An Exploration of Factors that Impact Uptake of Human Papillomavirus Vaccines

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An Exploration of Factors that Impact Uptake of Human Papillomavirus Vaccines

David Samuel Redd

A thesis submitted to the faculty of 
Brigham Young University
in partial fulfillment of the requirements for the degree of

Master of Science

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ABSTRACT

An Exploration of Factors that Impact Uptake of Human Papillomavirus Vaccines

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Master of Science

Introduction

The discovery and continued development of vaccines is arguably one of the most important innovations in human history. Vaccination greatly reduces the worldwide incidence and transmission of diseases, preventing permanent injury and premature death. Mass vaccination campaigns have led to the eradication or partial eradication of severe infectious such as smallpox and polio, have reduced childhood mortality, and has led to an overall increase in average health in the human population globally.

Despite the documented benefits of vaccination, vaccine hesitancy is increasing, and the uptake of some vaccines is low. Vaccines have been so successful at preventing disease that portions of the population are now more afraid of the possible side-effects of vaccines than they are of the serious symptoms and maladies that vaccines prevent. Vaccine hesitancy is a serious concern for the global medical community. The incidence of infectious disease is inversely proportional to vaccine uptake; as fewer people are vaccinated against preventable diseases, the frequency at which people get sick increases. A reduction in vaccination rates due to vaccine hesitancy reduces herd immunity, which increases the risk for the whole population, especially immunocompromised individuals who are unable to receive vaccines.

Vaccines that protect against high-risk strains of Human Papillomavirus (HPV) have recently been developed and released to the worldwide population. High-risk HPV strains can cause persistent infection and various cancers. Although HPV vaccines have been extensively tested and are recommended by the Centers for Disease Control and Prevention and the World Health Organization, uptake among some demographics is low. Understanding what factors impact HPV vaccine hesitancy can guide the design of effective interventions which can increase vaccine uptake. High HPV uptake will lead to a reduction of HPV associated cancers and reduce the transmission of high-risk subtypes.

Research Significance

Vaccine hesitancy is a growing challenge for the medical community and could potentially put global health at risk by undermining 200 years of progress towards eliminating infectious diseases. A better understanding of what factors impact vaccine hesitancy allows public health professionals to design better policies and interventions which can increase uptake. Understanding of the factors which cause vaccine hesitance can be used to tailor education about vaccines. This leads to higher vaccine uptake and better community health overall.
Methodology

Electronically distributed surveys and statistical analysis were the primary tools used in this research. Surveys were used to generate data from a sample population, including: demographic factors, attitudes towards vaccination, and intent to vaccinate against HPV. Barriers to HPV vaccine uptake and factors that impact HPV vaccine acceptance were identified through statistical analysis, including confirmatory factor analysis, structural equation modeling, regression, and univariate analysis.

Findings

We found that general attitudes toward vaccination had the greatest impact on the intent of parents to vaccinate their children against HPV. Parents who view vaccination positively intend to vaccinate their children against HPV or have already vaccinated their children against HPV. Parents who are somewhat unsure about vaccines are more hesitant about vaccinating their children against HPV. Knowledge about HPV increases intent to vaccinate. We found that traditionally religious parents who felt that religious adherence provided some protection against HPV were more hesitant about HPV vaccinations. We found that both a religious-focused intervention and an education-focused interventions increased parental intent to vaccinate more than a control intervention.

Our study of Utah residents confirmed our earlier findings that general attitudes toward vaccination had the greatest impact on the intent of parents to vaccinate their children against HPV. Our study also confirmed that knowledge about HPV increases intent to vaccinate. We found that high religious practice negatively impacts parental intent to vaccinate. Cautious sexual attitudes also negatively impact intent to vaccinate against HPV. High religious practice is correlated with cautious sexual attitudes which explains the negative impact of high religious practice on intent to vaccinate.

The findings of this research work will be used to inform future religious and educational based interventions in Utah and beyond.

Keywords: vaccination, vaccine hesitancy, vaccine acceptance, Human Papillomavirus, HPV, Utah, Christian, religion
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Introduction

1. History of Vaccinations

1.1 Variolation

Vaccines are a relatively modern invention, however, attempts to prevent disease through controlled exposure has been practiced for hundreds of years. Variolation, the practice of deliberating inoculating uninfected persons with infectious materials, was practiced in Africa, Asia, and the middle east as a protective measure against smallpox. The practice was discussed in scientific correspondences throughout Europe and England, but the practice was not actively adopted [1]. Variolation was popularized by lady Mary Wortly Montagu who learned of the practice in the ottoman court where her husband served as an ambassador. Lady Montague had her young son and daughter inoculated in an effort to protect them against smallpox. Upon returning to London Lady Montague strongly advocated for the procedure. Although Variolation reduced the mortality rate of smallpox infection the practice was not without risk. Variolation could cause serious illness or death, it could trigger a smallpox outbreak because recently inoculated patients were infectious, and a constant supply of infected individuals was necessary to provide inoculation material [2].

1.2 Edward Jenner and the Discovery of Smallpox Vaccination

The practice of vaccination was developed by Edward Jenner, an English physician in the late 1700’s. As a teenager Jenner was apprenticed to a local physician. He continued his studies at St. Georges Hospital in London, where he was mentored by the renowned surgeon Sir John Hunter. After completing his studies Jenner declined a position at the hospital and returned to the countryside where he started practicing as a physician. Jenner, like other physicians of his day, became an expert at administering variolation [3]. As a country physician, Jenner observed that some patients who had previously contracted cowpox were resistant to receiving variolation. Upon further inquiry he learned that local dairy workers believed that cow pox was preventative of smallpox. While contemplating the fact that cowpox infection was preventative of smallpox. Jenner concluded that cowpox could be deliberately transmitted from one person to another as a protective mechanism against smallpox [4].
In order to test his theory and convince his physician colleagues that cowpox inoculation could protect against smallpox, Jenner performed an inoculation experiment. In May 1796, Jenner inoculated an 8-year-old boy named James Phipps with material from the lesions on the hands of Sarah Nelms, a dairymaid who had recently contracted cowpox. Phipps developed symptoms due to the inoculation but recovered within a few days. Jenner inoculated Phipps with fresh smallpox matter a couple of months after the initial cowpox inoculation. Phipps did not develop symptoms from the smallpox inoculation, which showed that cowpox inoculation did prevent smallpox [4].

