Status

Overall, 30.0% of adults with diabetes reported a COVID-19 diagnosis. The prevalence of infection was significantly lower among adults who were vaccinated than among those who were not, with 27.9% of the vaccinated adults having infection compared to 41.6% of those who were not vaccinated (absolute weighted difference of 13.7 percentage points). The cluster of symptoms was similarly lower among those who reported a prior COVID-19 diagnosis, among whom those who were vaccinated also had lower symptom burden. Nearly 53.0% of the vaccinated group who had previously been infected said that their symptoms were severe or very severe 65.7% of the unvaccinated group said the same. Among adults that were vaccinated with previous infection, the weighted prevalence of Long COVID was 23.7%, and 28.0% among those that were not vaccinated. In both groups, the current symptoms of COVID-19 were the same 18.8% of those who had received the shots and 19.2% of those who had not. Table 3 shows that there was no significant difference between the infection burden among the vaccinated and unvaccinated adults with DM.However, no significant difference was observed in infection burden among the vaccinated and unvaccinated adults with DM (Table 3). The prevalence of COVID-19 diagnosis, severe symptoms, Long COVID, and fair or poor general health were lower among the vaccinated participants.

**Table 3. Weighted infection and health burden according to COVID-19 vaccination status**

| Outcome | Unvaccinated, weighted % | Vaccinated, weighted % | Absolute difference, percentage points |
|---|---|---|---|
| Self-reported COVID-19 diagnosis | 41.6 | 27.9 | −13.7 |
| Severe or very severe COVID-19 symptoms* | 65.7 | 53.0 | −12.7 |
| Long COVID* | 28.0 | 23.7 | −4.3 |
| Current post-COVID symptoms* | 19.2 | 18.8 | −0.4 |
| Fair or poor general health | 49.6 | 39.4 | −10.2 |

*Calculated among participants with a self-reported previous COVID-19 diagnosis.

Figure 2 shows the difference between COVID-19 vaccination status and infection-related and general health outcomes. The greatest decreases in vaccinated adults were for COVID-19 diagnosis and for severe symptom burden.

