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Booster uptake of COVID-19 vaccines among people who self-reported hypertension, cardiovascular diseases, respiratory problems, or diabetes: Data from the community survey tool of the PR-CEAL

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Learning, leadership, and commitment to the improvement of society are my north. I wrote this phrase when applying to the Honors Program. However, today I want to use it because I found that research is crucial to making a change, especially community-based research. Throughout my future studies and career, I hope to continue this mission. I express my sincere gratitude to everyone who has supported me throughout this journey and this mini thesis.

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Table of Contents

I. Abstract

Introduction – In Puerto Rico, half of all adults have at least one chronic disease, according to official data from the Health Department. People with health conditions are at greater risk of serious COVID-19 illness, this highlights the importance of receiving the booster.

Objectives – This study aims to evaluate the effect of having chronic diseases such as hypertension, cardiovascular diseases, respiratory problems, or diabetes on booster uptake.

Methods – The PR-CEAL Community Outreach Group developed a survey conducted from October 2021-December 2022 addressing the community's needs for COVID-19 education and prevention. Health promoters completed the survey in 117 outreach activities reaching 1,806 participants and gathered demographic and chronic disease information that was analyzed statistically using STATA.

Results – The median age of participants was 57 years, and 79% were women. 81% of the participants were boosted. The most prevalent health problems reported were hypertension (40%), diabetes (35%), respiratory problems (20%), and cardiovascular diseases (14%). Bivariate analysis showed a significant statistical association in participants who received their booster uptake and reported either (45%) hypertension or (37%) diabetes. In comparison with healthy participants, logistic regression analysis suggested no significant differences between participants with hypertension, diabetes, respiratory problems, or cardiovascular disease with booster uptake.

Conclusions – In this study differences between reporting hypertension, diabetes, respiratory problems, or cardiovascular diseases, and being boosted were compared. While we analyzed these groups independently, adjusted analyses found no significant association. This suggests that booster uptake was not affected by the presence or absence of chronic diseases. The age distribution was marked by the majority being 55 and older. However, this is favorable from a public health perspective, indicating that individuals with comorbidities are equally as likely to receive the booster dose as healthy people. Further research is needed to understand factors related to having a chronic disease and booster uptake. Identifying areas to increase booster will improve strategies of awareness and prevention by targeting those who need it.

Keywords: *Hypertension; Cardiovascular Diseases; Respiratory Problems; Diabetes; Booster Uptake; COVID-19; Puerto Rico*

II. Introduction

Background

The novel virus SARS-CoV-2 caused a global pandemic, and the severity of the coronavirus disease (COVID-19) on individuals is dependent on the comorbidities of the patient. Recently, Singh et al. (2020) reported that severity of COVID-19 symptoms is more common in patients with diabetes, hypertension, and cardiovascular disease (CVD). The Puerto Rican population is characterized by a high prevalence of chronic conditions associated with increased risk for COVID-19, including hypertension (73%) (García, et al., 2020). Older island-dwelling Puerto Rican adults are more likely to have diabetes, hypertension, and obesity than older adults residing in the U.S. mainland (Pérez & Ailshire, 2017), which makes older Puerto Ricans an especially high-risk groups for COVID-19 outcomes. The PR-CEAL Community Outreach Group collected data during community engagement activities to assess needs-related prevention and education of COVID-19, emergent topics related to COVID-19, and health concerns during the pandemic. Therefore, from this community data, we will study people who self-reported hypertension, cardiovascular disease, diabetes, or respiratory problems and study the association on booster uptake.

In Puerto Rico's most recent report (2014-2020) from the Chronic Disease Action Plan of the Department of Health, cardiovascular disease, such as hypertension, was the most prevalent chronic disease, followed by diabetes mellitus (Department of Health of Puerto Rico, 2014). During March-July 2020, a study reported 225 deaths associated with COVID-19 in Puerto Rico and 27.1% of these deaths were accounted for respiratory problems as one of the most contributing conditions to COVID-19 deaths (Azofeifa, et al., 2021).

The Puerto Rican population has two of the most at-risk emerging factors for COVID-19. In addition to the high prevalence of chronic diseases and equally as important, is the older population who have a high prevalence of comorbidities. According to the Centers for Disease Control and Prevention (CDC), older adults (65 years and older) have a higher risk of severe symptoms from COVID-19 and 81% of COVID-19-related deaths occur in this population. Estimates suggest that more than one in five residents is over 65, making Puerto Rico's share of older adults the 10th highest in the world (Matos et al., 2020). Walabita et al. (2021) describes as the "perfect storm" the relationship between disparities among the aging population and the high rates of morbidity and mortality due to COVID-19. Both studies mentioned above conclude that research and efforts to publish data on COVID-19 about the higher risk groups and older population helps to increase knowledge and awareness of COVID-19, identify the needs of the population, and increase immunization rates.

COVID-19 boosters are vital for people with preexisting chronic conditions who want to prevent serious outcomes from COVID-19. In addition, this population, as well as immunocompromised people, were one of the first populations that were recommended to benefit from the booster dose. Therefore, compared to healthy individuals this group could benefit more from their booster shot at 6 months or more after their initial series with a Pfizer-BioNTech or Moderna COVID-19 vaccine than healthy individuals. Thus, our purpose is to evaluate the effect of having a comorbidity on booster uptake. An investigation that studied the perception of people who auto-reported a chronic disease found that those reporting chronic respiratory or autoimmune diseases were significantly more likely than healthy controls to report COVID-19 as a threat to themselves (Smith, et al., 2022). Surprisingly, they found no difference in willingness to get a booster between either disease group or healthy controls. We theorized that individuals with

comorbidities would perceive a higher risk from COVID-19 and be more likely to receive a booster shot.

Problem

The problem being investigated arises from the increased risks of COVID-19 associated with comorbidities. Numerous studies show that being up to date with the COVID-19 vaccine and additional booster doses is essential to prevent hospitalizations and even death. Watanabe et al., (2022) concludes that obesity, hypertension, and smoking lowers the antibody count following the vaccination with the COVID-19 mRNA vaccine. However, receiving a booster dose increases the levels of protection against COVID-19. Therefore, it is highly recommended that patients with comorbidities are candidates and could benefit from boosters. Receiving a booster dose will increase the levels of protection against COVID-19. People with comorbidities are at high risk of COVID-19, receiving a booster will make them more protected and reduce the risk of developing a serious illness, hospitalization, and death.

Table 1. Requirements for COVID-19 vaccination considered up to date.

Age Group	Requirements
5-11 years	✓ Completed the primary series for the Pfizer vaccine and its booster dose, after becoming eligible.
12-17 years	✓ Completed the primary series for the Pfizer vaccine, 14 days have elapsed since the second dose was administered, and it has not been 5 months since the last dose. ✓ Completed the primary series for the Pfizer vaccine and received a booster dose, after being eligible.
18-50 years	✓ Completed the primary series for the Pfizer or Moderna vaccines, 14 days have elapsed since the second dose was administered, and it has not been 5 months since the last dose.

	✓ Completed the primary series for the Pfizer or Moderna vaccines and received a booster dose, upon eligibility. ✓ Completed one dose of the Johnson & Johnson Janssen vaccine, 14 days have elapsed since administration, and less than 2 months have elapsed since inoculation. ✓ Completed one dose of Johnson & Johnson's Janssen vaccine and received a booster dose, upon becoming eligible.
50 years and older	✓ A second booster was given 4 months after a first booster dose.