Following the successful experiment with Phipps, Jenner began inoculating other people and recording the results [5]. Jenner submitted a manuscript to the royal society which contained his research and observations about the protective action of cowpox and detailed his experimental inoculation of James Phipps. The manuscript was returned unread by the royal society. Jenner preformed additional experiments, reworked the manuscript and published it at his own expense [3]. Jenner chose to call his new inoculation procedure vaccination, derived from the Latin words for cow *Vacca* and for cowpox *Vaccinia* [4]. All protective inoculations were later named vaccines in honor of Jenner’s pioneering work.

Edward Jenner was not the first person to notice that contracting cowpox conveyed protection against smallpox, this was an acknowledged fact among dairy workers. He was also not the first person to deliberately inoculate someone with cowpox with the intent of preventing smallpox. Benjamin Jesty a farmer in Dorset, performed a cowpox inoculation on his wife and two sons in 1774, 22 years before Edward Jenner attempted it [6]. During a smallpox outbreak Jesty inoculated his wife Elizabeth and his two sons, with material from lesions on the udders of a cow that was exhibiting cowpox symptoms. His wife and sons developed mild symptoms including a fever but soon recovered. Elizabeth and Jesty’s two sons remained free of smallpox despite frequent exposure to disease [6]. It is unclear whether Jenner was aware of Jesty’s experiment. Jenner is revered not for being the first to attempt a cowpox inoculation, but because he documented his observations and experiments and then publicized his findings [5]. Through experimentation and careful documentation, Jenner showed that the protective effects of cowpox exposure were not just a superstition of dairymaids and farmers but was a viable method of
preventing smallpox on a grand scale. After his discovery Jenner worked tirelessly to promote his findings and provide the world with a ready supply of cowpox cultures for vaccination.

1.3 Louis Pasteur

Louis Pasteur, a French microbiologist, and chemist built on Edward Jenner’s pioneering vaccination work. Pasteur’s work showed that vaccines against most microbial diseases could be created in laboratories by deliberately weakening pathogenic agents. His work on rabies also showed that vaccines could be used therapeutically to treat patients who had already been exposed to a pathogen [7].

Pasteur’s early work was focused on fermentation and spoilage due to bacterial contamination. While studying fermentation using a microscope, he observed structures smaller than yeast (Bacteria) which he concluded were responsible for the spoilage [8]. Pasteur’s extensive microbiology experience was essential when he began working with fowl cholera, an endemic disease that was devastating domestic chicken production in France. Pasteur was able to isolate Pasteurella multocida, the bacteria that causes fowl cholera. By culturing the bacteria repeatedly Pasteur was able to attenuate the bacteria, which could then be used to vaccinate chickens against fowl cholera [9]. The method that Pasteur used to create the vaccine is more important than the vaccine itself, because it showed that vaccines for various diseases could be created by deliberately weakening pathogens by passaging them in culture.

After successfully developing a fowl cholera vaccine, Pasteur began work on developing an anthrax vaccine. Bacillus anthracis was discovered by a German physician and microbiologist named Robert Koch. Through a series of experiments Koch also found that bacillus anthracis could form spores which allowed the bacteria to persist in soil [10]. Soon after Koch announced the discovery of Bacillus anthracis, Pasteur repeated some of Koch’s experiments in an attempt to develop a vaccine. Pasteur found that the bacteria retained its pathogenicity even after being passaged 100 times. Pasteur had previously used this method to create a fowl cholera vaccine, but his work with anthrax was unsuccessful. Jean Joseph Henri Toussaint a veterinarian who was also working with anthrax successfully created a vaccine by heating a culture for 10 at 55C killing the bacteria [7].
Pasteur’s most innovative and controversial work is the development of a rabies vaccine. Rabies can infect most mammals including humans and is extremely deadly. Lyssavirus which causes rabies is transmitted by the bite of an infected animal. The virus infects the nerves at the bite site, where it is transmitted to the central nervous system and from there to the brain where it causes neurological symptoms and death [11]. Due to long incubation period of rabies as the virus travels up the nerves to the brain it was suggested that a therapeutic remedy could be used after infection but before the onset of symptoms [7]. Pasteur and Émile Roux a physician and frequent collaborator, attempted to attenuate the virus by passaging it through various susceptible species. They developed a vaccine by drying the nervous tissue of rabbits infected with rabies. The dried spinal cords were emulsified and injected using progressively newer samples which generated immunity in the test subjects [7]. Pasteur and Roux were able to successfully vaccinate dogs using this method [12].

Although Pasteur’s vaccine protected dogs against rabies, he also wanted to protect humans against the disease. He wrote to Dom Pedro II the emperor of Brazil, whom he had previously befriended, asking for permission to test his vaccine on convicted prisoners. Dom Pedro II denied Pasteur’s request [13]. The opportunity to test the effectiveness of the rabies vaccine on Humans arose sometime later. A 9-year-old boy named Joseph Meister was brought into the clinic of Dr Joseph Grancher, one of Pasteur’s closest collaborators. The boy had been bitten multiple times by a rabid dog. Pasteur agreed to vaccinate the child because otherwise he would likely die. The boy was given 12 consecutive injections of desiccated rabbit spinal cord. The experiment was successful, and the boy survived [8]. Pasteur and his colleagues developed new methods for producing vaccines and demonstrated that vaccines can be used both protectively before exposure, and the therapeutic after exposure to a pathogen.