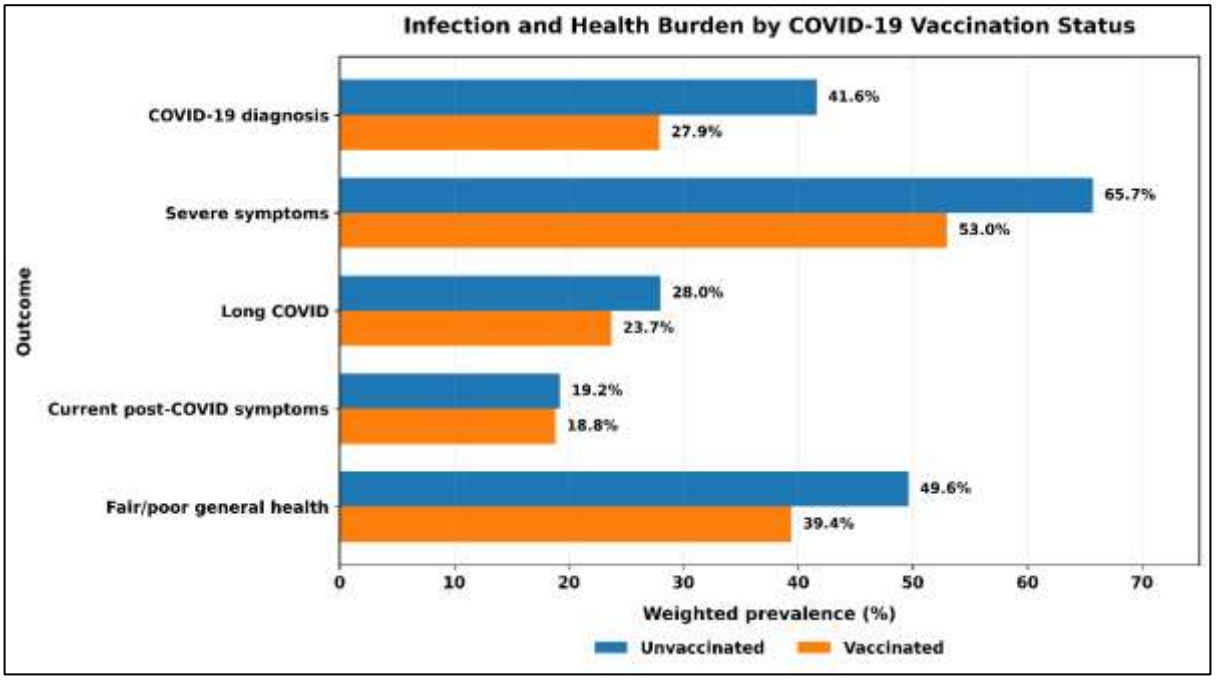


**Figure 2. Infection and health burden by COVID-19 vaccination status**

### 3.4 Multivariable Association Between Vaccination and COVID-19 Diagnosis

In the fully adjusted model 2,745 adults with diabetes had complete information about the outcome, vaccination status and selected covariates. The relationship between COVID-19 vaccination and the odds of reporting a COVID-19 diagnosis persisted after controlling for other factors, including age, sex, race and ethnicity, level of education, income category, health-insurance coverage, body-mass-index category, smoking, insulin use, hypertension, coronary heart disease, chronic obstructive pulmonary disease and cancer, and geographic region. Among adults, those who were not vaccinated were about 46.5% more likely (based on the adjusted odds) to report having been diagnosed with COVID-19 than those who were vaccinated.

Adjusted odds ratio [aOR] = 0.53; 95% confidence interval [CI]: 0.40–0.72; $p < 0.001$

The survey sample was positively associated with previous infection, where older age was negatively associated. COPD was independent factor associated with the reported diagnosis of COVID-19. The adjusted logistic regression results for self-reported diagnosis of COVID-19 are presented in Table 4. Higher odds of infection were significantly associated with COVID-19 vaccination, and higher odds with COPD.

**Table 4. Adjusted logistic regression model for self-reported COVID-19 diagnosis**

| Predictor | Adjusted OR | 95% CI | p-value |
|---|---|---|---|
| COVID-19 vaccinated vs unvaccinated | 0.53 | 0.40–0.72 | <0.001 |
| Age, per one-year increase | 0.97 | 0.96–0.98 | <0.001 |
| Female vs male | 1.13 | 0.91–1.40 | 0.261 |
| Health-insurance coverage | 1.81 | 0.97–3.37 | 0.063 |
| Obesity | 1.15 | 0.93–1.43 | 0.190 |
| Current cigarette smoking | 0.57 | 0.41–0.81 | 0.001 |
| Insulin use | 0.85 | 0.66–1.08 | 0.174 |
| Hypertension | 1.08 | 0.84–1.38 | 0.543 |
| Coronary heart disease | 1.15 | 0.85–1.56 | 0.367 |
| Chronic obstructive pulmonary disease | 1.59 | 1.16–2.19 | 0.004 |
| History of cancer | 1.04 | 0.79–1.37 | 0.792 |

Model additionally adjusted for race and ethnicity, educational attainment, income category and geographic region. OR: odds ratio CI: confidence interval.

### 3.5 Vaccination and Post-Infection Outcomes

For those who had previously been diagnosed with COVID-19, vaccination was also associated with reduced adjusted risk of severe COVID-19 symptoms with the confidence interval containing the null value. There was no statistically significant association with current post-COVID symptoms or Long COVID.

**Table 5. Adjusted association between COVID-19 vaccination and post-infection outcomes**

| Outcome | Analytical n | Adjusted OR | 95% CI | p-value |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| Severe or very severe symptoms | 734 | 0.66 | 0.39–1.09 | 0.106 |
| Long COVID | 680 | 0.90 | 0.54–1.49 | 0.675 |
| Current post-COVID symptoms | 681 | 1.19 | 0.65–2.15 | 0.577 |

Reference group: unvaccinated adults. Models adjusted for sociodemographic, healthcare-access, behavioural and clinical characteristics.

Statistically, there was no evidence of an independent association, although the point estimate for severe symptoms indicated that the odds were about 34% lower among the vaccinated participants. Post-infection results had wider confidence intervals due to the smaller number of respondents for these analyses. Self-reported COVID-19 diagnosis had the closest and most significant protective association with being. Self-reported COVID-19 diagnosis showed the closest and significant protective association. The adjusted association between vaccination and post-infection outcomes are shown in Table 5. Figure 3 displays odds ratios and 95% confidence intervals adjusted for potential confounding factors related to infection.

