Effect of COVID-19 burden on changes in HPV vaccination coverage among females between 2019 and 2022

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# 1. Summary/Abstract

# 2. Introduction

## 2.1 General Background Information

### 2.1.1 Description of data and data source

The difference in HPV vaccination coverage between 2022 and 2019 will be modeled using multivariable regression techniques, including multivariable linear regression *other information on new modeling techniques will be added*. Cumulative number of COVID cases per 100,000 persons as of December 31, 2022 was the explanatory variable. HPV vaccination program characteristics, country income information, and country-level demographics will be considered for adjustment. HPV vaccination coverage, HPV vaccine program characteristics, and cumulative number of COVID cases were extracted from publicly available data from the World Health Organization. Country sociodemographic information was publicly available from the United Nations. All information was collected at the country level, and data were restricted to countries that had HPV vaccination coverage estimates for both 2019 and 2022.

### 2.1.2 Questions/Hypotheses to be addressed

The objective of this work is to determine if changes in HPV vaccination coverage were correlated with COVID burden in 2020-2022. I hypothesize that HPV vaccination coverage was lower in 2022 than 2019 among countries with high burden of COVID-19 in 2020-2022 and comparable in countries with a low COVID-19 burden.

*This is to be determined based on methods learned later in the course, but this is an initial thought on how to implement one of the methods covered in a later module.* An additional objective of this work is to develop a classification tree analysis to assist with classifying countries by their change in HPV vaccination coverage using other country-level HPV vaccine program and sociodemographic characteristics. The purpose of this classification tree is to identify key sociodemographic indicators that may be used by policy makers for pandemic preparedness efforts to prevent reductions in HPV coverage if an epidemic or pandemic affects a country.

# 3. Methods

## 3.1 Data aquisition

Data on HPV vaccination coverage and vaccination program details are available at the country level through the World Health Organization’s (WHO) [HPV Dashboard](https://www.who.int/teams/immunization-vaccines-and-biologicals/diseases/human-papillomavirus-vaccines-(HPV)/hpv-clearing-house/hpv-dashboard). Briefly, coverage data reflect administrative and official HPV vaccination coverage reported annually through the WHO/UNICEF Joint Reporting Form on Immunization. HPV Dashboard include country income level (low, lower middle, upper middle, high), whether there was a national HPV vaccine schedule, year of vaccine introduction, primary delivery strategy (school-based, facility based, varies by region, mixed), number of doses in routine schedule, whether the program is gender neutral (target males and females), WHO region, and year-specific coverage from 2010 to 2023.

Country-specific weekly COVID-19 case and death counts are available from starting in 1/4/2020 through the WHO [COVID-19 dashboard](https://data.who.int/dashboards/covid19/data?n=o). In August 2023, WHO stopped requiring weekly reporting, although some countries continued to voluntarily report COVID-19 data.

Country-level demographics including life expectancy of females at birth and population size were available from the [United Nations](https://population.un.org/wpp/downloads?folder=Standard%20Projections&group=CSV%20format)

All data sources are publicly available for download and were downloaded on January 26-27, 2025.

## 3.2 Data import and cleaning

Each data source imported and merged based on country; all datasets had variables for a country code and name. Individual datasets were restricted to the variables of interest as follows:

* HPV vaccination coverage
  + HPV vaccination coverage in 2022
  + HPV vaccination coverage in 2019
* HPV vaccination program characteristics
  + WHO region
  + World Bank country income level
  + Indicator for whether HPV vaccine is offered through a national recommendation
  + Year of HPV vaccine program introduction
  + Primary HPV vaccine delivery strategy (e.g., school-based)
  + Indicator for gender neutral vaccination (i.e., female-only vaccination or females and males)
  + Recommended number of doses (1 or 2)
* United Nations country demographic data
  + Total Population, as of 1 July (thousands)
  + Population Density, as of 1 July (persons per square km)
  + Median Age, as of 1 July (years)
  + Population Growth Rate (percentage)
  + Total Fertility Rate (live births per woman)
  + Crude Death Rate (deaths per 1,000 population)
  + Life Expectancy at Birth, both sexes (years)
  + Net Migration Rate (per 1,000 population)
* COVID burden through Dec. 31, 2022
  + Cumulative number of COVID cases per 100,000 persons
  + Cumulative number of COVID deaths per 100,000 persons