1.4 Development of Toxoid Vaccines Against Tetanus and Diphtheria

The next major discovery in the field of vaccination was the development of Tetanus and Diphtheria vaccines. Emil Von Behring and Shibasaburo Kitasato preformed a series of experiments with the recently discovered bacterial pathogens *Clostridium tetani* and *Corynebacterium diphtheria* the pathogens responsible for tetanus and diphtheria. They reported that whole blood, or cell-free serum from rabbit’s immune to C. Tetani due to a previous inoculation would protect mice infected with a lethal dose of tetanus [14]. They also reported
that adding serum from immunized rabbits to a culture of C. tetani would block its lethality when injected into mice [14]. They concluded there was a component in the blood of tetanus-immune rabbits that could destroy the tetanus toxin. They also concluded that these properties were stable and remained effective even in other animals [15]. A week after Kitasato and von Behring published their results, von Behring presented similar research on diphtheria showing that serum from an immune animal protected against diphtheria toxin [15]. Both *Clostridium tetani* and *Corynebacterium diphtheria* create toxins that harm the infected host. Kitasato and von Behring’s research led to the development of toxoid vaccines which contain a chemically modified toxin which elicits an immune response and causes the body to produce neutralizing antibodies without harming the host.

**1.5 Adjuvant Development**

Researchers were beginning to understand that vaccines provided immunity by introducing antigens that trained the immune system to recognize and destroy pathogens. Various methods were used to attenuate pathogens so that could be safely used in vaccine preparations. Effective vaccines need to strike a balance between eliciting a strong enough immune response to convey immunity, and not causing undue harm to the individual. Gaston Ramon, a French veterinarian, noted that tetanus and diphtheria anti-sera produced from horses was higher if the animal had an abscess at the injection site. He injected breadcrumbs, tapioca, and starch to create sterile abscesses and thus increase anti-sera production [16]. Around the time of Ramon’s discovery, Alexander Glenny a British immunologist noted that aluminum salts enhanced an immune response. While concentrating and purifying diphtheria toxoids Glenny and his Collogues used potassium aluminum sulfate. They found that the vaccine prepared with aluminum salts produced a stronger antibody response then the vaccine prepared only with soluble toxoids [17]. The starches used by Ramon and the aluminum salts observed by Glenny acted as adjuvants, substances that enhance the body’s immune response to an antigen. Adjuvants stimulate the immune system which produces strong and lasting immunity without causing lasting harm. Aluminum salt adjuvants have been used safely for 90 years and are used in vaccines today [18].

**1.6 Founding of the World Health Organization, and Center for Disease Control**

Although vaccines are designed to be as safe and effective as possible, due to how diverse the human population is the effectiveness of vaccines can vary by individual. In addition,
due to immune complications some individuals cannot safely receive vaccines. The best way to protect those people who cannot receive a vaccine or for whom a vaccine does not convey adequate protection is to achieve a high rate of vaccination in the rest of the population. A high vaccination rate reduces the ability for diseases to spread through the population and protects individuals who were not vaccinated, this is called herd immunity. There have been various local efforts and mandates to promote vaccination since their discovery. Edward Jenner worked tirelessly to promote and distribute the smallpox vaccine after it’s discovery. Louis Pasteur founded the paster institutes to research and distribute vaccines. Vaccination has been mandated by various armies to protect soldiers from disease outbreaks. The first national and international vaccination campaigns were implemented in the early to mid 1900’s. In addition to vaccine campaigns organizations were founded that promoted vaccination, monitored vaccination efforts, and set vaccination guidelines. The center for disease control and Prevention (CDC), the national public health agency for the United states, was founded in 1946 in Atlanta [19]. The World Health Organization (WHO) which is the United Nations agency responsible for global health, was founded shortly after in 1948 [20]. Health organizations and vaccine campaigns have helped increase vaccine uptake which has led to a major reduction in the transmission of vaccine preventable diseases.

1.7 Elimination of Smallpox Through Global Campaign

One of the first major vaccination programs that the WHO launched was the global smallpox eradication program in 1967. The program was extremely successful, and smallpox was completely eliminated. The last recorded case of smallpox occurred in Somalia in 1977, the WHO declared that smallpox had been eradicated in 1980 [21]. There are three factors that made smallpox elimination possible according to Donald Henderson who led the effort. Smallpox is strictly a human disease with no animal reservoir; therefore, it couldn’t be reintroduced from another species. Smallpox could be easily diagnosed due to the characteristic rash that it produced. An inexpensive, heat-stable, and effective vaccine was produced that was easy to use [22]. To date, smallpox is the only human disease that has been totally eliminated through vaccination, but there are other diseases such as polio that could be eliminated by continued vaccination effort.

1.8 Development of Subunit Vaccines and Treatment of Polio
The development of the Polio vaccine made subsequent vaccination efforts possible. Poliomyelitis is enterovirus that can cause a fever, sore throat, and in more serious cases paralysis and death. Polio is transmitted through oral ingestion; it multiplies in the alimentary mucosa before moving into the blood. From the blood the virus can invade the central nervous system and cause paralysis due to neuron destruction [23]. The disease was first characterized in the mid 1800’s. At the beginning of the 20\textsuperscript{th} century Polio outbreaks became more frequent and sever in Europe and the United States [24]. A few early vaccines were developed and tested but were found to be ineffective or dangerous and were discontinued. The first polio vaccine that experienced widespread success was developed by Dr Jonas Salk, an American physician and virologist. Salk and his team formulated a vaccine using formaldehyde to inactivate the virus without destroying its antigenic properties. After extensive testing to establish safety and efficacy, Salk’s vaccine was widely distributed nationally and internationally [25]. While Salk was developing his vaccine, Dr Albert Sabin, and Dr Hilary Koprowski had also began working on developing a polio a vaccine. Sabin used a different approach then Salk. He cultured a trivalent live attenuated vaccine by passaging the virus in vitro then in vivo to reduce its virulence [24, 26]. Because Salk’s vaccine was already in use in the United States, Sabin tested his vaccine in other countries including the Soviet Union where millions of doses were given to children. Shortly after the onset of mass vaccination with Salk’s vaccine, some patients developed paralysis in the limb where the vaccine was administered. During preparation in the cutter and Wyeth laboratories the virus was inadequately deactivated. This led to the recall of thousands of doses and a decrease in trust in the vaccine [25]. Due to the complications with Salk’s vaccine and the success of Sabin’s vaccine in testing in the Soviet Union, Sabin’s vaccine received approval for use in the United States and was instrumental in the elimination of polio in most of the world [25, 26].