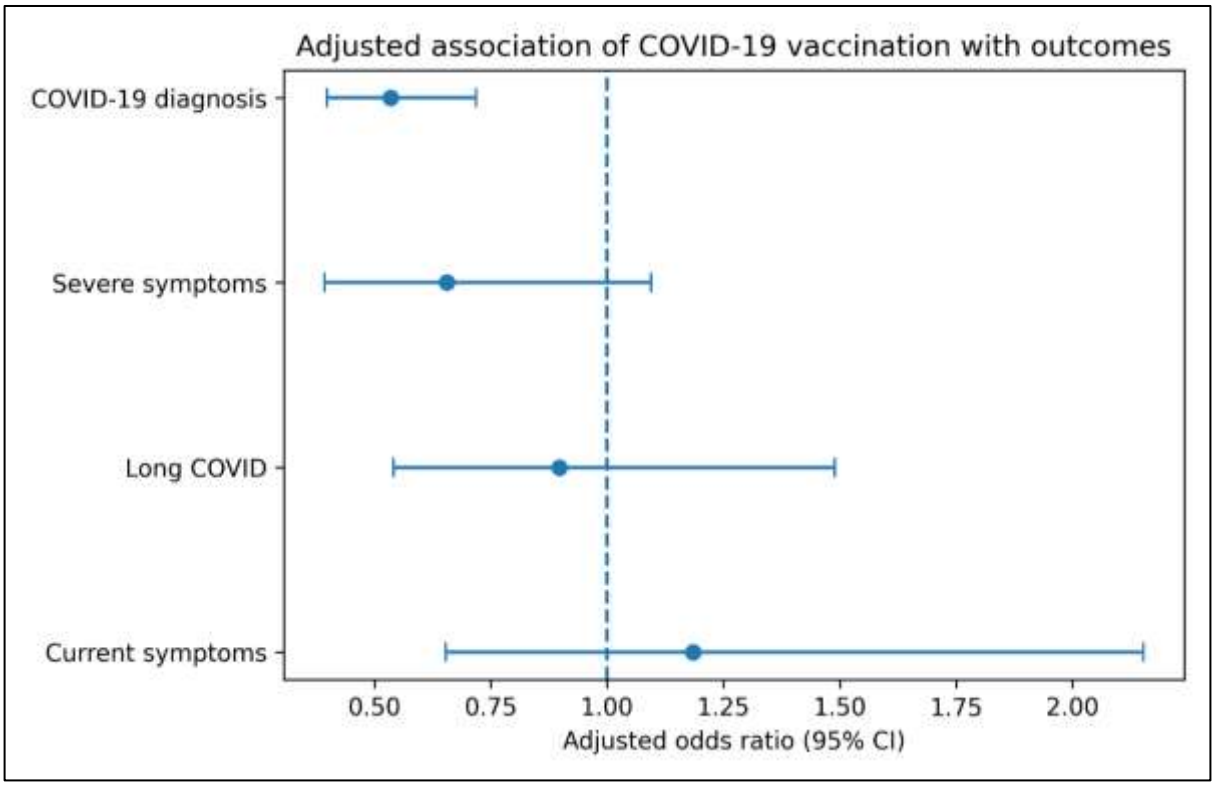


**Figure 3. Adjusted associations of COVID-19 vaccination with infection-related outcomes**

### 3.6 Summary of Principal Findings

The suggest a correlation between increased adult vaccination coverage and lower infection burden, especially reported COVID-19 infection, in adults with diabetes. However, the lack of a clear cross section, self-reported exposure and outcome, as well as the unclear temporal sequence, make results difficult to interpret as direct evidence of programme effectiveness.

