ANALYZING THE ASSOCIATION OF COVID-19 VACCINATION WITH CHANGES AMONG INDIVIDUALS WITH DIABETES AND OBESITY: A RETROSPECTIVE COHORT ANALYSIS AMONG INDIANAPOLIS METROPOLITAN RESIDENTS.

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DEDICATION

There is no one else I would rather dedicate this journey than to my loving and patient wife Marlene. Marlene and I started our relationship close to the beginning of this arduous endeavor and she has been nothing but understanding and supportive the entire way. I also want to dedicate this endeavor to my Mom and Dad. I know I am making them proud in becoming a doctor and they have supported me throughout my academic career.

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Shane M. Hanley

ANALYZING THE ASSOCIATION OF COVID-19 VACCINATION WITH CHANGES AMONG INDIVIDUALS WITH DIABETES AND OBESITY: A RETROSPECTIVE COHORT ANALYSIS AMONG INDIANAPOLIS METROPOLITAN RESIDENTS.

Introduction: The COVID-19 pandemic was detrimental in a multitude of aspects of health. One specific area of research that was touched on but not to a greater extent was the impact of the COVID-19 pandemic on the clinical visits for those with other comorbidities. In relation to this dissertation, the focus is to highlight the impact COVID-19 vaccines had on A1C levels and weight before and after vaccine availability.

Methods: A retrospective cohort was designed by selecting residents from Indianapolis metropolitan hospitals who were diagnosed with diabetes or obesity prior to January of 2019. The study period began in 2019 right before the COVID-19 pandemic and ended in December of 2022. Descriptive statistics were computed to display the difference in proportions of all covariates by vaccine status. Multiple logistic regression was conducted to test for the potential association between those who were vaccinated and lower on average AIC level or average weight in kilograms by end of study compared to those not vaccinated. Separate confounding and interaction testing were conducted as well on all other covariates individually with vaccine status.

Results: Those that were not vaccinated had a 0.11 greater AIC level by end of study compared to those that were vaccinated and while controlling for all other covariates was still 0.29 with the largest statistically significant confounder being diabetes at 0.30. Those that were not vaccinated had a 4.04 kilograms greater average weight by end of study compared to those that were vaccinated and while controlling for all other covariates was still 0.92 kilograms heavier among the non-diabetic group. Those that were not vaccinated had a 6.36-kilogram greater average weight by end of study compared to those that were vaccinated and while controlling for all other covariates was still 3.40 kilograms heavier among the diabetic group.

Conclusion: This study helps quantify the relationship between COVID vaccine status and A1C/weight management. More research is warranted to further observe these health outcomes beyond the height of the pandemic.

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Chapter 1: Introduction

The COVID-19 pandemic began in Wuhan, China in late 2019 and became widespread throughout the United States in early 2020 leading, the World Health Organization (WHO) to declare a pandemic on March 11th 2020 (1). There were comorbidities that resulted in more severe effects from this infectious disease of which diabetes and obesity were of focus in this dissertation. Moreover, research has shown there being an association between COVID-19 and poor diabetes management, however it was more limited to more emergency visits (2-5). This dissertation will expand on prior knowledge around COVID and diabetes by looking at the relationship among primary care visits. Prior literature also did not look specifically at the relationship between vaccination status on average A1C which adds another novel aspect to this research. The use of vaccine status will contribute to prior literature by using this covariate as a means to represent overall well-being as well as a way to construct discussions on whether those not vaccinated are more likely to not prioritize their diabetes and/or weight.

The focus in the obesity papers (chapters 3 and 4) will expand on prior literature around weight gain but with the separation between diabetic and non-diabetic for each chapter. The reason for this was prior research found only a small relationship of increased weight during the pandemic among individuals, but they did not isolate based on diabetes status or obesity status (7-11). Also, isolating each chapter based on diabetes status will help assess whether the relationship is more severe when looking at each group separately. Prior studies included both obese and non-obese patients in their analysis (7-8). This research only includes those who were diagnosed as obese to assess if this specific risk group experienced increased weight during the pandemic based on vaccination status. Another reason why diabetes and obesity were chosen is because of the consequences for those with these comorbidities if they were infected with COVID-19. Some of the potential links among type 2 diabetes patients that also have COVID-19 can range from insulin resistance or worsening hyperglycemia to a greater risk of ER level hospital visits (Figure 1). Some potential consequences from being infected with COVID-19 for obese individuals can range from difficulty staying active as well as increased anxiety (Figure 2). These factors both physiological and behavioral with COVID-19 indicate the importance of maintaining well-being given the individual contracts the infection. These findings can have an impact on overall well-being and assist providers in their management of their clients, especially those with comorbidities. The use of these findings can help the patients make healthier choices after knowing their potential risk. Some potential follow-ups from this would be increasing telehealth visits for patients in a similar situation, increasing funding for local and state health departments to get them more equipped to assist these higher risk patients find ways to maintain their health, as well as getting these patients to use devices that can help ensure they are taking the adequate food intake and keeping up with their A1C and weight management. It does not have to be related to COVID-19 vaccines as different health situations can be thought of as a proxy to their decline in choices around their weight and diabetes management. These next three papers will delve further into associations between not being vaccinated for COVID-19 and increased A1C and weight during the pandemic and the ramifications for well-being in the future.

Chapter 2: The potential association between COVID vaccination during the COVID pandemic and A1C levels among Indianapolis metropolitan residents

Introduction

The emergence of the COVID pandemic in the United States negatively impacted many populations including those with type 2 diabetes (2). Moreover, COVID greatly impacted the typical daily work processes in hospital settings (2). A study found that those with type 2 diabetes were experiencing an increased likelihood of more severe complications with COVID and hospitalizations (3). An additional study in Spain also observed that there was a significant decrease in in-person visits with patients as a result of the COVID pandemic (4). The researchers were able to conclude this significant decrease of in-person visits negatively impacted their diabetes management (4). It was also shown that uncontrolled type 2 diabetes is associated with more severe cases of COVID-19 with a greater potential for death (5). However, the researchers were mainly looking in emergency settings; there has been research looking at impact of COVID-19 on type 2 diabetes, but research is limited in primary care settings (2-5). This study seeks to expand on this research by assessing the impact of diabetes management during the height of the pandemic in primary care settings over a 2-year period.

Specifically, this study assessed not only COVID-19 impact on diabetic patients but compare those vaccinated with those not vaccinated during the pandemic. This study adds to the body of literature with specifically looking at the potential association between being vaccinated for COVID during the pandemic and lower A1C thus resulting in a better diabetes control. Patients were observed throughout the COVID-19 pandemic from the initial wave of the pandemic defined as March of 2020 until one year after vaccine availability (December of 2022). Overall, this study sought to show the positive impact COVID vaccines had on quality of life.

Materials and Methods

Study Population

Data was obtained from the Indiana Network for Patient Care (INPC). The INPC was started in the 1990s and is the largest clinical data repository which includes hospital data from more than 100 different hospitals throughout the state (6). The study population was a retrospective cohort of Indianapolis Metropolitan individuals with a diabetes and obesity status as of December 2019. The dataset started with 102,263 potential unique individuals but after inclusion exclusion criteria resulted in 18,914 individuals. Moreover, those that did not have an A1C reading in the dataset were excluded from the study since that was the main outcome. Also, those that died related to COVID in the study period were excluded from the study.

Study Design

A retrospective cohort was constructed from the initial derived dataset and included patients aged 18 or older that had at least one A1C reading since 2019. Patients were followed from the start of the COVID pandemic identified as March of 2020 (height of COVID pandemic) until December of 2022 which was chosen to allow for one year after COVID vaccine was available.