Live Attenuated vaccines, Inactivated vaccines, and toxoid vaccines have all been used to effectively treat various diseases, but each method of vaccine preparation has limitations. The incomplete inactivation of some batches of the Salk Polio vaccine is a well-known example of the limitations of inactivated vaccines. If vaccines are inadequately attenuated or inactivated, they can cause disease in patients. Attenuated live vaccines are unsuitable for immunocompromised individuals. Toxoid vaccines only work for a small subset of diseases where the pathogen produces toxins. Due to disadvantages mentioned above a new class of
vaccine was developed called a subunit vaccine. Subunit vaccines only contain components or antigens to stimulate the immune system, rather than whole attenuated or killed organisms. These vaccines are easier to produce, can be used against a wide range of pathogens, and cannot cause disease. The main downside of subunit vaccines is that they do not illicit as strong of an immune response as other vaccines, therefore booster shots are required. Subunit vaccines were made possible due to major advances in molecular biology and microbial genetics in the 1950’s and 60’s. The first subunit vaccine that was developed was a Hepatitis B vaccine developed by Baruch S Blumberg.

Baruch S. Blumberg, an American physician discovered an antigen he termed the Australian antigen (AuAg) named for the patient it was isolated from. Research later revealed that AuAg was the surface antigen of the viral envelope of the Hepatitis B virus (HBV) [27]. The first HBV vaccine was created by purifying the Hepatitis B antigen from the blood of infected donors. Antigen purification is a fairly involved process with a series of steps including Ultracentrifugation, pepsin digestion, denaturation, gel filtration, and treatment with formaldehyde [28]. Purifying a viral antigen was a novel approach to vaccine creation, it was also somewhat controversial because the blood was harvested from infectious patients who may have had HIV or other bloodborne pathogens. The lengthy filtration steps deactivated or destroyed all known pathogens making the vaccine safe for use. The Vaccine was licensed for use in The United States and France after extensive safety and efficacy testing [28]. Due to the high cost of producing the blood-derived HBV vaccine, it was eventually withdrawn and replaced by a vaccine that was produced by making viral antigens in recombinant yeast developed by Maurice Hillman.

1.9 mRNA Vaccines and Rapid COVID-19 Vaccine Development

The newest type of vaccine is mRNA based. The advantages of mRNA vaccines are that they can be developed extremely quickly, are cost effective to produce and safe to administer. An antigenic protein is encoded on mRNA which is translated by the ribosomes in cells to form proteins. These proteins are recognized by the immune system conveying immunity. mRNA is rapidly degraded within the body, so a polymer is used which protects the mRNA from degradation until it can be translated. Exogenous mRNA is immunostimulatory acting as a natural adjuvant [29]. The first major use of mRNA-based vaccines was developing vaccines for
the novel corona virus SARS-CoV-2. COVID-19 emerged in the Wuhan Province of China in late 2019. The disease quickly spread around the world and was declared a global pandemic by the WHO in March 2020. Two mRNA-based vaccines were rapidly developed by Moderna Biotechnology and a through a BioNtech and Pfizer collaboration. The vaccines were developed, manufactured, tested, and approved for use in less than a year [30]. Millions of vaccines were distributed worldwide, reducing the incidence and severity of COVID-19 infections. The speed at which the vaccines were developed illustrates the advantages of mRNA-based vaccines.

Table 1: Vaccine Types

<table>
<thead>
<tr>
<th>Vaccine Type</th>
<th>Mechanism:</th>
<th>Advantages:</th>
<th>Disadvantages:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Live attenuated</td>
<td>A weakened (attenuated) bacteria or virus</td>
<td>Creates strong-long lasting immune response with minimal doses</td>
<td>Requires refrigeration, may cause complications in immunodeficient individuals</td>
</tr>
<tr>
<td>Killed whole organism</td>
<td>non-infectious residue of killed pathogen</td>
<td>Safer for immunodeficient individuals</td>
<td>Requires refrigeration, provides weaker immune response then attenuated vaccine</td>
</tr>
<tr>
<td>Purified protein or polysaccharide</td>
<td>Purified protein or polysaccharide subunits</td>
<td>Elicits strong immune response, safe for immunodeficient individuals</td>
<td>May require subsequent &quot;booster&quot; doses to maintain efficacy</td>
</tr>
<tr>
<td>Genetically engineered</td>
<td>Protein or polysaccharide subunits produced by a recombinant organism</td>
<td>Elicits strong immune response, safe for immunodeficient individuals</td>
<td>May require subsequent &quot;booster&quot; doses to maintain efficacy</td>
</tr>
<tr>
<td>mRNA vaccine</td>
<td>pathogenic antigen encoded on RNA and produced by host</td>
<td>Elicits strong immune response, safe for immunodeficient individuals</td>
<td>Requires refrigeration, Longlong term efficacy unknown</td>
</tr>
</tbody>
</table>
2. The rise of Vaccine Hesitancy

2.1 Vaccine Hesitancy is a Global Health Concern

Although vaccines have proven to be a safe and effective method of preventing disease, there have been concerns about their use almost since their inception. Vaccine hesitancy has evolved over time based on misconceptions, fears, and changes in public perceptions. In 2019 the WHO listed vaccine hesitance as one of the top ten threats to global health [31]. Vaccine hesitancy is defined as a delay or refusal to vaccinate despite availability of vaccination. Vaccine acceptance is the norm in the majority of global populations, however, a smaller subset of the population delay vaccination or refuse certain vaccines [32].