## 4. DISCUSSION

Associations between vaccination and no or mild symptoms and fair or poor general health were also present, though not statistically significant. Low vaccine uptake among adults aligns with the theory of vaccine benefits as they are expected to have a lower rate of infection, which is associated with lower transmission and disease burden (Kashyap, 2026). This is important in the context of diabetes as hyperglycaemia, the effects on immune function and susceptibility to infection can be linked to development and poor outcomes (Casqueiro et al., 2012). This high level of infection burden is also mirrored by recent findings that infection severity can affect metabolic control in people with diabetes and vice versa (Holt et al., 2024). This association observed is in line with previous influenza studies. Flu vaccination has been shown to have clinical benefits for adults and elderly persons with diabetes (Looijmans-Van den Akker et al., 2006). Population-based data have also demonstrated that vaccination lowers hospital admission and death rates in people with type 2 diabetes (Vamos et al., 2016). In addition, the results of the meta-analysis reinforce the benefits of influenza vaccination as a protection measure for individuals with diabetes and its related severe outcomes (Dicembrini et al., 2023).

Vaccination against pneumococcus was greater than vaccination against tetanus or shingles, but was not complete. Clinically relevant because pneumococcal vaccination can reduce the risk of infection and related complications in people with diabetes (Silverii et al., 2024). There is also evidence that 23-valent pneumococcal polysaccharide vaccine is effective in older adults with diabetes (Kuo et al., 2016). Systematic reviews suggest pneumococcal vaccination could lower

hospitalisation and death rates in adults with diabetes (Del Riccio et al., 2023). Thus, there is potentially a large preventable burden of pneumococcal disease with incomplete coverage.

Other factors that can affect persistent symptoms include infection timing, viral variant, reinfection, treatment, comorbidities, and time since vaccination. Additionally, self-reported vaccination and infection histories are not immune from recall or classification errors. Variations in coverage between vaccines show that access to healthcare is not sufficient to achieve programme completion. Some major barriers between people with diabetes are limited awareness and concerns about safety; and poor recommendations from health care providers (Aldhahir et al., 2025). Studies have also demonstrated that there has been a longstanding discrepancy between influenza vaccination recommendations and uptake (Mastrovito et al., 2024). Therefore, routine diabetes consultations should include reviewing a patient's history of vaccinations, providing personalised counselling, and delivering vaccinations on the day of the consultation. Randomised evidence is available for targeted interventions for diabetes patients, and systematic evidence is available for hospital-based interventions for older adults and high-risk adults (Guerra et al., 2023; Pennisi et al., 2025).

It also has policy and economic implications derived from the findings. In vulnerable groups with high risk of complications, adult vaccination might be cost effective (Leidner et al., 2019) and influenza vaccination may have specific economic benefits in adults with T2DM (Akın et al., 2016). It may therefore be possible to integrate vaccination into the management of chronic diseases, which should help minimise healthcare utilisation due to infection and improve the continuity of preventive care. There are a few restrictions that should be noted. The NHIS is not longitudinal and therefore, cannot determine if vaccination occurred before infection. No laboratory confirmation of exposure and/or outcome; no clinical records; no infection-specific vaccine-effectiveness estimates.

There may be residual confounding for health seeking behaviour and timing of infection. However, the nationally representative design, diabetes-specific analysis, and multiple vaccination indicators, along with the use of survey-weighted regression, enhance the study. In conclusion, overall vaccination was significantly related to lower self-reported burden of COVID-19 infections among adults with diabetes, and providing a routine assessment and delivery of vaccination into diabetes care is warranted, along with conducting long-term studies that leverage clinically confirmed measures of infection, hospitalisation, and mortality.

## 5. CONCLUSION

This study highlights that adults who participate in adult immunization have less diabetes infection burden. Unadjusted associations were similar for vaccinated adults, with vaccinated adults exhibiting lower rates of severe symptoms, Long COVID and poor overall health however, there were no statistically significant associations for post-infection outcomes. The results emphasize the need to include assessment and provision of vaccines as part of diabetes management. While levels of COVID-19 vaccinations are fairly high, gaps in preventive care have persisted for influenza, pneumococcal, tetanus and shingles vaccines. Structured counselling, provider recommendation, reminder systems and same day vaccination may increase coverage among high-risk adults. However, the cross-sectional design and self-reported measures, along with the unknown time order of the vaccination and infection, reduces the ability to infer causality. Thus, any observed correlations should not be interpreted as proof of vaccine effectiveness. There is a need for future longitudinal studies with confirmed vaccination status, laboratory confirmation of infections, hospitalisation and mortality data. In general, improving adult vaccination programs has the potential to significantly decrease diabetes-related morbidity due to vaccine-preventable diseases.

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