The outcome of average A1C after vaccine was identified as the average of the last A1C reading in the study period. This variable was used to observe the difference on diabetes prevention/management between those who were vaccinated versus those that were not vaccinated during the study period. The exposure variables of interest in this study included demographics along with COVID history, insurance status, diabetes status, obesity status, and COVID testing history.

Data Analysis

Descriptive statistics were calculated to test for the difference in proportions among all the covariates between those that were vaccinated and those that were not vaccinated. Chi-square testing was part of the descriptive analysis on the categorical predictors and a t-test was performed for both before vaccine average A1C and after vaccine average A1C as well as A1C difference. A1C difference was calculated by subtracting the baseline from the last recorded A1C in reading for each person. Missing responses for variables outside the outcome of average A1C were categorized under unknown. A simple logistic regression was conducted on the main exposure of vaccine status to test for significant differences in average A1C level after first vaccine. Each subsequent covariate was tested along with vaccine status to assess potential confounding. Moreover, all covariates were tested together with vaccine status on average A1C level after first vaccine. Interaction testing was also conducted with each of the covariates with vaccine status. All data analyses were conducted using SAS Enterprise Guide.

Results

There were 11,230 individuals that were vaccinated (59.37%) compared to 7,684 that were not vaccinated (40.63%) (1.1). All of the covariates showed a significant difference in proportions with vaccine status except COVID test history. As the age increased those that were vaccinated had a greater percentage. There was a slightly larger percentage of females vaccinated and a slightly larger percentage males not vaccinated. The largest difference in proportions among race was observed among other race where 7.52% making up the vaccinated population compared 4.71% of the not vaccinated population (1.1). There was a larger proportion of those not Hispanic/Latino/a that were not vaccinated (56.29%) compared to those vaccinated (49.38%) (1.1). However, there were both larger proportions of Hispanic/Latino/a and unknown vaccinated as opposed to not vaccinated. There was a larger proportion of those not vaccinated (27.13%) with COVID history compared to those vaccinated (23.63%) (1.1). However, there was a larger proportion of those vaccinated without COVID history (44.26%) compared to those not vaccinated (39.89%) (1.1). The largest difference in proportion for insurance status was observed for Medicare where those vaccinated comprised of 35.98% compared to those not vaccinated being 26.97% (1.1). There was a larger proportion of those vaccinated that had type 2 diabetes (82.10%) compared to those that were not vaccinated (71.32%) (1.1). There was not much of a difference between vaccinated and not vaccinated for obesity status. The average A1C before vaccine was the same as the not vaccinated group but was significantly lower for the after-vaccine average (6.91) compared to those not vaccinated (7.02) (1.1). Those that were vaccinated had a 0.42 decrease in A1C compared to those not vaccinated being 0.19 decrease in A1C (1.1).

Those that were not vaccinated had a 0.11 greater A1C on average by the end of study compared to those that were vaccinated (<0.0001) (1.2). All other covariates when assessed individually with vaccine status were statistically significant. The covariate that had the largest confounding on after vaccine average A1C was diabetes where those not vaccinated had a 0.30 on average greater A1C by end of study compared to those vaccinated (<0.0001) (1.2). When controlling for all other covariates together, those not vaccinated had a 0.29 on average greater A1C by end of study compared to those vaccinated (<0.0001) (1.2). There were three variables that presented a significant interaction with vaccine status which were sex, diabetes status, and obesity status. Those that were male and not vaccinated had the largest difference at 0.49 on average greater A1C by end of study compared to females that were vaccinated (0.0002) (1.3). Those that were not vaccinated and diabetic had a 1.96 on average greater A1C by end of study compared to those that were vaccinated and not diabetic (<0.0001) (1.3). Lastly, those that were not vaccinated and obese had a 0.90 lower average A1C by end of study compared to those vaccinated and not obese (<0.0001) (1.3). A1C difference was tested as another outcome through logistic regression but there was not a statistically significant difference between each vaccine status.

Discussion

This study was able to further support previous research on diabetes during the COVID pandemic being related to worse overall management (1-4). However, the previous papers mainly observed whether the diabetic patients missed appointments and adverse outcomes related to diabetes during the pandemic (1-4). This research was able to quantify a potential association with those being diabetic and missing more of their appointments by observing whether they were vaccinated for COVID. This covariate was used as a means to observe if not being vaccinated for COVID during the pandemic could be an indicator of poor diabetes management.

We were able to find that those being not vaccinated overall on average had a 0.11 higher A1C level compared to those not vaccinated. At the surface that might seem low, but it is important to factor in the impact of that difference between the groups. That 0.11 increase can be the difference between controlled diabetes versus uncontrolled diabetes management. Specifically, both groups were considered above managed levels of diabetes at a 7.21 average A1C level before vaccine. However, by end of the study those not vaccinated for COVID still did not on average have a managed A1C level but those vaccinated were considered controlled. Furthermore, when observing between the levels of interaction covariates you can see there can be much different differences in AIC level by end of study.

This study was not devoid of limitations with the main issue being missing A1C readings for patients. This decreased the overall cohort and those without a single reading had to be deleted from the analyses. Another limitation was lack of data around diabetes medication use and ER visits related to diabetes. These two data points would be valuable to assess whether those not vaccinated also had a potential association with less prescription refills and more ER visits related to uncontrolled diabetes. A strength of this study was despite the missing data; we were able to assess over 18,000 unique patients over a 2-year period. The most important takeaway from this study is that vaccine use can be seen as a potential link to other overall health outlooks for a particular person.

Conclusion

This study helped demonstrate the impact of the COVID vaccine on diabetes management. The decrease in A1C level was quantified and showed that those with a history of a COVID vaccine was lower on average compared to those without a COVID vaccine. These findings indicate the potential link between vaccination status and overall well-being. Further research needs to be done on these patients beyond the 2-year study period to observe if the findings remained consistent or resulted in any noticeable differences. Other future studies can expand on these findings by observing diabetes medication refills and diabetes related ER visits.

Chapter 3: The potential association between COVID vaccination during the COVID pandemic and weight change among non-diabetic obese Indianapolis metropolitan patients

Introduction

An area of research that has been studied on is the impact of the COVID pandemic on weight management (7). One study was able to observe a statistical association between being overweight and weight gain a year after the COVID pandemic (7). Furthermore, those that were not overweight experienced less of weight gain during the same time (7). Another study mentioned the evidence of this association among other literature is limited by the source being convenience samples (8). This study was able to expand on the samples from other studies by using patients from an electronic database (8). These researchers observed the patients from the pandemic into 2021 and noticed small differences and most notably in obese females (8). However, these studies did not separate out or isolate their research to only those overweight or isolate diabetes status (7,8). There was another Canadian study that used convenience sampling as referenced with other papers and observed the covid pandemic among these sampled patients negatively impacting their overall weight management (9). Moreover, there was a survey study that included those 18 and older and reached out to over 26 countries (10). These researchers observed that the COVID pandemic had a greater negative impact on those younger and obese which was similar to the first study mentioned (7-10).

These papers have in common differences that our study expands on in the next two papers. In this respective paper, we are looking to isolate among only those that are not diabetic and are obese. The reasoning behind this specific inclusion criteria is to demonstrate the impact of looking at only the obese population as well as the difference when isolating the diabetic and non-diabetic groups. This paper is a novel addition to the body of literature given prior studies did not attempt to isolate two of the most important risk factors for COVID in obesity and diabetes. Overall, this study seeks to show despite the group being non-diabetic that those not vaccinated for COVID experienced a greater weight by end of study.