*Information retrieved from the Health Department of Puerto Rico as of March 2023

As of March 2023, data from the Department of Health of Puerto Rico shows that 1,741,530 people are missing the second dose or additional boosters of the COVID-19 vaccines. In **Table 1**, we summarize the requirements that the Department of Health of Puerto Rico uses to be considered as "up to date" with the COVID-19 vaccination which includes booster dosage. Booster uptake is essential for people with comorbidities, like chronic diseases, as they produce lower titers of antibodies, and it could potentially prevent severe outcomes from this virus. Another study conducted between September 2021 and April 2022 in Massachusetts recollected data in 462 communities. Through unadjusted analysis found that booster uptake was higher in wealthier areas and adjusted analysis showed that it was higher in areas with more vaccine providers and primary care physicians. Unfortunately, in both unadjusted and adjusted analyses, uptake was lower in communities with more uninsured residents and those in which fewer residents received routine medical check-ups. (Gaffney, et al., 2023). In September 2021, the Advisory Committee on Immunization Practices recommended that persons over 65 years old, residents aged 18 years or older in long-term care settings, and persons aged 50–64 years with certain underlying medical conditions should receive a booster dose and that persons aged 18–49 years with certain underlying

medical conditions may receive a single Pfizer-BioNTech COVID-19 vaccine booster dose based on individual benefits and risks (Mbaeyi, et al., 2021).

Purpose

The main objective of this study was to evaluate the effect of having a chronic disease such as hypertension, cardiovascular diseases (CVD), respiratory problems, or diabetes on COVID-19 vaccine booster uptake. We hypothesized that individuals with these conditions would have higher booster uptake of COVID-19 in comparison with healthy groups.

Limited studies of boosters have examined associations between booster uptake and people with underlying conditions and immunocompromised individuals on the island. On the other hand, studies in other countries have found that this population is more vulnerable towards the risks and effects of COVID-19.

Questions

1) Are people with hypertension more likely to have the booster in comparison to healthy participants?
2) Are people with cardiovascular diseases more likely to have the booster in comparison to healthy participants?
3) Are people with diabetes more likely to have the booster in comparison to healthy participants?
4) Are people with respiratory problems more likely to have the booster in comparison to healthy participants?

Justification

Hypertension is one of the most common chronic conditions in the older population of Puerto Ricans. In data collected from the U.S. Census Bureau (2018) about 73% of the population who were 65 years and older suffer from hypertension. Amid the COVID-19 pandemic, data has shown that people with one or more comorbidities suffer from a higher risk of suffering from COVID-19 and, in some cases, develop severe symptoms. Most of the data available that study the relationship between COVID-19 and chronic diseases is from other countries. In Puerto Rico, there are still investigations to be developed to better understand the effect of having a chronic disease and the booster uptake on the local population. As of December 2022, data from the Health Department of Puerto Rico shows that 1,749,412 people are missing their second dosage or additional boosters. Overall, there is no information in the official data available that reports based on previous medical history (including chronic diseases) on the COVID-19 vaccinated and unvaccinated population in Puerto Rico. Hence, the importance of these types of investigations to categorize and make this data visible to increase the information, prevention, and education depending on the needs of the population.

III. Literature Review

Chronic Diseases in Puerto Rico

Figure 1. Prevalence of chronic diseases in adults according to the Puerto Rico Department of Health.

Chronic diseases are long-lasting conditions most frequent as we advance in age, often can be controlled and managed, but can rarely be cured. In Puerto Rico, half of all adults have at least

one chronic disease, according to the Health Department. The Centers for Medicare and Medicaid Services (2021) list the 10 most common chronic conditions for adults over 65 years old in decreasing order of incidence as hypertension, high cholesterol, arthritis, coronary heart disease, diabetes, chronic kidney disease, heart failure, depression, Alzheimer disease, and chronic pulmonary disease. Compared to the U.S.A. mainland, Puerto Rico has a larger population of adults aged 65 and older. The data from the U.S. Census Bureau (2022) shows that the population of adults 65 years and older on the mainland represents a 16.9%, while in Puerto Rico it's 22.7%. The Centers for Disease Control and Prevention identified that people aged 65 years and older, with chronic lung disease, asthma, heart conditions or diabetes are at risk of developing serious outcomes from COVID-19 (Centers for Disease Control and Prevention, 2020). Furthermore, people with hypertension or cardiovascular disease who get infected with the virus are three to four times more likely to develop severe disease compared to those without pre-existing conditions (Wang et al., 2020). Another study of 380 participants performed in Puerto Rico by Cepero et al. (2021) shows that 39.2% of the sample studied suffered from hypertension.

Cardiovascular disease

Figure 2. Prevalence of Congenital Cardiovascular Conditions in children according to the Department of Health of Puerto Rico.

Cardiovascular disease (CVD) is also known as heart disease. For many years, cardiovascular diseases have been the leading cause of death in Puerto Rico. In the literature, many of the investigations have been studying the Latinx population in the United States. In addition, cardiovascular disease (CVD) depends on many risks' factors including hypertension,

hypercholesterolemia, obesity, diabetes, and smoking. An important risk factor for CVD in Puerto Rico is obesity. Recent data shows that the prevalence of obesity is 30.1% among adults and it is more common among women, those with educational levels and people living in poverty (Pérez et al., 2013). The literature shows that the incidence of heart failure in Hispanics is higher compared to non-Hispanic whites. The most recent Chronic Disease Action Plan (2014-2020) of the Department of Health states that the prevalence of congenital cardiovascular conditions is 1 out of 10 children in Puerto Rico.

Hypertension

Figure 3. Prevalence of Hypertension in adults according to the Center for Disease Control and Prevention.

Hypertension is the name for the medical term of having high blood pressure. According to the National Institute of Health (NIH), half of all Americans have high blood pressure. Hypertension can be controlled, but uncontrolled hypertension can potentially lead to other health issues. Other health issues that may arise from uncontrolled hypertension that are a significant risk factor are cardiovascular diseases and chronic kidney disease (CKD). Therefore, laboratory analyses and diagnosis are important to target and control this condition. Otherwise, untreated high blood pressure increases the risk of heart attack and stroke. According to the CDC, some risk factors of hypertension are high blood pressure pressure (from 120/80 mmHg to 129/80 mmHg), family history, unhealthy diet (high on sodium and low in potassium), poor exercise, obesity, and other comorbidities (including diabetes). Wang et. Al (2020) in a retrospective study conducted near Wuhan found hypertension as the most common co-morbidity observed in patients affected by COVID-19, ranging from 15% to 30%. Puerto Ricans have been mentioned in investigations

as one of the Hispanic groups more likely to have hypertension due to numerous factors including diet. In addition, data from the Center for Disease Control and Prevention (2018), reveals that in Puerto Rico the prevalence of self-reported hypertension of 42.2% substantially is substantially higher than the national prevalence (30.9%).

Diabetes

Figure 4. Prevalence of Diabetes in adults according to the Puerto Rico Department of Health.

Diabetes is a disease that occurs when your pancreas doesn't produce insulin or it's not enough to be used by your body. There are different types of diabetes: diabetes type 1, diabetes type 2, and gestational diabetes. Among these three, diabetes type 2 is the most common and it's caused when your body can't use insulin well to keep blood sugar at normal levels. Diabetes can cause other health problems such as heart disease, chronic kidney disease, nerve damage, feet problems, oral health, vision, hearing, and mental health. The Department of Health of Puerto Rio in 2020, found that 15.8% adults of the population of Puerto Rico live with diabetes and in 2019 it was the third leading cause of death.

Respiratory Problems

Figure 5. Prevalence of Asthma in Puerto Rico according to the Puerto Rico Behavioral Risk Factor Surveillance System (2008).

Respiratory problems are a wide range of pulmonary diseases that include asthma, chronic obstructive pulmonary diseases, pulmonary fibrosis, pneumonia, and lung cancer (CDC, 2017).

Usually, this disease is exacerbated by other risk factors like smoking or prolonged exposure to harmful chemicals. Puerto Ricans have the highest asthma rates in the world, with the disease affecting roughly 14.2 percent of Puerto Ricans at some point in their lives (Weiler, 2020). Additionally, Puerto Ricans are significantly affected by respiratory illnesses including pneumonia and bronchitis (Wohlford et al. 2020). This information is crucial to understand this comorbidity in relation to getting infected with the virus that causes COVID-19. Respiratory problems are among the common symptoms presented by COVID-19 infection. According to a study by Huang et al. (2020), approximately 81% of patients with COVID-19 experience mild to moderate respiratory symptoms. One of the primary ways that COVID-19 affects the respiratory system is by infecting and damaging the cells in the airways and lungs.

