A System Dynamic Model of HPV Vaccinations Among Adolescent Boys in New York State

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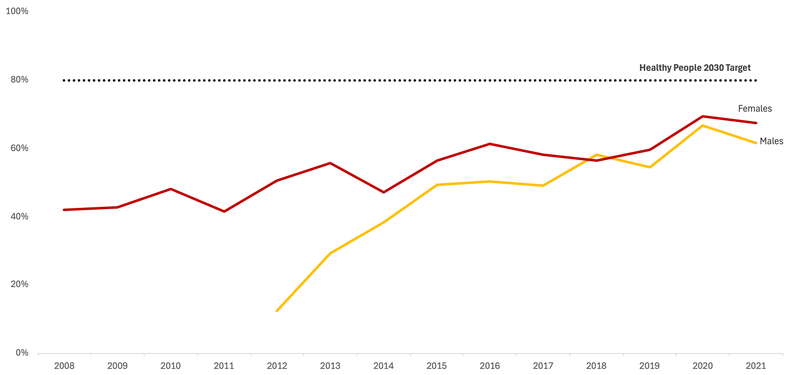
Introduction

- Human Papillomavirus (HPV) is the most common sexually transmitted infection (STI) in the US with approximately 13 million new infections each year.[1,2]
- Although the majority of newly acquired HPV infections go undetected clinically and are spontaneously resolved within two years, persistent infection can cause HPV-related diseases such as genital warts and HPV-associated cancers. These types of cancers can be prevented through early vaccination against HPV which has shown high effectiveness when administered before exposure.[3,4]
- While the HPV vaccine was initially approved by the Food and Drug Administration (FDA) in 2006 for females, its recommendation was not extended to males until 2009. This delayed in recommendation has led to disparities between males and females with male adolescents being less likely to initiate the HPV vaccine[5].
- Given the prevalence of HPV and its related cancers among males, it is important to undertake studies aimed at improving HPV vaccine uptake among boys.

Figure 1: Coverage of the first dose of the HPV vaccine in New York State by sex



Source: National Immunization Survey (NIS-Teen), Center for Disease Control and Prevention (CDC)

Objective

Use a system dynamic model to simulate HPV vaccine uptake among adolescent boys in New York State

Methods

- Adapted a previously developed System Dynamics (SD) model of HPV vaccine uptake among adolescents aged 9–17 in New York State.[6]
- The model simulates interactions among parents, adolescents, and healthcare providers that influence vaccination behavior.
- Parental decision-making is represented in three stages:
  1. Hesitant
  2. Intending to vaccinate
  3. Parents of vaccinated children
- Hesitant parents may become intending through:
  1. Positive provider recommendation
  2. Positive word-of-mouth (WOM) from other vaccinated parents.
- Adolescents are modeled using an aging chain where they age and get the 1st, 2nd, or 3rd dose.
- The model is calibrated using data from the New York State Immunization Information System (NYSIIS), National Immunization Survey–Teen (NIS-Teen), and U.S. Census estimates of adolescent population
- Calibration was performed using historical data from 2008–2019
- Post-2019 simulations project vaccination trends through the COVID-19 pandemic period and are compared with historical data.