Methods

Study Population

Data was obtained from the Indiana Network for Patient Care (INPC). The INPC was started in the 1990s and is the largest clinical data repository which includes hospital data from more than 100 different hospitals throughout the state (6). However, this study population was a subset containing those that were not diabetic but also had at least one weight reading in the dataset. This subset was a retrospective cohort where the individuals had a history of diabetes and obesity status as of December of 2019. The overall dataset included 102,263 unique patients but after excluding those without a weight reading or being diabetic resulted in 18,090 unique patients. This dataset also only includes those that were obese in the dataset. Furthermore, those that died of COVID during the study period were excluded.

Study Design

A retrospective cohort was constructed including those with at least one weight reading since 2019 and were 18 years or older. These patients were similarly followed from the start of the COVID pandemic in March of 2020 for about two years ending in December of 2022. As stated, prior, the end point of the study was chosen based on being approximately 1 year after the COVID vaccine was available.

The outcome of average weight after vaccine was determined as the average of the last weight reading in the study period. This variable was chosen to analyze the difference in weight management among obese patients based on COVID vaccination status. We wanted to isolate this paper to only those without diabetes to observe a potential association with weight change without a confounder of diabetes status. The exposure variables of interest in this study were demographics along with COVID history, insurance status, and COVID testing history.

Data Analysis

Descriptive statistics were calculated to test for the difference in proportions among all the covariates between those that were vaccinated and those not vaccinated. Chi-square testing was conducted with the descriptive analysis on the categorical independent variables and a t-test was performed for both before vaccine weight and after vaccine weight average as well as weight change. Weight change was calculated by subtracting the baseline weight from the last recorded weight reading for each person. All variables outside of the outcome variable average weight that were missing were replaced with unknown. A simple logistic regression was performed on the main exposure of vaccine status to assess if there were significant differences on average weight by end of study. Each of the covariates were analyzed with vaccine status individually to observe potential confounding on average weight. Furthermore, all the covariates were included with vaccine status to observe the overall relationship between vaccine status and average weight while assessing all potential confounding. Interaction testing was also conducted to assess the levels of each covariate with vaccine status. All data analyses were conducted using SAS Enterprise Guide.

Results

There were 12,409 individuals that were vaccinated (68.60%) compared to 5,681 (31.40%) that were not vaccinated (2-1). All of the covariates showed a significant difference in proportions with vaccine status. Similarly to paper one as age increased those that were vaccinated had a greater percentage. There was a greater percentage of women vaccinated compared to a greater proportion of men not vaccinated in the study group. The largest difference in proportion among race was African American/Black where 35 percent of this race made up the vaccinated population compared to 40 percent of this race made up the not vaccinated group (2-1). There were both larger proportions of Hispanic/Latino/a and non-Hispanic/Latino/a patients that comprised the vaccinated group compared to the not vaccinated group (2-1). However, there was a larger proportion of unknown ethnicity that were not vaccinated. There was a larger proportion of those vaccinated that had COVID history as opposed to a larger proportion of the no COVID history patients being not vaccinated (2-1). Medicare and Medicaid insurance status both had the largest proportions of those being vaccinated and those with other insurance status had the largest proportion of those not vaccinated. The average weight among the vaccinated group prior to first vaccine was about 4 kilograms lighter than those not vaccinated (2-1). It was statistically significant but the difference between before and after first vaccine weight average was negligible. Neither had a large decrease in average weight between the two. Those that were vaccinated had a slight decrease in weight compared to their baseline (-0.07) while those not vaccinated had a 0.49 increase in weight compared to their baseline (2-1).

Those that were not vaccinated had a 4.04 greater weight on average by end of study compared to those that were vaccinated (<0.0001) (2-2). All other covariates when assessed with vaccine status were statistically significant. When including all significant covariates in the model, those that were not vaccinated had only a 0.92 greater on average weight by end of study compared to those that were vaccinated (0.02) (2-2). There were 4 covariates that presented a significant interaction with vaccine status on average weight by end of study which were sex, insurance status, age group, and ethnicity. Those that were male and not vaccinated had a 14 times larger weight on average compared to those that were female and vaccinated (<0.0001) (2-3). Those that were not vaccinated and had Medicare insurance presented a 9 times smaller weight on average compared to those vaccinated and commercial insurance status (0.003) (2-3). All age groups had a greater weight on average among the not vaccinated group compared to the 65 and older vaccinated patients. The largest difference was among the not vaccinated 18–45-year-old patients at 17.89 kilograms and decreased as the age group was older (2-3). Lastly, those that were not vaccinated and unknown ethnicity had a 4 kilogram on average greater weight compared to not Hispanic/Latino/a vaccinated patients (0.0580) (2-3). Weight change was tested as another outcome through logistic regression but there was not a statistically significant difference between each vaccine status.

Discussion

This study was able to expand on prior research around weight management during the COVID pandemic (6-9). However, the previous research was lacking in isolating the patients based on diabetes and obesity status. This paper was able to demonstrate an association between weight gain/loss while only including those that are non-diabetic and obese. The reason behind this specific inclusion criteria was due to diabetes status being a major risk factor for COVID and may demonstrate different results depending on being diabetic or non-diabetic. Furthermore, this study was able to support prior studies on the association between younger obese individuals and weight gain.

Despite only including those that were non-diabetic, we observed those not vaccinated having a 1-kilogram greater weight by end of study compared to those vaccinated. Contrary to one previous study, we observed that those being male were more likely to have a larger weight change among the non-vaccinated group compared to females who were vaccinated by end of study (6). Our study was aligning with previous studies in that weight on average was the largest difference by end of study among the youngest age group (18-45 years old).

This study was not devoid of limitations with the main issue being the missing weight readings in the dataset. Those that did not have a weight reading had to be excluded from the study which hinders the overall result. Another limitation is the lack of medication data around weight loss. The use of weight medication data can be a potential confounder on weight loss that we were unable to account for in this study. A strength of this study is the ability to include over 18,000 unique patients despite the missing outcome data. Overall, this study was able add a new study variation to prior literature as well as supporting prior associations with similar covariates.

Conclusion

This study was able to quantify the influence of the COVID vaccine on weight management while isolating to those being non-diabetic. The importance of this specific criteria was due to this covariate being a potential confounder and effect modifier for weight management. The inclusion of only non-diabetic still was able to show a significant relationship between being vaccinated for COVID and weight decrease. More research is warranted to observe these patients beyond the 2-year study period to observe if they continue to show a significant difference in weight. Furthermore, observe if those not diabetic during the study period later did develop the disease and whether they experienced an increase in weight based on vaccine status.

Chapter 4: The potential association between COVID vaccination during the COVID pandemic and weight change among diabetic obese Indianapolis metropolitan patients

Introduction

As mentioned in paper 2, there has been research conducted on the COVID pandemic and the related impact on weight management (7-10). However, the focus behind this paper is to highlight the differences when observing the impact among type 2 diabetic individuals. There was a study in Italy that observed a negative association between diabetes management and weight gain during the pandemic where those with type 2 diabetes experienced both an increase in weight and glycemic levels during the lockdown (11). It is well known from prior research that there is a link between these two where those who are diabetic are at risk for becoming obese and those obese are at risk of developing type 2 diabetes (3). We observed in the first paper that diabetes status was the main confounder in A1C management, and we want to isolate for this study. It has been estimated that obese men and women have 7 and 12 times the risk of developing diabetes as opposed to those not obese (3). The prior research did observe significant weight gain albeit small among those who were obese but did not isolate the important confounder in diabetes status. Given the known link between obesity and diabetes we want to observe if there is a significant difference when only looking at those with type 2 diabetes. We hypothesize that among the diabetic group those vaccinated will have larger decrease in weight by end of study compared to those not vaccinated. Furthermore, we expect to observe a larger difference between the two groups than among the non-diabetic group in study 2. This research will expand on previous knowledge and may shed more light on the impact of weight control during the COVID pandemic when observing among a key risk factor in diabetes.