COVID-19 Pandemic

The World Health Organization declared COVID-19 a pandemic on March 11, 2020 (Ghebreyesus, 2020). COVID-19 is caused by Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2) which is a respiratory disease that targets the respiratory tract including the lungs. Most people infected from the virus experience mild to moderate symptoms, however according to the World Health Organization (WHO, 2020) the most likely to develop serious symptoms are older people and those with conditions like cardiovascular disease, diabetes, chronic respiratory disease, or cancer. In Puerto Rico, the first confirmed case of COVID-19 was on March 13, 2020. COVID-19 reflects the geographical and political contexts under the intersectional ties of gender, race-ethnicity, and socioeconomic level; according to Mendez (2021). As of time of writing, data from the John Hopkins COVID-19 Dashboard shows that 649, 939,037 cases since the beginning of the pandemic have been reported. From this data, the total deaths count is

6,654,988. Even though the restrictions and measures to restrain the spread of COVID-19 have been more flexible now a days, this is an on-going problem and global health risk; that as data show can lead to death. In Puerto Rico, as of December 2022, more than 428, 000 confirmed cases of COVID-19 have been reported with more than 5,400 deaths related to the virus (Department of Health of Puerto Rico, 2022).

Comorbidities and COVID-19

The literature available shows that the risk of COVID-19 increases and could be associated with comorbidities. Some of the increased risks could be in the symptoms of COVID-19 and increased mortality rate. Since the beginning of the pandemic in Wuhan, China, Zhou et al. (2020) found that the most common comorbidities reported were hypertension, cardiovascular diseases, and diabetes. It was also found that although this emerging virus affects all age groups, individuals aged above 60 years, along with comorbidities such as diabetes, chronic respiratory disease, and cardiovascular diseases, are at a higher risk of developing infection (WHO, 2020).

COVID-19 Vaccination

Two messenger RNA (mRNA) vaccines against COVID-19 manufactured by Pfizer-BioNTech and Moderna, and one viral vector vaccine manufactured by Janssen/Johnson & Johnson were developed. In 2020, these vaccines were approved for Emergency Use Authorization (EUA) by the U.S. Food and Drug Administration (FDA). These vaccines have shown to be effective and reduce the risk of severe symptoms, hospitalization and even death. A study done by Huang et al. (2020) reported that the Pfizer-BioNTech vaccine had a 95% effectiveness, while the Moderna had a 94.1%. Despite the proven effectiveness of these vaccines, as of December 2022 about 1,750,800 patients received the first dosage of the vaccine but are missing the following

doses including the booster uptake in Puerto Rico (2022, Data from the Health Department of Puerto Rico). However, the effect of this vaccines has shown to wary over time and reduce effectiveness as new variants surge. Hence, the importance of additionally booster doses after the primary series of vaccines.

Booster Uptake

As stated before, the importance of COVID-19 vaccines is crucial to reducing the risks and severe symptoms amid infection with this virus. In addition, it has been shown that vaccines effectiveness is reduced over time. However, booster uptake is recommended in individuals after exposure with COVID-19 and people who are immunocompromised. Boosters are equally as important to protect individuals among the new variants. People with health conditions are at risk of developing serious outcomes or even death due to COVID-19. In May of 2022, the Center for Disease Control and Prevention announced that immunocompromised patients could receive a fifth dose (second booster) of an mRNA COVID-19 vaccine. A recent study of immunocompromised individuals and booster uptake reported that adherence to Centers for Disease Control and Prevention mRNA monovalent COVID-19 booster dose recommendations among immunocompromised individuals was low (Tartof, et al., 2023).

Vaccination and booster uptake guidelines

Also, it is very important to stay up to date with the latest vaccine and booster guidelines and recommendations. In **Table 2**, we summarize the information and changes that the Health Department of Puerto Rico and the Centers for Disease Control and Prevention have made since the start of the pandemic back in December of 2020. As of time of writing the most recent

recommendations after the primary monovalent series of COVID-19 vaccines is receiving the updated or also known as bivalent booster in people aged 6 months or older. In addition, the Centers for Disease Control and Prevention has only recommended one dose of the bivalent booster dose. Thus, after completion of the primary series vaccination (which includes vaccination of the monovalent booster dose) and receiving the bivalent booster dose according to the CDC you are considered as up to date.

Table 2. Vaccination Guidelines.

Month	Updated Guidelines
December 2020	• On December 2020, the Food and Drug Administration issued an Emergency Use Authorization for the Pfizer-BioNTech COVID-19 vaccine for people 16 years and older and Moderna. • Puerto Rico began **Phase 1A** vaccinating essential health workers.
January 2021	• After 21 days, the second dose was administered to the Phase 1A vaccinated group. • Puerto Rico began **Phase 1B** which included people over 65 years or older who do not live in a congregate environment. • First responders or frontline essential workers were included in **Phase 1B**.
February 2021	• The booster dose began available for whom completed the primary series for the Pfizer or Moderna vaccines, upon eligibility. • Completed one dose of Johnson & Johnson's Janssen vaccine and received a booster dose, upon becoming eligible.
March 2021	• In Puerto Rico, **Phase 1C** started and included people with chronic illnesses aged 16 and over.
April 2021	• Modifications to the **Phase 1C** were made to include people in prison, with disabilities, in shelters, spiritual assistance, students attending universities or colleges, staff who work in restaurants or workers in other essential services.
September 2021-October 2021	• A single booster dose for Pfizer and Moderna COVID-19 vaccine was authorized by the FDA for people over 18 years old who are at increased risk for serious complications of COVID-19 after 6 months of receiving the first primary series. • The FDA approved the vaccination of COVID-19 in minors from 5 to 11 years old.

November 2021	• The Advisory Committee on Immunization Practices (ACIP) issued recommendations for an additional primary mRNA COVID-19 vaccine dose for immunocompromised persons and a COVID-19 vaccine booster dose in eligible groups.
December 2021	• The Center for Disease Control and Prevention and FDA expand COVID-19 booster recommendations to include everyone ages 16 years and older.
January 2022	• ACIP shortens the recommended time between the primary vaccination series and a booster shot for the Pfizer-BioNTech COVID-19 vaccine from 6 months to 5 months.
February 2022	• CDC releases data showing that COVID-19 vaccine boosters remain safe and were highly effective against severe disease during the Omicron and Delta variant surges for everyone ages 5 years and older.
May 2022	• ACIP recommends everyone ages 12 years and older who is immunocompromised and those ages 50 years and older receive a second booster dose at least 4 months after their first to prevent severe disease, hospitalization, and death.
October 2022	• In fall 2022, the Center for Disease Control and Prevention recommended a bivalent mRNA COVID-19 vaccine booster dose for persons aged 5 and older, administered 2 months after the primary serios or monovalent booster dose.

*Information retrieved from the Health Department of Puerto Rico and the Center for Disease Control and Prevention COVID-19 Museum

Community Efforts and Strategies

NIH Community Engagement Alliance (CEAL) against COVID-19 Disparities is a network of 21 teams that work closely with communities hit hard by COVID-19 pandemic. The objective of CEAL is to improve diversity and inclusion in our research response to COVID-19. The PR-CEAL study (Puerto Rico Community Engagement Alliance Against COVID-19 Disparities) was intended to develop urgent research that contributes to promote prevention and education about COVID-19, thus reducing the existing distrust and misinformation about this

public health crisis. As a part of an interdisciplinary team that consisted of five main components, the community outreach group of PR-CEAL participated in more than 100 community events and in local venues island-wide providing one-on-one educational support to decrease COVID-19 vaccine misinformation and gathering the community's concerns and perspective around COVID-19 that helped to develop specific educational and prevention on strategies. Overall, community efforts and strategies are crucial and of great importance during investigations that include community assessment to understand the needs and increased the efforts for the disadvantaged population.