Figure 2: Conceptual Stock and Flow Diagram of the HPV Model

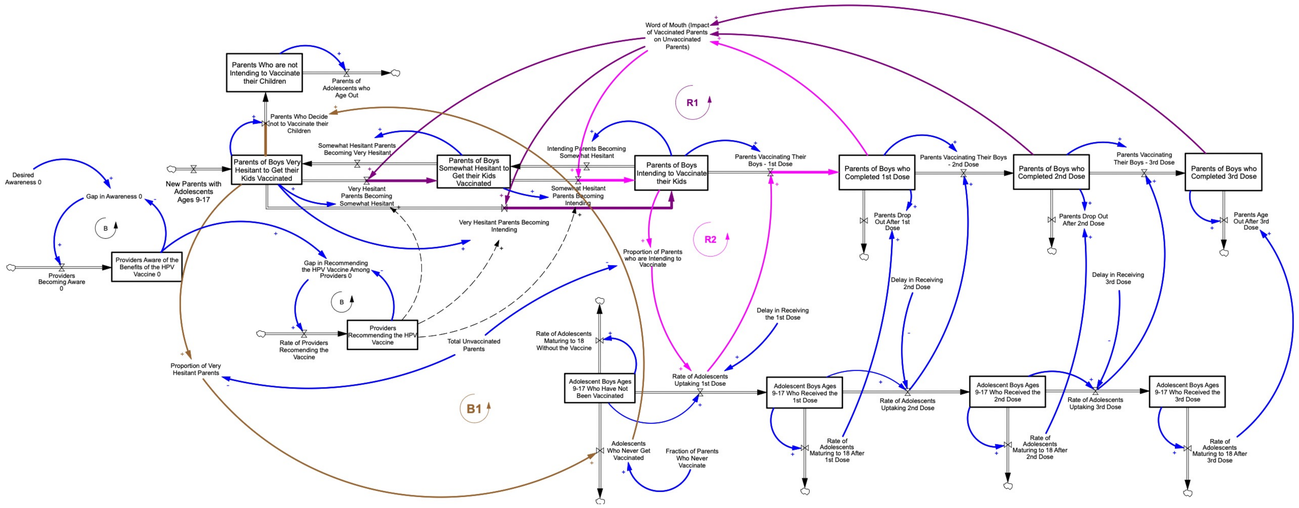
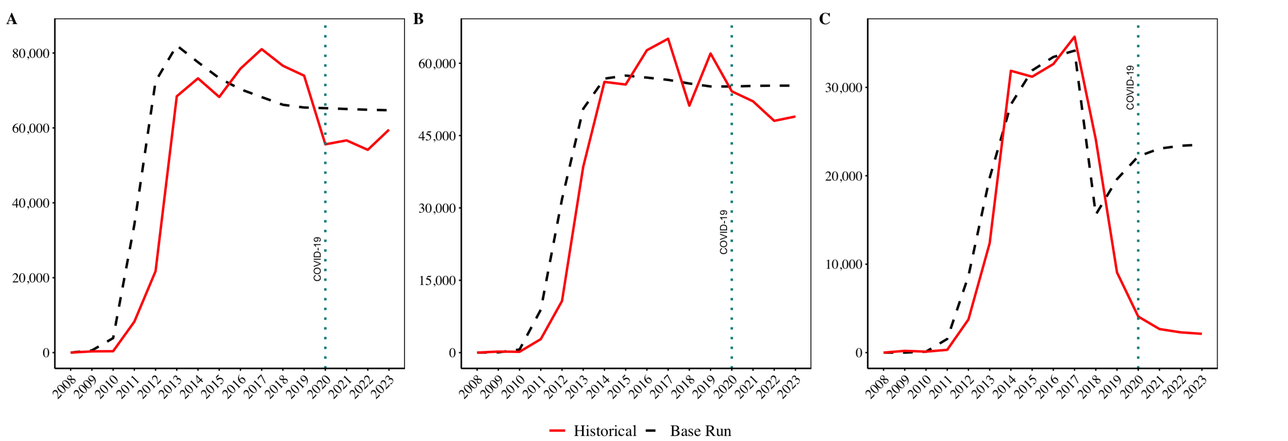


Figure 3: Model Fit and Post-COVID Projection of HPV Vaccine Uptake: Comparing Simulated and Historical Trends (2008–2023)



The graphs show the simulated and historical trends of HPV vaccine uptake before and post Covid-19. It shows uptake of the A) first dose, B) second dose, and C) third dose.

Results

- **Model update:** Replaced "parental awareness/knowledge" with **parental hesitancy**, a stronger predictor of vaccination decisions.
- **Reinforcing loop:** More vaccinated parents → positive word-of-mouth → hesitant parents become intending → more vaccinated children → increases vaccinated parents. R1 and R2 show similar loops for different levels of hesitancy.
- **Balancing loop:** A fixed share of parents who will *never* vaccinate exits the system, capping maximum coverage. In this simulation, the percent of parents who will never vaccinate was calibrated as 1% of the proportion of very hesitant parents.
- **Figure 3 :**
  - **First & second doses:** Historical uptake dipped after COVID-19; the simulation (assuming no pandemic shock) stays flat.
  - **Third dose:** Simulation shows modest gains, but real-world uptake has fallen since the 2016–17 guideline change—interpret with caution.

Conclusion

- Covid-19 disrupted uptake of the first and second doe of the HPV vaccine.
- Parental hesitancy plays a pivotal role in HPV vaccine uptake. Targeted interventions that shift parents' perspectives can help in increasing uptake of the vaccine.
- Future objectives include:
  - Testing the effect of provider recommendation and word of mouth.
  - Calibrating the model for females.
  - Compare NYC with the rest of NYS.
  - Incorporate ethnicity and socioeconomic status.

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