Methods

Study Population

The data obtained was obtained from the same overall INPC dataset. However, this study population was a subset containing those that were diabetic but also had at least one weight reading in the dataset. This subset was a retrospective cohort where the individuals had a history of diabetes and obesity status as of December of 2019. The overall dataset included 102,263 unique patients but after excluding those without a weight reading or being not diabetic resulted in 12,040 unique patients. This dataset also only includes those that were obese in the dataset. Furthermore, those that died of COVID during the study period were excluded.

Study Design

A retrospective cohort was constructed including those with at least one weight reading since 2019 and were 18 years or older. These patients were similarly followed from the start of the COVID pandemic in March of 2020 for about two years ending in December of 2022. As stated prior, the end point of the study was chosen based on being approximately 1 year after the COVID vaccine was available.

The outcome of average weight after vaccine was determined as the average of the last weight reading in the study period. This variable was chosen to analyze the difference in weight management among obese patients based on COVID vaccination status. We wanted to isolate this paper to only those with diabetes since we observed that this covariate demonstrated the most noticeable differences in weight management among the obese patients. The exposure variables of interest in this study were demographics along with COVID history, insurance status, and COVID testing history.

Data Analysis

Descriptive statistics were calculated to test for the difference in proportions among all the covariates between those that were vaccinated and those not vaccinated. Chi-square testing was conducted with the descriptive analysis on the categorical independent variables and a t-test was performed for both before vaccine weight and after vaccine weight average. Similar to the last chapter, weight change was measured as well. All variables outside of the outcome variable average weight that were missing were replaced with unknown. A simple logistic regression was performed on the main exposure of vaccine status to assess if there were significant differences on average weight by end of study. Each of the covariates were analyzed with vaccine status individually to observe potential confounding on average weight. Furthermore, all the covariates were included with vaccine status to observe the overall relationship between vaccine status and average weight while assessing all potential confounding. Interaction testing was also conducted to assess the levels of each covariate with vaccine status. All data analyses were conducted using SAS Enterprise Guide.

Results

There were 9,440 individuals that were vaccinated (78.41%) compared to 2,600 (21.59%) that were not vaccinated (3-1). All of the covariates showed a significant difference in proportions with vaccine status except history of being tested for COVID. Similarly to the other 2 papers as age increased those that were vaccinated had a greater percentage. There was a greater percentage of women vaccinated compared to a greater proportion of men not vaccinated in the study group. The largest difference in proportion among race was with White where 46 percent of this race made up the vaccinated population compared to 53 percent of this race made up the not vaccinated group (3-1). There were both larger proportions of Hispanic/Latino/a and non-Hispanic/Latino/a patients that comprised the vaccinated group compared to the not vaccinated group (3-1). However, there was a larger proportion of unknown ethnicity that were not vaccinated. There was a larger proportion of those not vaccinated that had COVID history as opposed to a larger proportion of the no COVID history patients being vaccinated (3-1). Medicaid insurance status had the largest proportion of those being vaccinated and those with other insurance status had the largest proportion of those not vaccinated (3-1). The average weight among the vaccinated group prior to first vaccine was about 4 kilograms lighter than those not vaccinated (3-1). It was statistically significant and the difference between before and after first vaccine weight average was about 2 kilograms (3-1). Those that were vaccinated had a 3 kilogram decrease in weight compared to their baseline compared to those not vaccinated being 0.96 decrease (3-1).

Those that were not vaccinated had a 6.55 greater weight on average by end of study compared to those that were vaccinated (<0.0001) (3-2). All other covariates when assessed with vaccine status were statistically significant except history of COVID. When including all significant covariates in the model, those that were not vaccinated still had a 3.75 greater on average weight by end of study compared to those that were vaccinated (<0.0001) (3-2). Similarly, those that were not vaccinated had a 2.50 greater weight change between their baseline and final reading compared to those vaccinated (3-2). Furthermore, each of the covariates were put in the model and removed through pruning and it was observed that as each variable is removed the overall weight average decreased. There were 5 covariates that presented a significant interaction with vaccine status on average weight by end of study which were sex, insurance status, age group, ethnicity, and COVID history. Those that were male and not vaccinated had an 18.00 larger weight on average compared to those that were female and vaccinated (<0.0001) (3-3). Those that were not vaccinated and had self-pay insurance presented a 9.64 larger weight on average compared to those vaccinated and commercial insurance status (<0.0001) (3-3). All the age groups had a greater weight on average among the not vaccinated group compared to the 65 and older vaccinated patients (3-3). The largest difference was among the not vaccinated 18–45-year-old patients at 24.91 kilograms and decreased as the age group was older (3-3). Those that were not vaccinated and unknown ethnicity had a 5.81 kilogram on average greater weight compared to not Hispanic/Latino/a vaccinated patients (0.05) (3-3). Lastly, both COVID history and unknown COVID history among not vaccinated patients had a greater weight on average by end of study compared to vaccinated patients without COVID history (3-3). The largest difference was among those with COVID history at 10.02 kilograms (3-3).

Discussion

We were able to expand on prior research while looking at only those being diabetic and obese. Overall, those that were not vaccinated had a 3 times greater weight by end of study compared to those that were vaccinated. This was more than 2 times greater of a difference in the diabetic population compared to the non-diabetic group. Each of the significant covariates individually contributed to confounding the relationship between vaccination status and weight change. This indicates that each of the covariates being assessed together is more important than assessing separately with vaccination status. As hypothesized, the diabetic group would show a larger impact of not being vaccinated on weight change. Furthermore, the diabetic group had larger differences in all of the interaction results with vaccination status compared to the non-diabetic group paper. This is important conceptually because prior research did not separate these two groups out which can hinder overall results. The practical aspect of these findings can assist health care providers with their management of care with the emphasis on their non-vaccinated patients. We were able to observe that those that are male and diabetic can be up to 18 kilograms than those that were vaccinated and female. The vaccinated males were 9 kilograms less than the non-vaccinated group which shows a significant difference in health among the non-vaccinated group. We were also able to show that as the person increases in age the average weight change decreases. This is important for future research to isolate studies around younger age groups to establish healthy habits earlier in life.

This study has limitations in that missing data for weight readings had to be removed from the study. The lack of medication data is also limiting the study because weight loss medications could potentially be a confounder or interaction with vaccine status. It would be helpful to assess how those with weight medication differ from those without among the obese patients. A strength of this study is that despite the missing data, we were able to assess over 12,000 unique patients over a 2-year period. Overall, this study expands on the knowledge we have around weight management during the COVID pandemic by removing the potential influence of diabetes status.

Conclusion

This study was able to quantify the influence of the COVID vaccine on weight management while isolating to those only being diabetic. The importance of this specific criteria was due to this covariate being a potential confounder and effect modifier for weight management. The inclusion of only diabetic still was able to show a significant relationship between being vaccinated for COVID and weight decrease. More research is warranted to observe these patients beyond the 2-year study period to observe if they continue to show a significant difference in weight. Furthermore, observe if those being diabetic during the study period later experience worse outcomes related to their diabetes management among the not vaccinated group.