IV. Theoretical Framework

Many studies on different disciplines have used the Health Belief Model (HBM) to understand and predict the likeliness of two variables. A study examining the likelihood of cancer screening behaviors found that perceived susceptibility, perceived benefits, and cues to action were significant predictors of screening behavior (Shubayr, et al., 2022). Individuals who perceive themselves to be at high risk of developing cancer and who believed the screening would benefit their health were more likely to the expected behavior. Another study about healthcare workers' attitudes towards the influenza vaccine using the HBM found that perceived susceptibility, severity, benefits, and barriers were all significant predictors of vaccine uptake (Brewer, et al., 2007). Thus, healthcare workers that perceived themselves to be at risk of fur contracting the flu and belief the vaccine to be effective were more likely to get vaccinated while those who perceived barriers such as time constraints or concerns about side effects were less likely to do so.

The theoretical framework that was used to guide this on-going study and to develop the community assessment tool was the Health Belief Model. According to Hochbaum, et al. (1952)

this model is used to understand and predict health behaviors, including vaccination. The Health Belief Model is one of the most widely used models for understanding vaccination behavior against COVID-19 (Limbu, et al., 2022). According to Betsch et al. (2015) individuals that feel there at risk from serious outcomes of COVID-19 will be more likely to express higher levels of intentions to vaccinate against COVID-19. Using this framework, we could understand the prevalence of having a chronic disease and receiving a booster of the mRNA vaccine and reach the target immunization rate in Puerto Rico.

V. Methods

Study design

Figure 6. Process flow of the methodological analysis.

We conducted a secondary analysis using data from the community survey tool conducted by health promoters of the PR-CEAL Community Outreach Group (COEG). Specifically, the study design used for the present investigation was a secondary cross-sectional study. A secondary analysis consists of analyzing data that was already recollected. A cross-sectional study design involves studying data in a certain period from a specific group. This type of study is useful to

gather information about health-related behaviors, risk factor and disease outcomes in a population.

The PR-CEAL Community Outreach Group team is still gathering information, but our focus in this study was analyzing the corresponding data from October 2021 to December 2022. During this period, 117 community events island-wide were reached. This survey was completely anonymous, voluntary and the inclusion criteria was being 21 years or older. The community engagement tool was developed using Qualtrics XM to assess the community's needs for COVID-19 education and prevention. Information collected from this survey include sex, age, city, vaccination status for COVID-19 including booster, willingness, screening practices for chronic disease and cancer, health perception, self-reported health problems and reasons to not be vaccinated.

Study population

Although in this study we didn't have direct contact with people, it was a priority to protect their information during the complete survey and data analysis. In the first place, the PR-CEAL investigations from where we obtained the data already had the approval of the Institutional Review Board (IRB) of the University of Puerto Rico Medical Sciences Campus and the Comprehensive Cancer Center of Puerto Rico. In addition, this study received approval of the Institutional Committee for the Protection of Human Beings in Research of the University of Puerto Rico Río Piedras Campus. The study population subjected was recruited during 117 community events across many towns in Puerto Rico. The Community Outreach Group of PR-CEAL reached approximately 50 municipalities across the Island and more than 1,800 participants. Health fairs were the major participation setting of these events. Therefore, participants already had a willing to educate themselves or were accompanying other people with this intention. To

participate in this survey health promoters made sure that participants were more than 21 years old and resided in Puerto Rico. Therefore, no exclusions were associated to gender, race, or ethnicity.

Data collection

The process for data collection was anonymous and completely voluntary. The survey administered represented low risk and no economic benefit was given to participants who answered the survey in its totality. A total of two phases of this survey were conducted. The first one was implemented in November. The second phase occurred in December, to include new booster vaccine recommendations. A total of 1,806 participants were reached. This study only considered data in relation to demographic information, self-reported health problems (hypertension, diabetes, cardiovascular disease, and respiratory problems), and monovalent booster uptake of the mRNA COVID-19 vaccine. Although this survey is still recollecting data to this day, our study will only take into consideration the data from October 2021 to December 2022.

Statistical Analysis

The selected software that was used to perform the statistical analysis was STATA. The statistical analysis that was used in this study consisted of three parts: univariate, bivariate and multivariate. In the univariate analysis, summary and graphic measures were used for a better visualization of the distribution of the sociodemographic data and self-reported chronic diseases of the participants. The frequency distributions were used to describe the categorical variables. On the other hand, summary measures such as mean and standard deviation were used for those quantitative variables. The bivariate analysis evaluated the statistical association factors associated with booster vaccination uptake against COVID-19. Finally, the multivariate analysis was adjusted for age, sex, education, and medical insurance to observe the association between each disease and

booster uptake. Although we evaluated four different chronic conditions (hypertension, cardiovascular diseases, respiratory problems, and diabetes) each one was analyzed independently.

Work Calendar

Before starting this investigation, we made sure to get the authorization for the protocol. Once, approved we started analysis of the data from the database of PR-CEAL from the period of October 2021 through December 2022 and focused on specific variables: sex, age, educational level, medical insurance, and comorbidities (respiratory problems, cardiovascular diseases, hypertension, and diabetes). Afterwards, we proceeded to make logistic regression analysis. Lastly, we began analyzing the results and developed future recommendations and conclusions.

Limitations

This study is subject to important limitations, considering that it is a secondary analysis. The study is limited to self-reported data which can lead to important bias. Also, the data collection is limited to specific variables and remains the possibility of losing incomplete data relevant for the analysis. In addition, the data base was updated and modified on several occasions to follow and go accordingly with the CDC guidelines for COVID-19 vaccination and booster uptake which affects not only the variables that we will take into consideration in this study, but the possibility of lost values due to variables not being tested in a previous version of the survey.

The original survey tool included information starting from 18 years and older. Due to the expedite protocol of the IRB of University of Puerto Río Piedras campus, we only analyzed adults over 21 years and older. Therefore, we lost over 20 observations that were part of this survey during the time frame under study.

VI. Results

As mentioned earlier, the tool used for recollecting our data went through a series of modifications to stay up to date with the most recent guidelines of the official institutions that regulate vaccination. In other words, two versions of this questionaries were made. Consequently, some variables were added later in the questionnaire which already limits the number of responses that were completed in its total. Therefore, when we began performing our statistical analysis a series of data were lost in the process because we only took into consideration the ones that had completed all our variables under study (sex, age, education, medical insurance, booster uptake, and comorbidities).

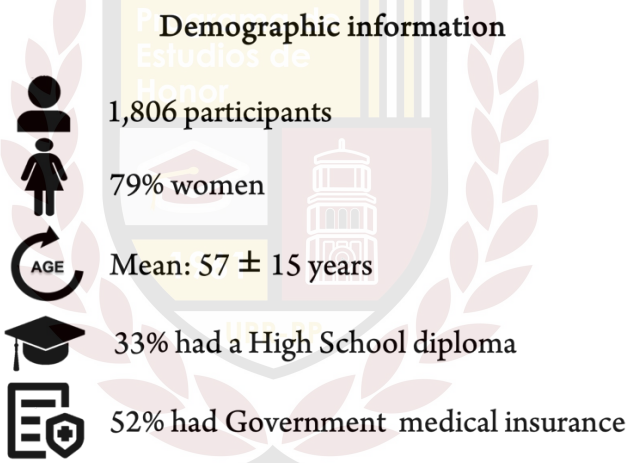

Figure 7. Summary of the most prevalent sociodemographic information among our participants

From October 2021 to December 2022 a total of 1,806 participants were reached. After dropping observations who had variables of interest missing our sample was reduced and the total was n=1,653. We began the analysis of this study with univariate analysis to assess the sociodemographic data from our study sample. As the name suggests, univariate analyses are useful when studying independent variables to study the distribution and identify trends or patterns. In **Figure 7** we summarize the most prevalent demographic information and in **Table 3** we include the sociodemographic characteristics of the participants.

Table 3. Sociodemographic characteristics of participants.