2.2 Vaccine Hesitancy Through History

Vaccine hesitancy has existed almost as long as the practice of vaccination. Variolation, a preventative practice used before the development of the smallpox vaccine, killed, or caused other diseases (e.g., tuberculosis and syphilis) in 2% to 3% of recipients [4]. Benjamin Jesty, the first person recorded to have used a cowpox inoculation to protect against smallpox, was ridiculed by his neighbors after inoculating his wife and children [6]. Jenner’s vaccine work was initially met with skepticism, and some people declared that vaccination was contrary to God’s will [33]. The polio vaccine developed by Jonas Salk caused limb paralysis in a number of patients; During the manufacture of the vaccine the virus in some batches wasn’t adequately neutralized and remained virulent. Because everyone is different, vaccines can sometimes cause side effects despite being prepared correctly and undergoing extensive safety testing. Common side effects that occur after vaccination are pain or swelling at vaccination site, mild fever, chills, fatigue, headache, as well as muscle and joint aches [34]. Most of these symptoms are caused by the immune system responding to the vaccine. In rare cases vaccines can cause severe side effects including difficulty breathing, swelling of the face and throat, an elevated pulse, a severe rash across the whole body, dizziness and weakness, and in extreme cases death [34]. Although vaccines are safe for the vast majority of people there is a small risk of side effects. Vaccines are orders of magnitude safer than contracting the diseases they are designed to prevent. Fears about vaccine side effects, both real and imagined, can be magnified by social media causing far more concern about vaccination than is actually warranted.
One of the most widespread vaccine concerns is the purported, but disproven, hypothesis that vaccination causes autism. This unsubstantiated concern arose when Andrew Wakefield, a British gastroenterologist and collaborators, published a paper that described 8 children whose first symptoms of Autism spectrum disorder (ASD) manifest within 1 month of receiving the measles-mumps-rubella (MMR) vaccine. Wakefield postulated that the MMR vaccine caused inflammation which affected development and lead to the onset of ASD [35]. There were problems with the study including a lack of control subjects and a sample population too small (n=12) to preclude that the development of ASD symptoms following MMR vaccination was not merely coincidence [24, 36]. Soon after the paper was published, epidemiological studies were conducted and published which refuted the implied link between ASD and vaccination [24, 36]. 10 of the 12 authors on the paper retracted their interpretation of the data stating that “no causal link was established between MMR vaccine and autism as the data were insufficient” [37]. In 2010 The Lancet, the journal that originally published the paper by Wakefield et al., retracted the paper stating that “several elements in the paper were incorrect, contrary to the findings of the earlier investigation” [38]. Wakefield et al. were later found guilty of failure to disclose financial interests, falsifying facts, and deliberate fraud [24, 39]. In a study conducted on parents of under vaccinated children in Utah, the most commonly reported concerns regarding immunization safety were autism, immune system overload, and the potential of serious adverse reactions. This study indicates that parental fear of ASD development impacts vaccine hesitancy [40]. Although the unsubstantiated link between vaccination and ASD has been thoroughly disproven, vaccine hesitancy has increased due to concerns about developing ASD, and there has been a drop in vaccine uptake.

In addition to the risks associated with early vaccines and flawed information from spurious studies, there are a myriad of other factors that influence vaccine hesitancy. Lack of access to accurate information, and the spread of misinformation through social media has a significant negative impact on confidence in vaccines. Misinformation can quickly spread through social media, making it difficult to differentiate between fact and fabrication [41]. In addition to the rapid spread of misinformation, changes in the medical system have greatly constrained the time doctors have per appointment, making it difficult for them to educate and
address the concerns of their patients. [41] The low incidence of contagious diseases due to vaccination has led to the perception that the risk posed by these diseases is also low. [42] Due to the success of vaccination in preventing most major disease outbreaks, fear has shifted away from vaccine-preventable diseases to fear of the vaccines themselves. [43]

3. Human Papillomavirus

3.1 HPV Biology and Replication

Human Papillomaviruses are a family of over 150 related, small non-enveloped, double stranded DNA viruses [44, 45]. HPV infects cutaneous and mucosal stratified epithelium cells that form the epidermis and the linings of the genitals and upper respiratory tract. The virus enters the epithelium through microlesions where it infects basal epithelial cells. The virus begins to replicate with in the infected cells. As the infected basal cells divides, copies of the viral genome are distributed into both daughter cells. One of the daughter cells migrates up through the epithelium where it starts to differentiate while the other daughter cell remains part of the basal epithelium where it continues to replicate. As the daughter cell travels up through the epithelium, the virus halts differentiation because a fully differentiated epithelial cell lacks the cellular machinery necessary for viral DNA synthesis. The virus stimulates G1 to S-phase progression to while inhibiting differentiation making an environment where viral DNA, and capsid proteins can be produces [46]. The viral DNA is replicated as the cell passes through the Stratum Granulosum and viral particle assembly occurs within the Stratum Corneum. Once the infected cell reaches the surface it can be sloughed off allowing viral transmission to other individuals. The modulation of the cell can increase cell proliferation creating growth called papilloma, or warts [46]. The virus can also cause oncogenic mutations, which eventually lead to the development of cancer [47].
Figure 1: Epithelium Cross Section Illustrating HPV Replication. 1 Basal epithelium - the first cells infected. 2 infected cells migrating through epithelium. 3 infected cells undergo DNA replication in the Stratum Granulosum. 4 infected cells are sloughed off. (Created using Biorender)

3.2 HPV Transmission

HPV is usually transmitted through direct skin-to-skin or skin-to-mucosa contact. HPV strains that infect the mucosal membranes are usually transmitted through sexual intercourse, but can also be transmitted through other types of sexual contact [45]. Though less common than skin-to-skin transmission, HPV can be transmitted on surfaces or medical implements [48]. HPV is very durable and resists most commonly used disinfectants [49]. HPV is the most commonly sexually transmitted infection in the United States. An estimated 80% of sexually active individuals will contract HPV sometime during their lifetime [45]. HPV has co-evolved with humans for millions of years and is therefore well adapted. HPV infections are usually mild and cause minimal symptoms or are completely asymptomatic [44]. Most HPV infections are cleared within one to two years by the immune system; persistent HPV infection is strongly
associated with an increased risk of genital warts and cancer [45]. There are approximately 40 HPV strains that are sexually transmitted. Oncogenic HPV strains are classified as high-risk (16, 18, 31, 33, 35, 39, 45, 51, 52, 58). Non-oncogenic strains that cause genital warts are classified as low risk (6, 11, 40, 42, 43, 44, 54). HPV strains 16 and 18 are the most dangerous strains, they cause approximately 70% of all HPV associated cancers [45]. Due to the prevalence of HPV transmission and the danger presented by high-risk strains, vaccination is an important health safety measure that protects against the most pernicious HPV strains.