The final project dataset was restricted to countries with vaccination coverage estimates in both 2019 and 2022 (N = 100). The outcome variable was coded as HPV vaccination coverage of at least one dose among females in 2022 minus coverage in 2019. Of the 100 included countries, 2 countries were missing some vaccine program characteristic information and 1 country was missing income level. All other countries had complete data for all variables.

## 3.3 Statistical analysis

#### 3.3.0.1 Exploratory/Descriptive analyses

The mean (standard deviation (sd)) and median (interquartile range (IQR)) were calculated for each continuous country characteristic (e.g., number of cumulative COVID cases). For categorical variables, the distribution (n, %) of each level was calculated. A histogram of the difference in coverage was graphed. Bivariate associations between each characteristic and the change in HPV vaccination coverage between 2022 and 2019 were visually assessed using scatterplots for continuous variables and violin plots for categorical variables.

#### 3.3.0.2 Multivariable modeling

Multivariable linear regression was performed to identify primary predictors of change in HPV vaccination coverage. Model selection was performed using backwards elimination; variables with the largest *p*-value were eliminated one at a time until all variables in the model had a *p*-value < 0.1. *Information on additionally modeling techniques will be added later*

#### 3.3.0.3 Classification tree analysis

All data management and analysis was conducted using R (Version 2024.12.0+467). Classification tree analyses were conducted using the XXXX package.

# 4. Results

## 4.1 Exploratory/Descriptive analysis

##### 4.1.0.0.1 Difference in HPV vaccination coverage between 2022 and 2019

The difference in HPV vaccination coverage between 2022 and 2019 appears normally distributed centered around 0 (i.e., no change in coverage).([Figure 1](#fig-Figure1)) The mean (sd) difference in coverage was -5.5 (23.4); the median (IQR) was 0.0 (-15.0, 6.0).([Table 1](#tbl-Table1_coverage_covid))

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| Figure 1: Histogram of difference in HPV vaccination coverage between 2019 and 2022 |

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| Table 1: HPV vaccination coverage and COVID burden among countries with HPV vaccination programs in 2019 and 2022 |

##### 4.1.0.0.2 COVID burden

Between January 1, 2020, and December 31, 2022, the mean (sd) number of cases per 100,000 persons was 8,132.1 (6,470.6). The median was lower at 6,960.7 (2,387.3, 13,567.2).([Table 1](#tbl-Table1_coverage_covid)) The mean 3-year COVID death rate was 56.9 (47.6) deaths per 100,000 persons; the median was similar at 6,960.7 (2,387.3, 13,567.2).

##### 4.1.0.0.3 Vaccination program characteristics

The median year of vaccine introduction was 2014 (2010, 2017).([Table 2](#tbl-table1_vac_program)) School-based delivery programs were the most common ( ). A majority of programs had a gender nuetral vaccination recommendation and a 2-dose routine recommendation (rather than a 1-dose recommendation).

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| Table 2: HPV vaccination program characteristics among countries with HPV vaccination programs in 2019 and 2022 |

##### 4.1.0.0.4 Sociodempgraphic characteristics

Sociodemographic metrics were presented in [Table 3](#tbl-table1_demo). The most common WHO region was the Euro region, and the most common country income level was high-income. Mean life expectancy was 75.2 (6.5).

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| Table 3: Sociodemographic characteristics among countries with HPV vaccination programs in 2019 and 2022 |

## 4.2 Basic statistical analysis

## 4.3 Full analysis

# 5. Discussion

## 5.1 Summary and Interpretation

## 5.2 Strengths and Limitations

## 5.3 Conclusions

# 6. References