Independent variables	Categories	n, %	
Sex	Men	344 (21%)	
	Women	1,283 (79%)	
Age (57±15**)**		1627	
	21-24	46 (3%)	
	25-34	122 (8%)	
	35-44	153 (9%)	
	45-54	272 (17%)	
	55+	1,034 (64%)	
Education	Elementary school incomplete	239 (16%)	
	9^{th}-11^{th} grade	126 (8%)	
	High school diploma	493 (33%)	
	Some university courses	347 (23%)	
	Bachelor's degree	225 (15%)	
	Master / Doctoral Degree	63 (4%)	
Medical insurance	Government	772 (52%)	
	Medicare	358 (24%)	
	Private	316 (21%)	
	Uninsurance	41 (3%)	
	Other	5 (<1%)	
Booster uptake	Yes	1,160 (81%)	
	No	264 (19%)	
Comorbidities		**Yes**	**No**
	Cardiovascular disease	227 (14%)	1,400 (86%)
	Respiratory problems	318 (20%)	1,309 (80%)
	Diabetes	566 (35%)	1,061 (65%)
	Hypertension	657 (40%)	970 (60%)

Of the total eligible sample, the mean age was 57 years, and the majority were women (79%). The age distribution of this study was predominantly older adults, this means that the results may not be generalizable to young adults. Even though the population was predominantly of older adults the advantage is that the comorbidities under study are more common in this age group. In **Figure 8** we show the distribution of our participants in relation to the independent variable age. Most had at least completed a high school diploma (33%) and the most common medical insurance was government (52%) followed by Medicare (24%), Private (21%), and uninsured (3%). Overall, the majority of participants had received their booster uptake (81%). These sociodemographic characteristics are important to consider when analyzing the factors associated with booster vaccination acceptance against COVID-19 vaccines, as they can provide insights into potential disparities or differences in booster uptake rates among different populations in our sample.

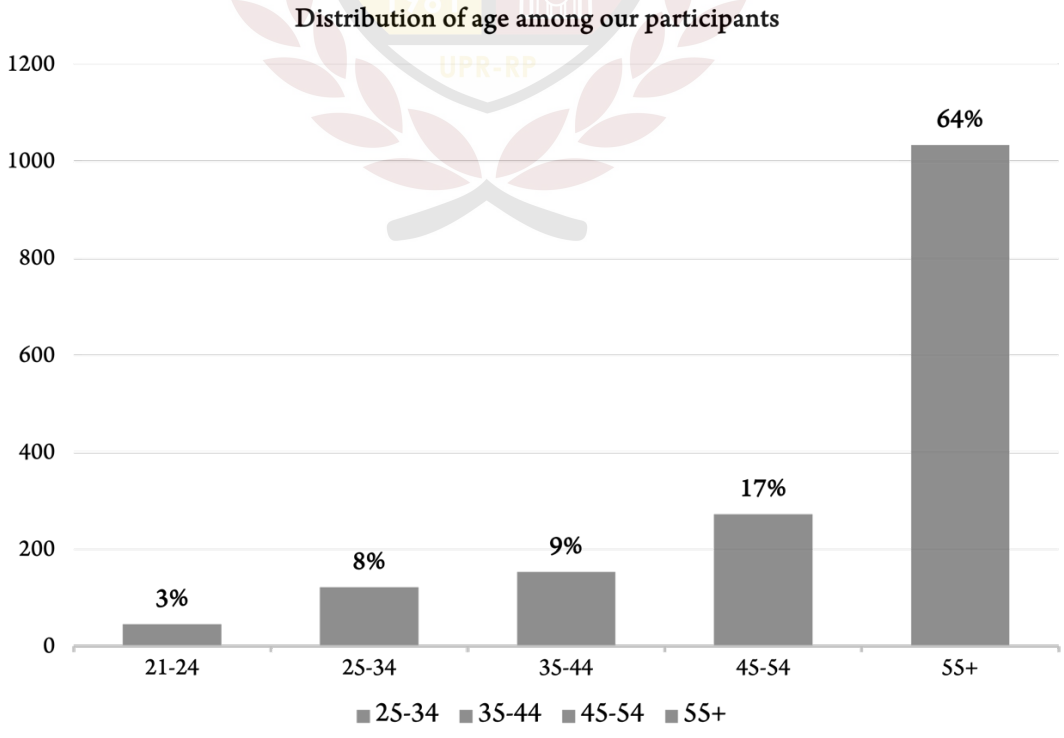

Figure 8. Distribution of age among our participants.

In terms of age, 64% of the participants were 55 years old and older, and 37% were between 21 and 54 years old. In **Figure 9** we summarize the most reported comorbidities by our participants and in **Figure 10** we compare the comorbidities self-reported among different age groups.

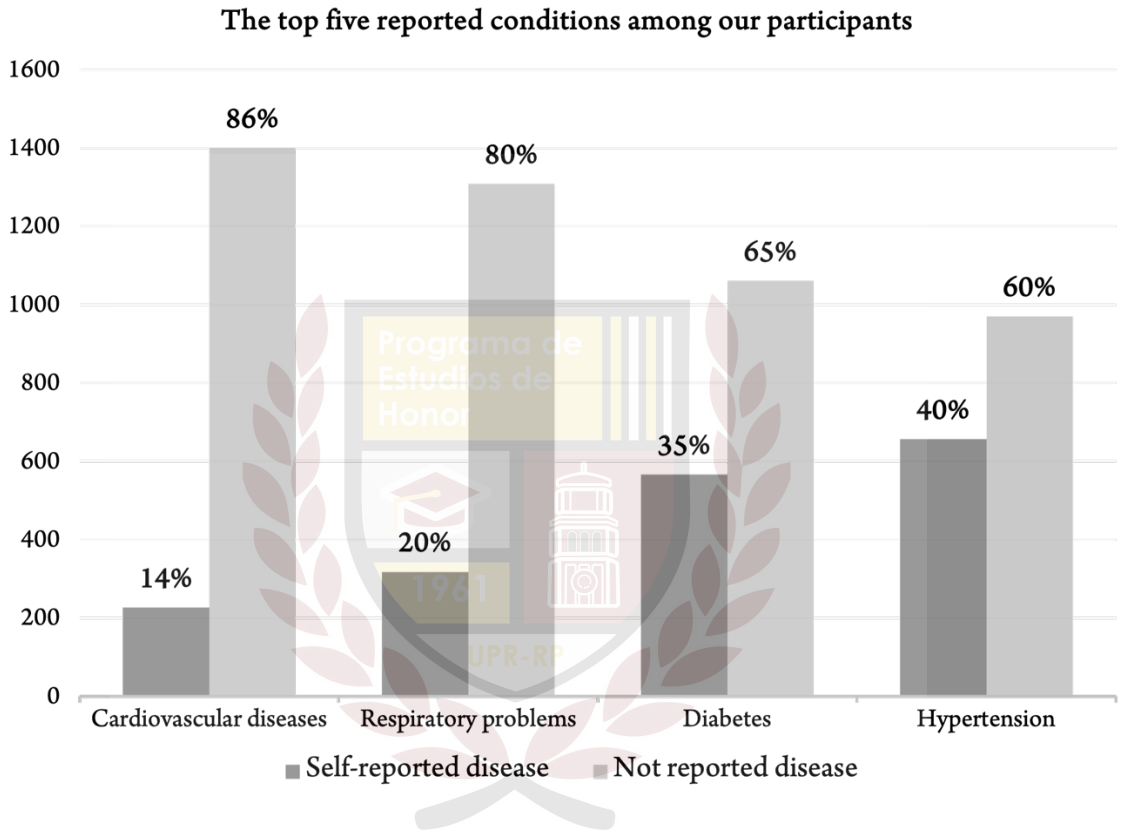

Figure 9. The top five reported conditions among our participants.

From the comorbidities under study, the most reported chronic diseases were hypertension (40%), followed by diabetes (35%), respiratory problems (20%) and lastly cardiovascular diseases (14%).