3.3 Development of HPV Vaccine

Two HPV vaccines were developed and released around the same time. The first HPV vaccine to be released was Gardasil, a quadrivalent recombinant vaccine produced by Merck & Co. Gardasil is protects against HPV subtypes 6, 11, 16, and 18, received FDA approval, and was released in 2006 [50]. The second HPV vaccine to be released was Cervarix, a bivalent vaccine developed by GlaxoSmithKline. The vaccine provides protection against subtypes 16 and 18 and received FDA approval in 2007. In 2014 Merck released Gardasil 9, a nine-valent vaccine that provides protection against 6, 11, 16, 18, 31, 33, 45, 52, and 58. Cervarix was voluntary withdrawn from the market in 2016. Gardasil and Cervarix are both purified protein vaccines which contain virus-like particles (VLP) of the major papillomavirus capsid protein L1. The major capsid protein is produced through recombinant expression, and then purified. The structural proteins self-assemble into highly immunogenic VLP’s which mimic virions [51]. In addition to VLP’s the Cervarix vaccine contains Monophosphoryl lipid A and aluminum hydroxide as adjuvants, and Gardasil and Gardasil 9 contain aluminum hydroxide as adjuvants [52].

3.4 HPV Vaccine Hesitancy

Although safe and effective vaccines against HPV have been developed, uptake is low. The Advisory Committee on Immunization Practices (ACIP) recommends that all children aged 11 to 12 receive HPV vaccination. Despite ACIP recommendations, vaccination rates have remained low. In 2013 57.3% of girls and 34.6% of boys initiated an HPV vaccination series. Less than 40% of girls and less than 15% of boys completed the series showing rates well below the target of 80% [53]. There are many barriers that could prevent parents from vaccinating their kids against HPV. Some barriers that have been identified are: lack of knowledge about HPV,
financial concerns, parental attitudes, lack of information about HPV vaccines, concerns about the vaccines’ effect on sexual behavior, and low perceived risk of HPV infection [54, 55]. A major barrier that could negatively impact HPV vaccine uptake is concerns about the safety of HPV vaccines. In recent years the number of parents who have declined HPV vaccination for their child due to safety concerns has increased despite reports of serious health complications after vaccination being consistently rare [56].

There are many demographic factors that can influence HPV vaccine uptake. Europe has a higher HPV vaccine uptake then the United States, and England and Scotland have higher rates then continental Europe [57]. England and Scotland’s high vaccine uptake rate is in part due to in school vaccination programs, which most other European countries lack. Australia also has a school-based vaccination program and consequently high HPV vaccine uptake rate. Without a school-based vaccination program, vaccine uptake in the United States is dependent on parents and primary care providers [57]. Multiple studies have shown that religious and spiritual beliefs impact HPV vaccine uptake [58, 59]. Highly religious individuals who identify as Christian may feel that their or their children’s risk of contracting HPV is low due to religious values such as abstinence before marriage. Some religious individuals may also object to some ingredients in vaccines or how certain vaccines are manufactured. Understanding what factors negatively affect vaccine uptake would aid primary care providers and Public Health as they address concerns which would improve HPV uptake.

Geography is another factor that influences HPV vaccine uptake. For the past 5 years Utah has had the one of the lowest HPV vaccination rates in the country [60]. There are many factors that could influence Utah’s low vaccination rate. A recent study of Utah health care providers found parental misconceptions to be the greatest barrier to HPV vaccination [59]. Utah also has a highly religious population which could have an impact on HPV vaccine acceptance.
Figure 2: National HPV Vaccination Rates. This figure shows vaccination rates by state for the last 5 years. Darker blues indicate lower vaccination rates. Utah has one of the lowest rates and is consistently below 50%.
Chapter 1

Effects of Religious Practice and Teachings About Sexual Behavior on Intent to Vaccinate Against Human Papilloma Virus

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Abstract:

Human Papillomavirus (HPV) is the most common sexually transmitted infection in the United States. Most infections are mild and clear without treatment in 1 to 2 years. Some HPV strains result in persistent infection which can cause various cancers including cervical, penile anal mouth and throat cancers. Vaccines have been developed which provide protection against the highest risk HPV strains. Despite HPV vaccines having been proven to be safe and effective, uptake has been low. Religiosity has been negatively correlated with HPV vaccine uptake in some studies. It is hypothesized that religiosity and Christian religious affiliation could impact parents’ decision to vaccinate their children against HPV via teachings and beliefs about sexual behaviors. A survey was distributed to participants to determine what factors, including religiosity and views about sex, impacted HPV vaccination. The survey results (n=442) were analyzed using confirmatory factor analysis, structural equation modeling, and univariate factor analysis. The association between religious practice and vaccine attitudes were complex, with religious practice slightly positively correlated with provaccine attitudes and vaccine knowledge, but also with the belief that religious adherence to expectations surrounding sexual behavior will protect children from HPV infection, and more negative views towards vaccines in general.