Chapter 5: Conclusion/Future Directions

Overall, the findings from these analyses indicate a potential importance to have a comprehensive understanding of the health of individuals who are diabetic and/or obese in relation to COVID-19. Specifically, reviewing more why those that are diabetic and not vaccinated are having less controlled A1C levels compared to those vaccinated for COVID-19. An understanding into the healthy habit differences between these groups of individuals would help clarify if there are other links related to their health choices. This research can guide health care providers in their management of these particular patients to ensure they stay up with their weight loss or diabetes management. A potential way to help these patients would be to instruct these patients to download applications that can keep them accountable with tracking their daily A1C levels. Specifically, one study found that the use of a diabetes tracking application resulted in a 0.86% decrease in A1C and the combination of the application and personal coaching resulted in a 1.32% decrease in A1C (12). There was another study that looked more at weight loss applications and the meta-analysis found that the use of weight applications was associated with decreased weight (13). There was a more significant decrease in weight as well with the combination of behavioral modifications (13). These applications can be used as motivation to stay on track with their health. These will build habits that can be harder to break if a similar situation arises in the future where it is more difficult to make appointments in-person. Furthermore, it serves as an example of what can happen to this population if a pandemic of this nature or similar arises in the future. This is important considering the literature has shown that pandemics are becoming more common in the

21st century (14). Specifically, one study found that the last 4 major pandemics are about 15 years apart on average (14). The rapid progression of subsequent pandemics compared to before further stresses the need for building these types of healthy habits before the next pandemic occurs. It will also be important to use these findings to coordinate with state health departments on how to provide funding on research around the relationship between COVID-19 and diabetes/obesity to be more prepared given a future pandemic arises.

There were noticeable patterns across the research in chapters 2, 3, and 4. The variability of diabetes being the most noticeable among the covariates in association with each of the outcomes. Moreover, diabetes status demonstrated the largest association with average A1C level along with average weight being less than a kilogram on average more among the not vaccinated non-diabetic group (paper 2) compared to more than 3 times greater among the diabetic group (paper 3). Specifically, the association between average weight and COVID vaccine status was more noticeable when isolating to only those with type 2 diabetes. Separating out these last two papers by diabetes status not only was novel compared to prior literature but also helps further understand the relationship between COVID-19 infection and obesity. The research demonstrated that when looking at only those who are diabetic, that each of the covariates contribute equally to the overall outcome of average weight whereas among those not diabetic showed some covariates contributed more than others. However, in both instances only looking at vaccine status alone would have been an overrepresentation of the association with average weight. In chapter 2, we learned that despite both vaccine groups having a lower A1C average by end of study, those without a COVID-19 vaccine were still in non-controlled levels.

There is still more to learn about these relationships which would require either following up with these patients currently or performing a similar study among a larger group of individuals during this time potentially in a different location.

It is crucial that these patients maintain their health which includes regular provider appointments, so their health does not decline. Telehealth is one option to assist them during future outbreaks if they are unable to attend on-site in order to ensure the patients are monitoring their health. The goal is to potentially follow these same patients currently to see if any changes have been made or if bad habits merged that have been difficult to change after the pandemic.

One variable that would have been helpful to assess and be a potential follow-up study is looking at medication refills for weight loss drugs and type 2 diabetes specific medication. The lack of medication refills during the pandemic might be a potential confounder or effect modifier on the overall relationship with diabetes and weight management. Additional future studies would be to assess non-primary care hospital visits during the study period to see if patients were hospitalized due to not managing their diabetes during the pandemic or after. These two variables were not available in this research but would be useful. A future study can expand with these variables by assessing if those not vaccinated had an uptake in ER visits or more severe complications that needed extra visits beyond primary care. The use of medication data in a future study would be useful because there could be a potential link between failure to regularly refill their prescriptions during the pandemic and increased A1C and weight.

Another association that follows similarly to the worsened outcome of diabetes is long COVID. Long COVID is where individuals experience symptoms of the infection that last longer than typical and can range from weeks to months (15). There is also literature that suggests type 2 diabetes being a potential risk factor for long COVID (16). This link was not able to be observed in these papers but can be a follow-up study to assess whether these individuals experienced lengthened COVID-19 symptoms. Furthermore, the diabetic group could be compared to the non-diabetic group to observe if there was a significant difference in long COVID symptoms between the groups. There has also been literature that suggests obesity being linked to increased chances of long COVID (17). Overall, a study observing these findings in relation to COVID-19 vaccination status would add to this research.

Lastly, the isolation of diabetic patients and non-diabetic patients for chapters 2 and 3 can be used to analyze the potential mechanisms of why the diabetic group had larger weight changes among the non-vaccinated group compared to the non-diabetic patients. It would be beneficial to observe these specific populations unwilling to be vaccinated and see what the influence is on their well-being. This is only the starting point, and these findings can be replicated in larger settings or for a longer study period to observe similarities or other health related associations to those not being vaccinated in this specific population over time.

List of Tables

1-1: Descriptive statistics those vaccinated and not vaccinated for COVID in Indianapolis MSA (N=18,914)

Variable	Vaccinated 11,230 (59.37%)	Not Vaccinated 7,684 (40.63%)	P^b
Sex			
Male	4,029 (35.88)	3,030 (39.43)	
Female	7,201 (64.12)	4,654 (60.57)	<0.0001
Age Group (years)			
18-45	2,286 (20.36)	3,033 (39.47)	
46-55	2,747 (24.46)	1,876 (24.41)	
56-64	3,179 (28.31)	1,463 (19.04)	<0.0001
65>	3,018 (26.87)	1,312 (17.07)	
Race			
White	4,030 (35.89)	2,926 (38.08)	
African American/Black	5,644 (50.26)	3,973 (51.70)	<0.0001
Other	845 (7.52)	362 (4.71)	
Unknown	711 (6.33)	423 (5.50)	
Ethnicity			
Non-Hispanic/Latino/a	5,554 (49.38)	4,325 (56.29)	
Hispanic/Latino/a	1,425 (12.69)	788 (10.26)	<0.0001
Unknown	4,260 (37.93)	2,571 (33.46)	

COVID History			
Yes	2,654 (23.63)	2,085 (27.13)	<0.0001
No	4,970 (44.26)	3,050 (39.69)	
Unknown	3,606 (32.11)	2,549 (33.17)	
Type of Insurance			
Commercial	365 (3.25)	265 (3.45)	<0.0001
Medicaid	2,015 (17.94)	1,702 (22.15)	
Medicare	4,040 (35.98)	2,072 (26.97)	
Self-Pay	441 (3.93)	449 (5.84)	
Other	4,239 (37.75)	2,916 (37.95)	
Unknown	130 (1.16)	280 (3.64)	
Type 2 Diabetes			
Yes	9,220 (82.10)	5,480 (71.32)	<0.0001
No	2,010 (17.90)	2,204 (28.68)	
Obesity			
Yes	5,631 (50.14)	4,001 (52.07)	0.0092
No	5,599 (49.86)	3,683(47.93)	
Covid Test History			
Yes	7,624 (67.89)	5,135 (66.83)	0.13
Unknown	3,606 (32.11)	2,549 (33.17)	
	Vaccinated Mean (SD)[c]	Not Vaccinated Mean (SD)[c]	P[d]

Before Vaccine Status A1C[e]	7.21 (2.01)	7.21 (2.30)	<0.0001
End of Study A1C	6.91 (1.72)	7.02 (2.11)	<0.0001
A1C Difference[e]	-0.43 (13.19)	-0.19 (1.69)	<0.0001

[a] Frequency and percent for exposure variables between those vaccinated and not vaccinated during the COVID Pandemic

[b]Chi-square test for difference in proportions between those vaccinated and not vaccinated during the COVID Pandemic

[c]Mean and Standard Deviation for difference in average A1C before and after first vaccination date between those vaccinated and not vaccinated during the COVID Pandemic

[d]T-test for the difference in means between those vaccinated and not vaccinated during the COVID Pandemic.