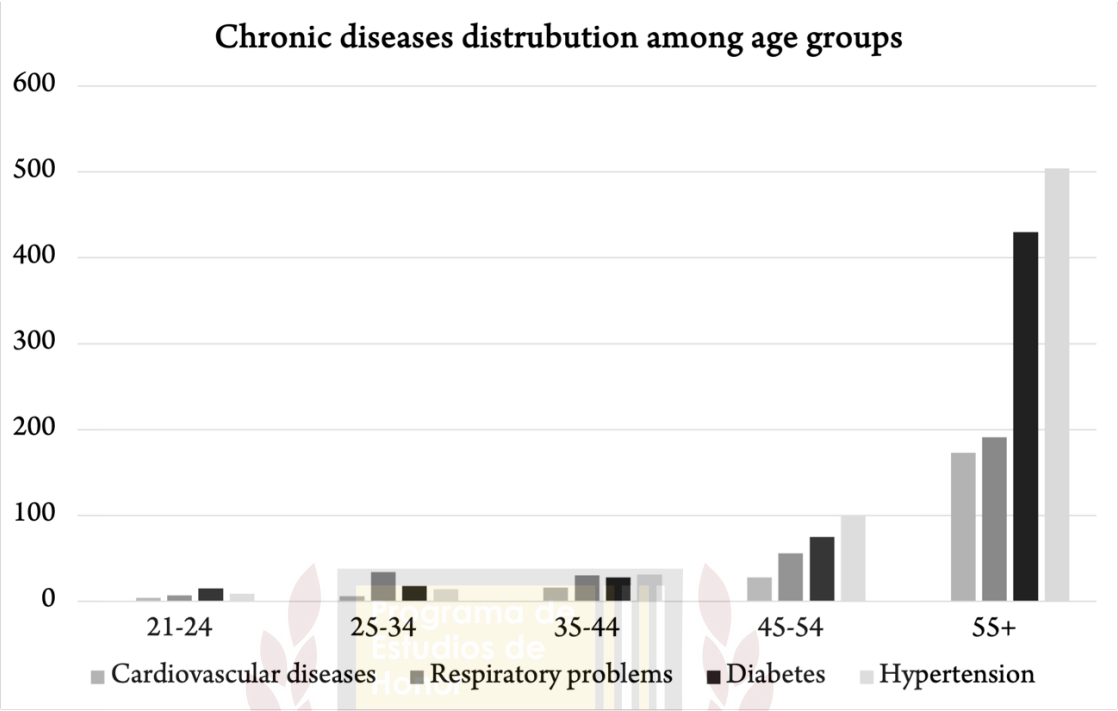

Figure 10. Chronic diseases distribution among different age groups.

Figure 10 shows the number of self-reported chronic diseases (hypertension, diabetes, respiratory problems, and cardiovascular diseases) among different age groups (21-24, 25-34, 35-44, 45-54, and 55+). In this figure is presented that the prevalence of the different chronic studies under study increases with age. In the first age group (21-24), the most prevalent chronic disease was diabetes. Meanwhile, in the second age group (25-34), respiratory problems were the most prevalent disease. In the third age group (35-44), the most prevalent chronic disease was hypertension. Once again, diabetes was the most prevalent disease in the fourth group (45-54). Lastly, in the fifth group (55+) the most prevalent chronic disease was hypertension.

To evaluate the statistic association between our independent variables associated with booster vaccination uptake against COVID-19 we performed bivariate analysis as shown in **Table 4**.

Table 4. Bivariate analysis of factors associated with booster vaccination acceptance against COVID-19 vaccines.

Independent variables	Categories	Booster uptake		P-value
		No (n=264)	Yes (n=1,160)	
Sex	Men	51 (19%)	250(22%)	
	Women	213 (81%)	910 (78%)	0.422
Age (57±15)	21-24	4 (1.5%)	22 (1.9%)	<0.05
	25-34	33 (12.5%)	63 (5%)	
	35-44	36 (13.6%)	96 (8%)	
	45-54	55 (20%)	189 (16%)	
	55+	136 (51%)	790 (68%)	<0.05
Education	Elementary school incomplete	39 (16%)	183 (16%)	0.001
	9^{th}-11^{th} grade	30 (13%)	81 (7%)	
	High school diploma	88 (37%)	366 (32%)	
	Some university courses	46 (20%)	282 (25%)	
	Bachelor's degree	20 (9%)	184 (16%)	
	Master Doctoral Degree	12 (5%)	47 (4%)	
Medical insurance	Government	148 (63%)	568 (50%)	0.001
	Medicare	40 (17%)	286 (25%)	
	Private	37 (16%)	254 (22%)	
	Uninsurance	10 (4%)	29 (3%)	
	Other	0	4 (<1%)	
Comorbidities				
	Cardiovascular disease	36 (13.64	164 (14.1%)	0.832
	Respiratory problems	55(21%)	233 (20%)	0.785
	Diabetes	59 (22%)	430 (37%)	<0.005
	Hypertension	97 (37%)	518 (45%)	0.019

In the bivariate analysis we added the p-value to measure the probability and significance of observing the desired effect as stated in our hypothesis. A p-value is considered significant enough to reject the null hypothesis when its value is less than 0.05. All this taken into consideration, in regard to the variable sex the results show that there is no significant difference in booster uptake between men and women (p=0.422) as shown in **Figure 11**.

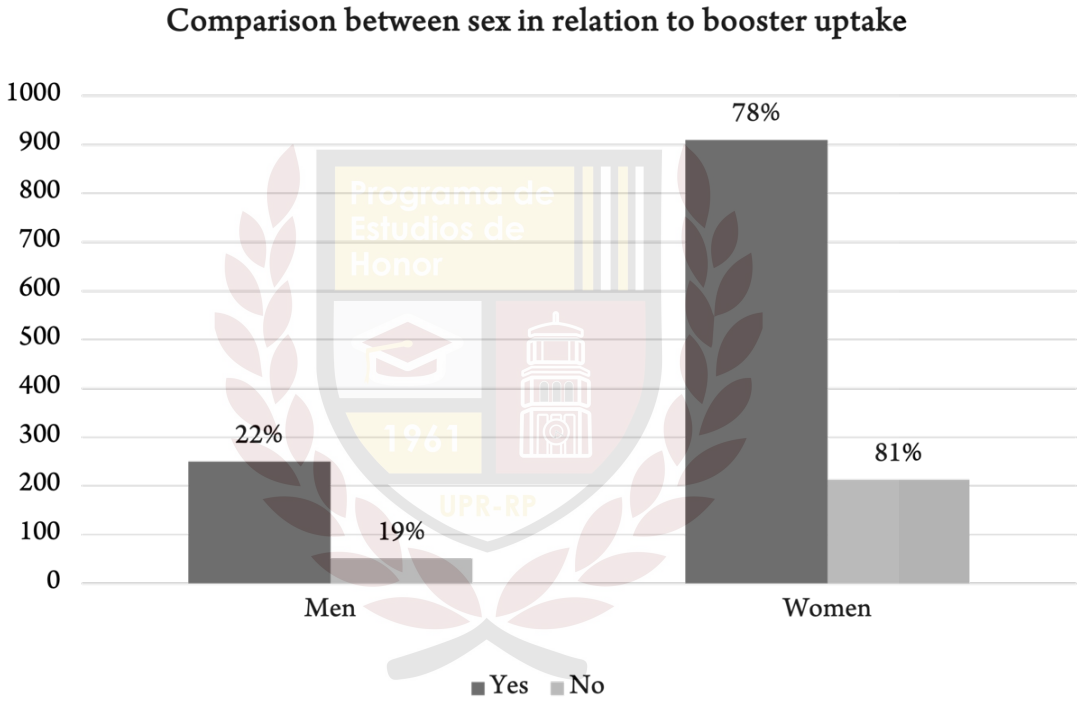

Figure 11. Comparison between sex in relation to booster uptake.

However, there is a significant difference in booster uptake between different age groups with those aged 55 and over more likely to have received the booster vaccine compared to those aged 21 to 54. There is also a significant association between education level and booster uptake. Participants with higher education levels were more likely to receive the booster dose than those with lower education levels (p=0.001). Also, medical insurance is significantly associated with

booster uptake (p=0.001), those who have government or Medicare insurance being more likely to have received the booster compared to those with private insurance or who are uninsured. In relation to the comorbidities investigated in this study and booster uptake, bivariate analysis showed a significant statistical association in participants who received their booster uptake and reported either hypertension or diabetes. Regardless, participants reporting booster uptake and reported either cardiovascular diseases or respiratory problems did not demonstrate a statistical significance.