Keywords: Human Papillomavirus; Sexually transmitted infection; Vaccine Attitudes; Vaccine hesitancy; Christian religious views

1. Introduction

Human papillomaviruses (HPV) are a family of human, nonenveloped, double-stranded DNA viruses [61]. HPV is the most commonly sexually transmitted infection in the United States. It is estimated that over 80% of sexually active individuals will contract HPV sometime during their lives [45, 61]. HPV is generally transmitted through skin-to-skin, or sexual contact,
where it infects cutaneous and mucosal epithelium [45, 46]. Most HPV infections do not cause serious symptoms and resolve without treatment within 1 to 2 years [45]. Because HPV often presents asymptomatically it can be passed unknowingly between sexual partners. Although many HPV strains are not a serious concern, some strains can cause persistent infection which can result in genital warts and cancer in mucosal membranes including cervical, anal, penile and throat cancers. HPV is the primary causative agent of cervical cancer; HPV is responsible for over 95% of cervical cancer cases. Oncogenic HPV strains are classified as high risk; strains 16 and 18 are the most dangerous causing 70% of HPV-associated cancers [46].

Due to the risk presented by persistent HPV infection and the cancers associated with it, significant effort was made to develop a vaccine. Three vaccines have been approved by the Food and Drug Administration (FDA) for use in the United States. Multiple studies have determined that the three approved vaccines have an acceptable safety profile and are effective at preventing high-risk HPV infection [62]. HPV vaccination is recommended for both males and females ages 9 to 45 [63, 64]. HPV vaccines provide the best protection if administered before an individual becomes sexually active. It is recommended that vaccination be administered during the early teens, but it can be administered later [63, 65]. Vaccination efforts have been highly effective at reducing incidence and transmission of strains covered by the vaccine [66]. It is anticipated that cervical cancer could be completely eliminated in areas with high rates of vaccine uptake [67].

Despite HPV vaccines having proven effectiveness and an acceptable safety profile, the vaccination rate in the United States is low. Recent estimates of adolescent (ages 11-17) vaccination coverage show that 41.9% of females and 28.1% of males have completed a vaccination series [68]. The reported vaccination rates for young adults are even lower than adolescents. The US department of Health and Human Services (HHS) estimates that in the United States less than half of young adults (ages 18-26) have received an HPV vaccine dose and only 22% have completed a vaccine series [69]. HPV vaccination rates are increasing in teenagers but still fall below the vaccination target of 80%. HPV vaccination rates are also well below the rates of other vaccines recommended for adolescents such as Tdap and MenACWY [68, 69]. This indicates that the HPV vaccine is not being routinely recommended or administered when other adolescent vaccines are administered. HPV vaccination rates of
adolescents are closely monitored and studied, however there is less data on young adult vaccination rates. A study looking at vaccination trends in the 2010-2018 National health interview survey found that participants who reported having at least one dose increased between 2010 and 2018 from 32% to 55% for females and from 2% to 34% for males. The study also found that 4% of females and 3% of males initiated vaccination between ages 18 and 21. In comparison 68.1% of adolescents have received 1 or more doses [70]. Young adults have more control over health decisions than adolescents but may have less access to health care services, may be unaware they did not receive the vaccine, or may not actively seek medical care because they believe themselves to be healthy. If HPV vaccination series is not initiated as an adolescent, the series is less likely to be completed [70]. There are many factors that could impact HPV vaccine uptake including access to vaccination, health care provider recommendations, parental attitudes, religiosity, risk of infection, vaccine mandates, or sexual activity.

Multiple studies have shown a negative correlation between religious affiliation and HPV vaccine uptake [58, 59, 71]. In a study of female college students, the impact of religiosity/spirituality on sexual decision making was assessed. Bivariate analysis showed that sexual activity and religious/spiritual beliefs were independently associated with HPV vaccine uptake. However only sexual activity was significantly associated with vaccination in this study. After correcting for socio-demographic variables, sexual activity was found to fully explain the relationship between religious/spiritual beliefs and HPV vaccination [58]. This could indicate that the influence of religiosity on sexual behavior could impact HPV vaccine uptake. A national study investigated factors that influence HPV vaccination initiation. Survey participants who were sexually active and participated in religious services less than once a month were more likely to report initiation of HPV vaccination [71]. Another study of young adults in Utah found that participants who belonged to an organized religion were significantly less likely to have received a provider recommendation, and to have initiated or completed an HPV vaccination series [59]. Although these studies suggest that religiosity can have a negative impact on HPV vaccine uptake, more research in this area is necessary.

Understanding the impact of religiosity, religious affiliation, and religious beliefs about sexual behavior on whether parents decide to vaccinate their children is important, because HPV vaccination is recommended for children in their early teens before the initiation of sexual
activity. In a survey study of parents and caregivers of daughters it was found that parents who frequently attended religious services were more likely to decline vaccination than their less religious peers [72]. In a focus group study of rural parents, the impact of spirituality and religiosity on HPV vaccination attitudes was investigated. It was found that religiosity and spirituality influence health choices and play an integral role in the parents’ life. The study also showed that parents in rural communities have restricted access to healthcare providers, therefore the religious community could play a valuable role in encouraging parents to vaccinate their children [73]. The previous studies show that the impact of religiosity and religious affiliation is complex; religiosity can negatively impact parents’ decision to vaccinate children against HPV but addressing religious concerns could also be an avenue to increasing vaccine acceptance. We intend to explore the complex relationships found in these prior studies using Structural Equation modeling to look at how variables influence each other in terms of intent to vaccinate against HPV. The focus of this research is not on teachings about vaccination in church, which are likely minimal, but on how factors associated with religiosity affect attitudes towards vaccines. Since attitudes towards vaccines by the public can have a strong effect on public policy such as vaccine mandates to attend public school, efforts to improve vaccine attitudes in this population may have far-reaching effects.