[e]A1C difference is the last recorded A1C minus the baseline

1-2: Multiple Linear Regression Comparing those who were vaccinated and not vaccinated on Average A1C level (N=18,914)	
	Estimate (p-value)[a]
Vaccinated No Yes (Reference)	0.11 (<0.0001)
Vaccinated adjusted for Race No Yes (Reference)	0.12 (<0.0001)
Vaccinated adjusted for Sex No Yes (Reference)	0.10 (<0.0001)
Vaccinated adjusted for Insurance No Yes (Reference)	0.06 (<0.0001)
Vaccinated adjusted for Covid Test History No Yes (Reference)	0.11 (<0.0001)
Vaccinated adjusted for Diabetes No Yes (Reference)	0.30 (<0.0001)
Vaccinated adjusted for Age Group No Yes (Reference)	0.10 (<0.0001)

Vaccinated adjusted for Obesity No Yes (Reference)	0.13 (<0.0001)
Vaccinated adjusted for Ethnicity No Yes (Reference)	0.11 (<0.0001)
Vaccinated adjusted for All Covariates No Yes (Reference)	0.29 (<0.0001)

[a] Estimate and p-value to test for potential confounding with vaccination status and all other independent predictors

[b] Estimate and p-value to test for potential interaction with vaccination status and all other independent predictors

1-3: Interaction Results

Variable	Vaccinated	Not Vaccinated
Male	0.26 (0.19,0.33)	0.49 (0.4,0.57)
Female	0 (Reference)	0.01 (-0.06,0.08)
Linear Regression Estimates and 95% CI testing within levels of each interaction explanatory variable on After Vaccine A1C Average Level P-value for interaction between Sex and Vaccine Status: 0.0002		

Variable	Vaccinated	Not Vaccinated
Diabetes	1.54 (1.45,1.62)	1.96 (1.87,2.05)
No Diabetes	0 (Reference)	-0.09 (-0.20,0.01)
Linear Regression Estimates and 95% CI testing within levels of each interaction explanatory variable on After Vaccine A1C Average Level P-value for interaction between Diabetes and Vaccine Status: <0.0001		

Variable	Vaccinated	Not Vaccinated
Obesity	-0.73 (-0.80,-0.66)	-0.90 (-0.97 -0.83)
No Obesity	0 (Reference)	0.44 (0.36-0.51)
Linear Regression Estimates and 95% CI testing within levels of each interaction explanatory variable on After Vaccine A1C Average Level P-value for interaction between Obesity and Vaccine Status: <0.0001		

2-1: Descriptive statistics those vaccinated and not vaccinated for COVID in Indianapolis MSA (N=18,090)

Variable	Vaccinated 12,409 (68.60%)[a]	Not Vaccinated 5,681 (31.40%)[a]	*P*[b]
Sex			
Male	3,589 (28.92)	1,802 (31.72)	
Female	8,820 (71.08)	3,879 (68.28)	0.0001
Age Group (years)			
18-45	5,614 (45.24)	3,563 (62.72)	
46-55	2,490 (20.07)	889 (15.65)	
56-64	2,202 (17.75)	578 (10.17)	<0.0001
65>	2,103 (16.95)	651 (11.46)	
Race			
White	6,664 (53.70)	2,842 (50.03)	
African American/Black	4,424 (35.65)	2,327 (40.96)	<0.0001
Other	641 (5.17)	139 (2.45)	
Unknown	680 (5.58)	373 (6.57)	
Ethnicity			
Non-Hispanic/Latino/a	7,956 (63.11)	3,418 (60.17)	
Hispanic/Latino/a	1,291 (10.40)	243 (4.28)	<0.0001
Unknown	3,550 (28.61)	2,020 (35.56)	
COVID History			

Yes	2,921 (23.54)	1,503 (26.46)	<0.0001
No	5,938 (47.85)	2,418 (42.56)	
Unknown	6,155 (28.16)	1,760 (30.98)	
Type of Insurance			
Commercial	352 (2.84)	60 (1.06)	<0.0001
Medicaid	1,687 (13.59)	505 (8.89)	
Medicare	2,679 (21.59)	921 (16.21)	
Self-Pay	501 (4.04)	415 (7.31)	
Other	7,087 (57.11)	3,779 (66.52)	
Unknown	103 (0.83)	1 (0.02)	

	Vaccinated Mean (SD)[c]	Not Vaccinated Mean (SD)[c]	P[d]
Before Vaccine Status Weight[d]	100.9 (22.29)	104.8 (31.16)	<0.0001
End of Study Weight	100.7 (22.61)	104.8 (31.88)	<0.0001
Weight Change	-0.07 (14.24)	0.49 (11.49)	<0.0001

[a] Frequency and percent for exposure variables between those vaccinated and not vaccinated during the COVID Pandemic

[b] Chi-square test for difference in proportions between those vaccinated and not vaccinated during the COVID Pandemic

[c]Mean and Standard Deviation for difference in average Weight before and after first vaccination date between those vaccinated and not vaccinated during the COVID Pandemic

[d]T-test for the difference in means between those vaccinated and not vaccinated during the COVID Pandemic.

[e]Weight change is the last recorded weight minus the baseline

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2-2: Multiple Linear Regression Comparing those who were vaccinated and not vaccinated on Average Weight (N=18,090)	
	Estimate (p-value)
Vaccinated No Yes (Reference)	4.04 (<0.0001)
Vaccinated adjusted for Race **No** Yes (Reference)	3.65 (<0.0001)
Vaccinated adjusted for Sex No Yes (Reference)	3.79 (<0.0001)
Vaccinated adjusted for Insurance No Yes (Reference)	3.15 (<0.0001)

Vaccinated adjusted for Age Group No Yes (Reference)	2.57 (<0.0001)
Vaccinated adjusted for Ethnicity No Yes (Reference)	3.59 (<0.0001)
Vaccinated adjusted for All Covariates No Yes (Reference)	0.92 (0.02)
[a] Estimate and p-value to test for potential confounding with vaccination status and all other independent predictors	

2-3: Interaction Tables

Variable	Vaccinated	Not Vaccinated
Male	7.94 (6.96,8.92)	14.18 (12.90,15.46)
Female	0 (Reference)	2.70 (1.74,3.65)
Linear Regression Estimates and 95% CI testing within levels of each interaction explanatory variable on After Vaccine Average Weight Change P-value for interaction between Sex and Vaccine Status: <0.0001		

Variable	Vaccinated	Not Vaccinated
Medicare	-9.01 (-11.81,-6.21)	-9.43 (-12.53,-6.34)
Medicaid	-4.27 (-7.17,-1.38)	-0.13 (-3.56,3.30)
Self-Pay	1.65 (-1.67,3.73)	4.84 (1.26,8.42)
Other	1.03 (-1.67,3.73)	4.94 (2.19,7.70)
Commercial	0 (Reference)	6.96 (0.06,13.86)
Linear Regression Estimates and 95% CI testing within levels of each interaction explanatory variable on After Vaccine Average Weight Change P-value for interaction between Insurance and Vaccine Status: 0.003		

Variable	Vaccinated	Not Vaccinated
18-45	13.35 (12.10,14.60)	17.89 (16.54,19.23)
46-55	12.02 (10.57,13.47)	15.15 (13.20,17.11)
56-64	7.74 (6.24,9.23)	7.85 (5.55,10.15)
65>	0 (Reference)	-4.53 (-6.72,-2.33)
Linear Regression Estimates and 95% CI testing within levels of each interaction explanatory variable on After Vaccine Average Weight Change P-value for interaction between Age Group and Vaccine Status: <0.0001		

Variable	Vaccinated	Not Vaccinated
Hispanic/Latino/a	-7.32 (-8.82,-5.82)	-2.26 (-5.52,1.00)
Unknown	-0.41 (-1.46,0.64)	4.42 (3.17,5.66)
Not Hispanic/Latino/a	0 (Reference)	2.83 (1.81,3.85)

Linear Regression Estimates and 95% CI testing within levels of each interaction explanatory variable on After Vaccine Average Weight Change