In summary, this analysis suggests that older adults, higher education levels, and having diabetes or hypertension may be associated with higher COVID-19 booster uptake. However, further analysis had to be done to adjust for possible variables that could be influencing our results. In **Table 5**, we present the results of the multivariate analysis examining the association between booster uptake and the comorbidities under study while adjusting for age, sex, education, and medical insurance. We adjusted for this variable to minimize confounding variables that may affect the relationship between comorbidities and booster uptake against COVID-19. In addition, the results show the odds ratio (OR) for the association between having a specific chronic disease and having the booster. The OR is useful because it estimates the odds of having a comorbidity and having or not having the booster dose. In addition, each chronic disease was analyzed independently. Therefore, the OR is different and subjected to the specific participants with the chronic disease they auto reported in the community survey tool. Analyzing each chronic disease independently decreases the possible confounding variables that may affect the relationship between the comorbidity and booster uptake.

Table 5. Multivariate analysis between booster uptake and the comorbidities under study

Booster	**Hypertension**		**OR$_{crude}$ (CI 95%)**	**OR$_{ajusted}$† (CI 95%)**
	No	Yes		
No	167 (20%)	97 (16%)	1.39 (1.05-1.83) p=0.019	1.08 (0.45-2.55) p=0.854
Yes	642 (79%)	518 (84%)		
Total	809	615		
	Diabetes			
No	205 (78%)	730 (63%)	2.04 (1.49-2.80) p<0.05	1.36 (0.56-3.31) p=0.492
Yes	59 (22%)	430 (37%)		
Total	264	1,160		
	Respiratory			
No	209 (79%)	55 (21%)	0.96 (0.68-1.33) p=0.785	1.62 (0.49-5.26) p=0.426
Yes	927 (80%)	233 (20%)		
Total	1,136	288		
	Cardiovascular			
No	228 (86%)	36(14%)	1.04 (0.70-1.54) p=0.832	1.39 (0.41-4.66) p=0.594
Yes	996 (86%)	164 (14%)		
Total	1,224	200		

Adjusted by age, sex, education, and medical insurance.

The results show that hypertension was significantly associated with booster uptake in the unadjusted analysis with an OR of 1.39 [CI95%: (1.05-1.83), p=0.019] which indicates that participants were 39% more likely to have received the booster dose than those without hypertension. However, after adjusting for the variables mentioned above, the association was not significant, with an adjusted OR of 1.08 [CI95%: (0.45-2.55), p=0. 854]. This comparison between groups with this health disease is shown in **Figure 12**.

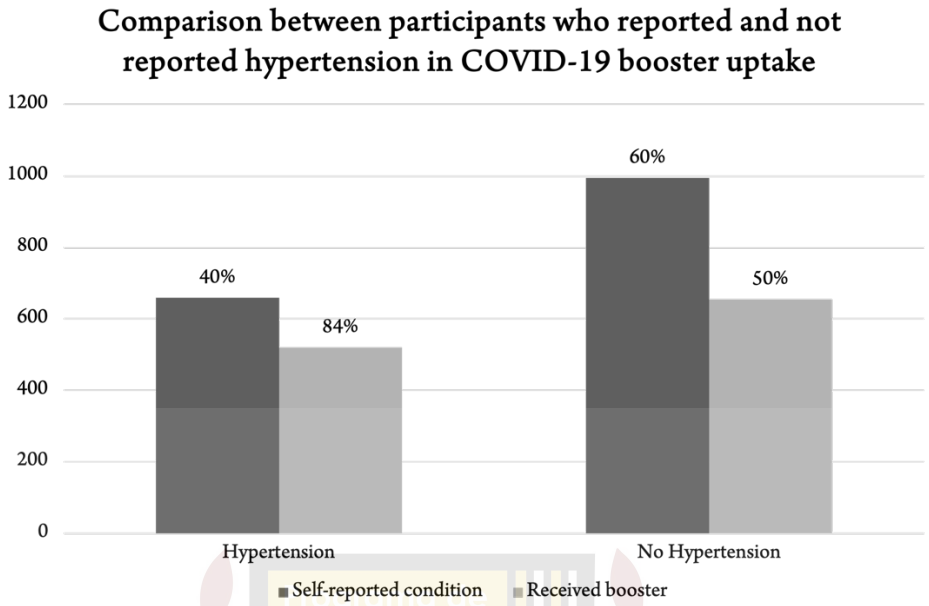

Figure 12. Comparison between participants who reported and not reported hypertension in COVID-19 booster uptake.

Likewise, diabetes was associated significantly with booster uptake in unadjusted analysis. The unadjusted OR was 2.04 [CI95%: (1.49-2.80), $p<0.05$]. This shows that participants who self-reported diabetes were more than twice as likely to receive the booster shot in comparison with those who didn't report the disease as seen in **Figure 13**. However, after adjusting the association wasn't significant [OR= 1.36, CI95%: (0.56-3.31), $p=0.492$)].

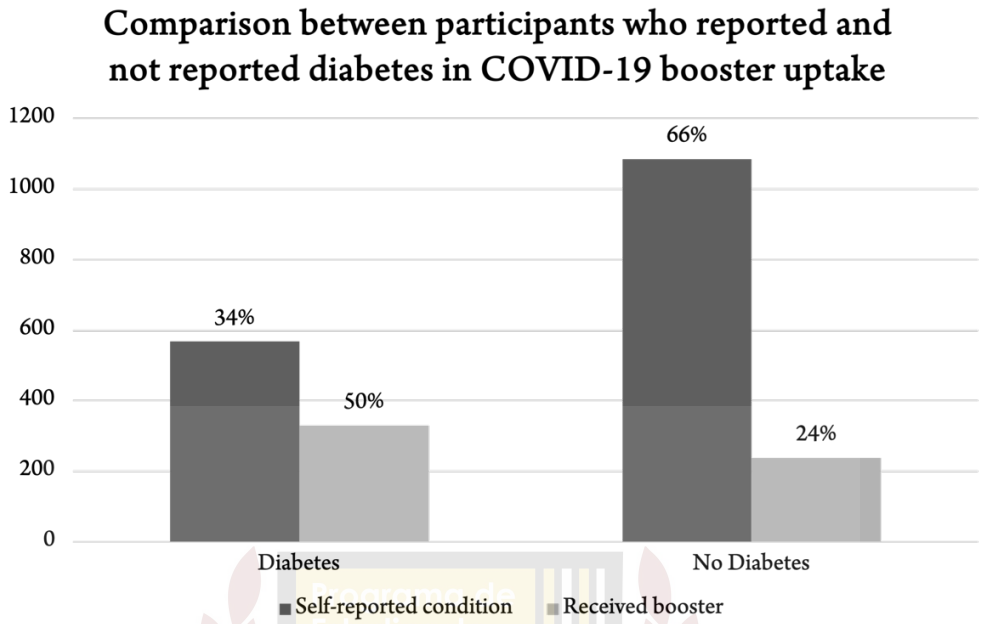

Figure 13. Comparison between participants who reported and not reported diabetes in COVID-19 booster uptake.

In contrast, respiratory diseases were not associated significantly with booster uptake in either the unadjusted or adjusted analysis with [OR= 0.99, CI95%: (0.72-1.38) p=0.969] and [OR=0.90, CI95%: (0.64-1.27), p=0.548], respectively and as shown in **Figure 14.** The same trend was observed with cardiovascular diseases meaning that neither respiratory nor cardiovascular diseases were significant. The unadjusted and adjusted comparison is seen in **Figure 15.**

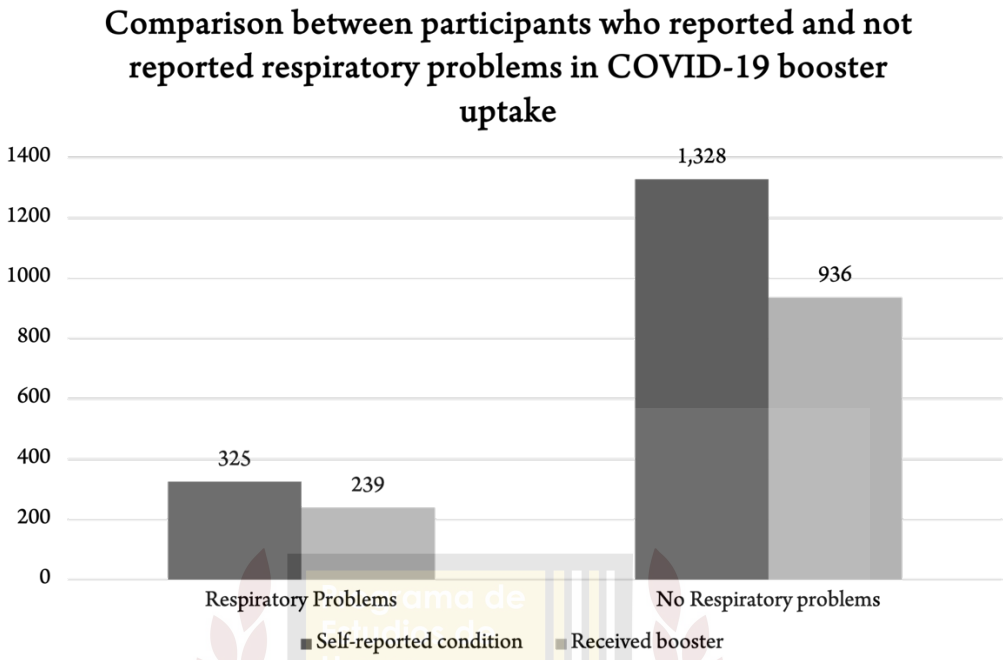

Figure 14. Comparison between participants who reported and not reported respiratory problems in COVID-19 booster uptake.

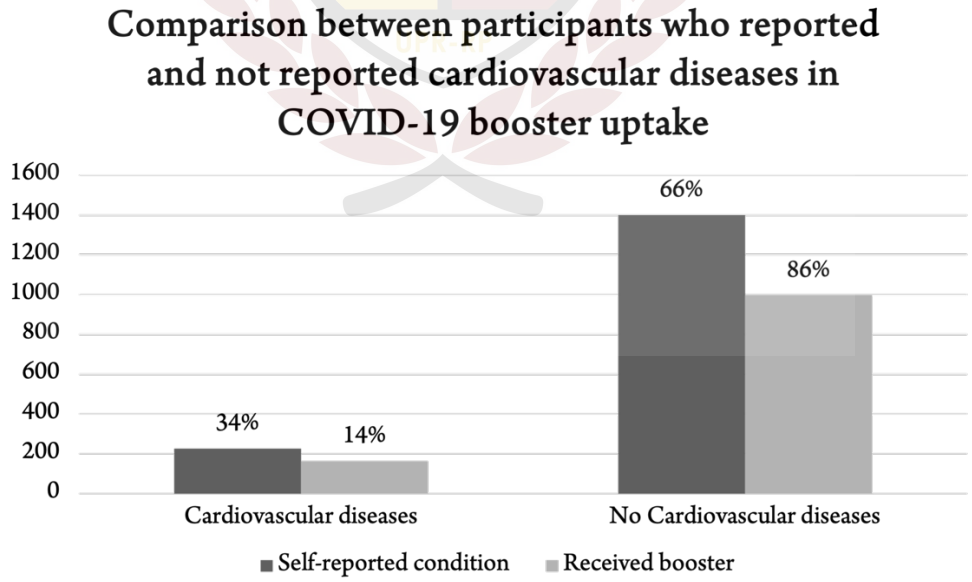

Figure 14. Comparison between participants who reported and not reported respiratory problems in COVID-19 booster uptake.

The multivariate analysis showed that after adjusting for age, sex, education, and medical insurance there was no significance in booster uptake and the comorbidities under study which are hypertension, diabetes, respiratory diseases, and cardiovascular diseases.

VII. Discussion

Our results show that 79%, the majority of participants, were women. Although there were no exclusions regarding sex. An investigation done by Sax, et al., (2003) found that women are more likely to answer web and paper surveys than men because women are more likely to be concerned about social and community events than men. Interestingly, the mean age of our participants was 57 years old. The prevalence of the four comorbidities under study increased with age. Taking into consideration that the surveys were completed during health and community events, this means that the older population attending these events already had an interest and a willing to get educated about COVID19 vaccines and additional boosters. These findings are of relevance since the recommendations of additional booster dose was of crucial importance to the two factors that Puerto Rico has very prevalent: comorbidities and an older population. In addition, this finding is supported by the literature where many studies conclude that older adults who perceive a high risk from COVID-19 are more likely to receive the booster dose. A study that focused on studying the elderly and willingness to consume the COVID-19 booster found that 82.8% of the recruited older adults were willing to receive it (Qin, et al.,2022). Interestingly, more than half of the people surveyed in our study had government medical insurance (52%) and most of our participants had received the booster shot (81%).

We hypothesized that individuals with chronic diseases would have higher booster uptake of the COVID-19 vaccine in comparison with healthy groups who didn't report having these diseases. A study done in Massachusetts by Gaffney, et al. (2023) published that booster uptake

was higher in the older population, but it was lower in communities with higher rates of chronic conditions. Contrary to our hypothesis, participants reporting a chronic disease were not more likely to receive the booster dose than dose without the condition. Unadjusted results indicate that booster uptake was significantly associated with diabetes and hypertension, while no relation was found with respiratory problems and cardiovascular diseases. However, none remained significantly associated with booster uptake after adjusting for age, sex, medical insurance, and education level.

Equally as important, the majority (64%) of our participants were 55 years and older. This important factor may be influencing the association between the variables that we are studying. This age group is known to be a risk factor for developing chronic diseases and developing worse outcomes after infection with COVID-19. Older adults may be more motivated to receive booster doses given their increased vulnerability. Although our results didn't demonstrate a relationship between comorbidities and booster uptake, it's important to mention that the age group could be influencing the findings. Additionally, these finding suggests that the efforts to vaccine this population at the beginning of the pandemic were fruitful.

VIII. Conclusions & Recommendations

In this study differences between reporting hypertension, diabetes, cardiovascular diseases, or respiratory problems and being boosted were compared. The multivariate adjusted analysis showed no significant association between booster uptake and the comorbidities under study: hypertension, diabetes, respiratory diseases, and cardiovascular diseases. While it may be expected that individuals with comorbidities would be more likely to receive the booster dose of COVID-19 vaccine as we hypothesized, our findings indicate otherwise. This suggests that booster uptake was not affected by the presence or absence of chronic diseases. Even though we didn't find an

association between comorbidities and booster uptake, these findings are considered favorable from a public health perspective. It means that people with comorbidities are equally as likely to administer the booster dose as those that don't have comorbidities.

Another factor to take into consideration is that most participants were over 55 years old. The age distribution of our participants could be influencing the results. Nevertheless, more research is needed to understand factors related to having a chronic disease and booster uptake. Future research could examine studying only younger age groups and compare how it relates to our findings. Identifying areas to increase booster will improve strategies of awareness and prevention by targeting those who need it.

Even though the most recent guidelines recommend the bivalent booster dose instead of the studied monovalent booster, these results remain significant and are important because it could give researchers a better understanding of the behavior between these variables. In addition, understanding the behavior of participants during the monovalent booster doses can provide an insight and could be helpful to improve community strategies and vaccination of the bivalent COVID-19 booster.

Our results provide data that is important for Puerto Rico where comorbidities and an older population are prevalent factors and could've been a perfect storm. However, efforts like the PR-CEAL Community Engagement Alliance Group have been and are still a crucial part of assessing disparities that arise during the pandemic and their significant efforts for educating the community. This data is important and relevant not only for the public knowledge, but for community leaders and academic scientists to continue studying and target the factors associated between comorbidities and booster uptake.

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