P-value for interaction between Ethnicity and Vaccine Status: 0.0580

3-1: Descriptive statistics those vaccinated and not vaccinated for COVID in Indianapolis MSA (N=12,040)

Variable	Vaccinated 9,440 (78.41%)[a]	Not Vaccinated 2,600 (21.59%)[a]	*P*[b]
Sex			
Male	3,372 (35.72)	1,087 (41.81)	
Female	6,068 (64.28)	1,513 (58.19)	<0.0001
Age Group (years)			
18-45	1,938 (20.53)	749 (28.81)	
46-55	2,260 (23.94)	600 (23.08)	
56-64	2,593 (27.47)	570 (21.92)	<0.0001
65>	2,649 (28.06)	681 (26.19)	
Race			
White	4,376 (46.36)	1,386 (53.31)	
African American/Black	4,080 (43.22)	1,034 (39.77)	<0.0001
Other	545 (5.77)	46 (1.77)	
Unknown	439 (4.65)	134 (5.15)	
Ethnicity			
Non-Hispanic/Latino/a	5,905 (62.55)	1,466 (56.38)	
Hispanic/Latino/a	934 (9.39)	60 (2.31)	<0.0001
Unknown	2,601 (27.55)	1,074 (41.31)	
COVID History			
Yes	2,358 (24.98)	725 (27.88)	0.0096

No	4,479 (47.45)	1,174 (45.15)	
Unknown	2,603 (27.57)	701 (26.96)	
Type of Insurance			
Commercial	196 (2.08)	23 (0.88)	
Medicaid	1,272 (13.47)	203 (7.81)	<0.0001
Medicare	3,582 (37.94)	953 (36.65)	
Self Pay	348 (3.69)	145 (5.58)	
Other	3,997 (42.34)	1,275 (49.04)	
Unknown	45 (0.48)	1 (0.04)	
Covid Test History			
Yes	6,837 (72.43)	1,899 (73.04)	0.54
Unknown	2,603 (27.57)	701 (26.96)	

	Vaccinated Mean (SD)[c]	Not Vaccinated Mean (SD)[c]	P[d]
Before Vaccine Status Weight[d]	105.9 (22.35)	109.6 (31.69)	<0.0001
End of Study Weight	103.2 (22.48)	109.6 (31.69)	<0.0001
Weight Change[e]	-3.41 (12.50)	-0.96 (10.45)	<0.0001

[a] Frequency and percent for exposure variables between those vaccinated and not vaccinated during the COVID Pandemic

[b]Chi-square test for difference in proportions between those vaccinated and not vaccinated during the COVID Pandemic

[c]Mean and Standard Deviation for difference in average Weight before and after first vaccination date between those vaccinated and not vaccinated during the COVID Pandemic

[d]T-test for the difference in means between those vaccinated and not vaccinated during the COVID Pandemic.

[e]Weight change is the last recorded weight minus the baseline

3-2: Multiple Linear Regression Comparing those who were vaccinated and not vaccinated on Average Weight (N=12,040)	
	Estimate (p-value)
Vaccinated No Yes (Reference)	6.55 (<0.0001)
Vaccinated adjusted for Race **No** Yes (Reference)	6.21 (<0.0001)
Vaccinated adjusted for Sex No Yes (Reference)	5.91 (<0.0001)
Vaccinated adjusted for Insurance No Yes (Reference)	5.97 (<0.0001)

Vaccinated adjusted for Age Group No Yes (Reference)	5.82 (<0.0001)
Vaccinated adjusted for Ethnicity No Yes (Reference)	5.8 (<0.0001)
Vaccinated adjusted for Covid Test History No Yes (Reference)	6.49 (<0.0001)
Vaccinated adjusted for All Covariates No Yes (Reference)	3.75 (<0.0001)
[a] Estimate and p-value to test for potential confounding with vaccination status and all other independent predictors [b] Estimate and p-value to test for potential interaction with vaccination status and all other independent predictors	

3-2: Multiple Linear Regression Comparing those who were vaccinated and not vaccinated on Average Weight Change (N=12,040)	
	Estimate (p-value)
Vaccinated No Yes (Reference)	2.45 (<0.0001)
Vaccinated adjusted for Race **No** Yes (Reference)	2.57 (<0.0001)
Vaccinated adjusted for Sex No Yes (Reference)	2.48 (<0.0001)
Vaccinated adjusted for Insurance No Yes (Reference)	2.50 (<0.0001)
Vaccinated adjusted for Age Group No Yes (Reference)	2.32 (<0.0001)
Vaccinated adjusted for Ethnicity No Yes (Reference)	2.61 (<0.0001)
Vaccinated adjusted for Covid Test History No	2.44 (<0.0001)

Yes (Reference)	
Vaccinated adjusted for All Covariates No Yes (Reference)	2.50 (<0.0001)
[a] Estimate and p-value to test for potential confounding with vaccination status and all other independent predictors [b] Estimate and p-value to test for potential interaction with vaccination status and all other independent predictors	

3-3: Interaction Results

Variable	Vaccinated	Not Vaccinated
Male	9.57 (8.54,10.59)	18.00 (16.44,19.57)
Female	0 (Reference)	4.19 (2.82,5.55)
Linear Regression Estimates and 95% CI testing within levels of each interaction explanatory variable on After Vaccine Average Weight Change P-value for interaction between Sex and Vaccine Status: <0.0001		

Variable	Vaccinated	Not Vaccinated
Medicare	-4.78 (-8.27,-1.29)	-3.13 (-6.87,0.60)
Medicaid	-3.20 (-6.86,0.45)	9.74 (4.97,14.51)
Self-Pay	3.39 (-0.87,7.64)	9.64 (4.42,14.86)
Other	3.72 (0.24,7.21)	11.64 (7.99,15.30)
Commercial	0 (Reference)	12.59 (2.09,23.09)

Linear Regression Estimates and 95% CI testing within levels of each interaction explanatory variable on After Vaccine Average Weight Change

P-value for interaction between Insurance and Vaccine Status: <0.0001

Variable	Vaccinated	Not Vaccinated
18-45	12.44 (11.04,13.85)	24.91 (22.96,26.86)
46-55	10.55 (9.21,11.90)	15.71 (13.58,17.83)
56-64	7.12 (5.82,8.42)	12.56 (10.38,14.73)
65>	0 (Reference)	0.12 (-1.91,2.14)

Linear Regression Estimates and 95% CI testing within levels of each interaction explanatory variable on After Vaccine Average Weight Change

P-value for interaction between Age Group and Vaccine Status: <0.0001

Variable	Vaccinated	Not Vaccinated
Hispanic/Latino/a	-10.65 (-12.35,-8.96)	-3.31 (-9.57,2.95)
Unknown	-1.51 (-2.65,-0.38)	5.81 (4.21-7.42)
Not Hispanic/Latino/a	0 (Reference)	4.88 (3.47,6.28)
Linear Regression Estimates and 95% CI testing within levels of each interaction explanatory variable on After Vaccine Average Weight Change P-value for interaction between Ethnicity and Vaccine Status: <0.0001		

Variable	Vaccinated	Not Vaccinated
COVID History	1.32 (0.09,2.56)	10.02 (8.06-11.94)
Unknown	0.33 (-0.86,1.53)	7.49 (5.52,9.46)
No COVID History	0 (Reference)	4.79 (3.20,6.39)
Linear Regression Estimates and 95% CI testing within levels of each interaction explanatory variable on After Vaccine Average Weight Change P-value for interaction between Ethnicity and Vaccine Status: <0.0001		

List of Figures

Figure 1: Physiology between COVID-19 and Type 2 Diabetes

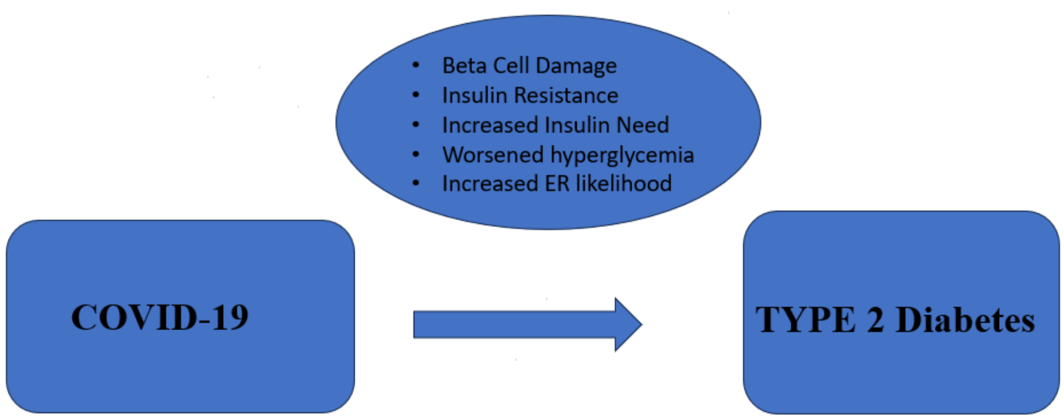
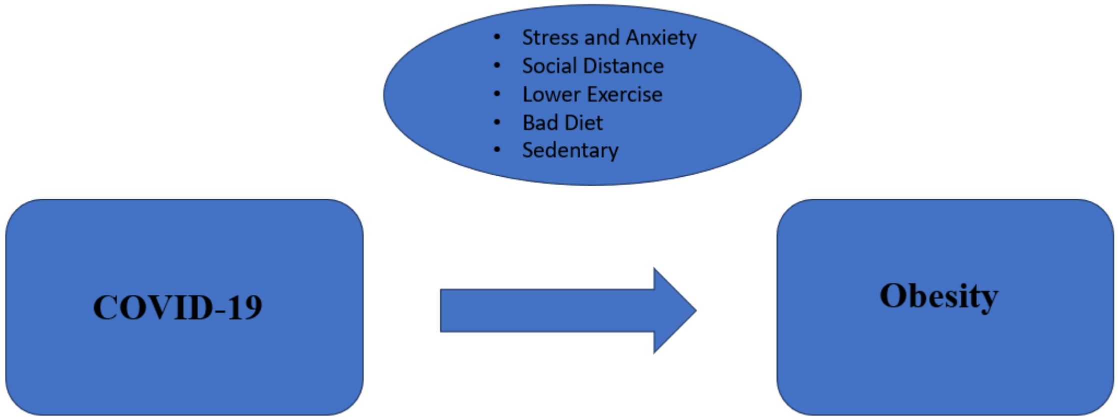


Figure 2: Physiology between COVID-19 and Obesity



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Curriculum Vitae

Shane M. Hanley

ORCID iD: 0009-0001-3547-2070

EDUCATION

Indiana University, Richard M. Fairbanks School of Public Health, Indianapolis, IN

December 2025

PhD in Epidemiology

GPA:3.90/4.00

Indiana University, Richard M. Fairbanks School of Public Health, Indianapolis, IN *May 2017*

Master of Public Health in Epidemiology

GPA: 3.92/4.00

Purdue University, College of Health and Human Sciences, West Lafayette, IN

December 2014

Bachelor of Science in Movement and Sport Sciences

GPA: 3.43/4.00

- *Other Areas of Study*: Pre-Medicine

TEACHING EXPERIENCE

Purdue University, West Lafayette, IN *January 2013 – May 2014*

Fundamentals of Biology: Teacher's Assistant

- Taught two lab sections per week.

- Collaborated with other teacher assistants through tutoring sessions to re-visit topics with students before exams.

EPIDEMIOLOGY EXPERIENCE

Pinnacle Solutions Incorporated, Indianapolis, IN April 2021-Present

Data Scientist

- Analyze data for clients to better fit their business operations
- Utilize SAS Viya to analyze real world situations
- Proof of concept and IoT projects

Marion County Public Health Department, Indianapolis, IN May 2017-March 2021

STD Epidemiology Coordinator

- Prioritize for investigation all electronic, paper and verbal reports of Gonorrhea, Chlamydia, Syphilis and HIV infections.
- Investigate and issue field records for investigation by Disease Intervention Specialists.
- Evaluate case investigations for closure.
- Design, conduct, interpret and report statistical analyses of epidemiologic trends to program leadership, collaborating agencies and the community.
- Design strategies to address epidemiologic trends to improve disease detection and control including case management and screening activities.
- Evaluate completeness of reporting by laboratories and providers in association with information management and health agencies and enforce compliance with reporting.
- Create systems to report performance of the STD Program to program leadership, state and federal officials.
- Supervise case management staff and the Liaison and Outreach supervisor.

Eskenazi Health, Indianapolis, IN *January 2017 – May 2017*

Infection Prevention and Control Intern

- Audit proper use of HCW compliance on hand hygiene, PPE use, isolation rooms, and foley/central line bundles on patients.

- Submit reportable communicable diseases using I-NEDSS. Provide admission, risk factors, antibiotic susceptibilities, and lab report data.
- Participate in environment care and safety rounds.
- Review patient electronic records for admission, laboratory, and disease-related data on hospital-acquired infections and device-related infections while learning NHSN definitions for CAUTIs and CLABSIs.
- Enter data on catheter, central-line, and ventilator days.

Indiana State Department of Health, Indianapolis, IN *August 2016– December 2016*

Syndromic Surveillance Epidemiologist Intern

- Conducted daily syndromic surveillance using ESSENCE, which analyzes daily emergency department visits submitted by hospitals.
- Updated the ESSENCE User's Guide for distribution to active users.
- Organized training sessions to teach employees how to use functionalities of the ESSENCE surveillance system.
- Communicated with subject matter expert epidemiologists to help create easily accessible ESSENCE dashboards for investigative use.
- Prepared the weekly influenza report for the Indiana State Department of Health webpage.

Indiana State Department of Health, Indianapolis, IN May *2016– August 2016*

Epidemiology Response Team Intern

- Interviewed salmonellosis cases with a standardized questionnaire to determine exposure history prior to infection.
- Contacted provider's offices and testing laboratories for salmonellosis case investigations.
- Supported enteric disease outbreak and cluster investigations by conducting supplemental, hypothesis-generating, and follow-up questionnaires.
- Conducted campylobacteriosis surveillance by assigning laboratory and communicable disease
- Summarized epidemiologic data on cases (e.g., in the form of line lists, epidemic curves, situational reports).
- Educated patients on prevention and control measures for salmonella.

TECHNICAL SKILLS

- Statistical Software: SAS, SPSS, UCinet, Netdraw
- Platforms: Microsoft Windows, Mac OS
- Databases: I-NEDSS, ESSENCE, Microsoft Office, EPIC, SWIMSS

ACHIEVEMENTS AND AWARDS

- Presented an abstract on the characteristics of the largest network component of individuals with or exposed to early syphilis in the Indianapolis Metropolitan Statistical Area: 2016-2017 at the STD Prevention Conference in Washington DC in 2018
- Submitting a paper on the increased risk of stroke among hospitalized and younger traumatic brain injury patients for publication.

PUBLICATIONS

- Increased Risk of Stroke Among Young Adults With Serious Traumatic Brain Injury
- Ending the HIV Epidemic: Contributions Resulting From Syphilis Partner Services
- Characteristics of the Largest Network Component of Individuals With or Exposed to Early Syphilis in Central Indiana: 2016 to 2017