The aim of this study was to determine how Christian religious activity and teachings about sexual relationships affects willingness to vaccinate children against HPV. We hypothesized that increased religious practice and stronger views about sexual relationships being sinful would affect such factors as trust in medicine, attitudes towards vaccines in general, belief that lifestyle protects against infection, and knowledge about vaccines and HPV. We further hypothesized that these factors would influence intent to vaccinate children against HPV. By understanding how these factors relate to each other, we hope to identify areas that can be emphasized in public health messaging or other mechanisms to improve vaccine uptake in this population.
2. Materials and Methods

2.1 Survey of Christian Parents

Parents were invited to participate in a cross-sectional study by completing an online survey designed to assess attitudes toward HPV vaccination, and Christian religious views and affiliation. The survey was distributed electronically by Qualtrics (Provo UT) using their nationwide survey panel. Inclusion criteria included self-identification as Christian and being the parent of at least one child under the age of 11. Education level of the respondents was also used to determine participation, to ensure conformity with the education proportions in the United States as a reference population and to diminish sampling bias. For an optimal structural equation model, 442 complete responses were recorded. Structural equation modeling is recommended to have at least 20 respondents per factor [74]. With our 9 factors, we need at least 180 respondents, so our sample size is more than adequate. Furthermore, post-hoc analysis using confirmatory factor analysis is effective at evaluating sample size [75], and our confirmatory factory analysis showed excellent validity with our sample. Incomplete responses were not provided by the surveying company. Quality control was performed using a timing method, whereby any participant who spent less than half the mean time completing the survey was rejected. The survey was open from April 9, 2021 to May 20, 2021.

2.2 Survey Description

The survey consisted of 10 sections. The first section was an informed consent page, which included a short explanation of the survey which stated that attitudes toward the human papillomavirus vaccine were being studied. Participants were told that participation was optional, that the survey would take approximately 20 min to complete, that survey responses would be used for research purposes, and that all responses would be kept anonymous. Respondents who were willing to participate in the survey could accept the terms and conditions and continue with the survey. Respondents who did not accept the conditions were thanked for their time and the survey concluded. The study was carried out under the principles of the declaration of Helsinki. The study received ethical approval from the institutional review board of Brigham Young University (Protocol # E2021-052).
The second section of the survey assessed demographic information including religious affiliation, number of children, age, sex, race, education, political affiliation, and socioeconomic status. The third section assessed participant views on the connection between sexual inactivity due to religious beliefs and contracting HPV (Beliefs that Religious Adherence Protects Against HPV). The fourth section assessed views towards vaccines in general (Positive Attitudes Toward Vaccines) and the HPV vaccine in particular (Fear of HPV Vaccine Side-effects and Intent to Vaccinate). The fifth survey section had questions evaluating participants’ knowledge about and understanding of vaccines (Vaccine Knowledge) and HPV (HPV Knowledge). The sixth section assessed participants’ religiosity (Religious Practice, Religious Influence, and Religious Hope). The seventh section assessed how participants’ religious affiliation viewed vaccines (Pro-Vaccine Religious Views). The eighth section assessed how religion influences participants’ views on sexual behavior (Religious Encouragement of Premarital Abstinence). The ninth section assessed the parental/peer influence on sexual behavior (Parental/Peer Influence on Sexual Behavior). The final section of the survey assessed participants’ trust in modern medicine (Trust in Modern Medicine). The survey itself was checked for face validity by a virologist (Dr. Poole), a specialist in biological education and religious influences (Dr. Jensen), and a public health expert (Dr. Sloan-Aagard). Intelligibility was checked by at least two undergraduate students. (The full survey can be found in the supplementary materials S1)

2.3 Confirmatory Factor Analysis and Structural Equation Modeling

To validate our survey, we used Confirmatory Factor Analysis (CFA) to confirm that the questions included in our surveys accurately represented our latent variables; to test the relationships between latent variables we performed structural equation modeling (SEM). Before starting analyses, we cleaned and organized the data using SPSS statistics software (IBM 2021 Armonk, NY). Mplus software ver. 8 (Muthen and Muthen, 1998-2010, Los Angeles, CA) was used to perform both CFA on the measurement portion and SEM on the structural portion of our models. Each latent variable in the model was represented by three or more survey items. CFA was performed with a request for modification indices. Items were removed until fit indices [root mean square error approximation (RMSEA), comparative fit index (CFI), Tucker-Lewis index (TLI), and standardized root mean square residual (SRMR) were acceptable. Instruments were combined into a full measurement model to ensure fit before commencing structural modeling.
SEM was performed on two hypothetical models comprised of validated latent variables and income as a covariate in model A.
[A] We hypothesize that religious practice and pro-vaccine religious views influence trust in modern medicine, vaccine knowledge, and general positive attitudes toward vaccines, which in turn influence intent to vaccinate children against HPV. [B] We hypothesize that religious practice and religious encouragement of premarital abstinence influence beliefs that religious adherence protects
against HPV and knowledge about HPV, which in turn influence intent to vaccinate. These connections are illustrated visually in the models.

2.4 Univariate analysis

Univariate analyses were performed using Pearson’s correlation analysis. The Intent to vaccinate score was derived by combining the items from section 4 of the survey. A score for Belief in vaccine efficacy was generated by combining the scores for the questions “Vaccines are more helpful than harmful” and “vaccines are effective at preventing disease.” A score for Vaccine safety was generated by combing the responses to “Vaccines contain dangerous toxins” and “Vaccines often have severe side effects.” These were then compared to the Intent to vaccinate score using Pearson correlation. A score for General vaccine knowledge was generated by scoring the responses to the questions “Smallpox has been eliminated because of mass vaccination,” “Vaccines increase the risk for allergies,” “Unvaccinated children are more resistant to infections,” “Routine immunizations can be given while a child is on antibiotics for an ear infection,” “Current scientific evidence supports associations between vaccines and chronic conditions such as autism or multiple sclerosis” and “The Food and Drug Administration (FDA) approval process for vaccines is the same as that for other drugs and pharmaceuticals.” These scores were compared to the Intent to vaccinate score using Pearson correlation.

3. Results

3.1 Characteristics of Study Respondents

We began analysis of the survey data by summarizing the baseline characteristics of the study respondents (Table 1). The majority of respondents were between ages 26 and 45 (77.59%). Approximately three fifths (60.4%) of respondents identified as female and two fifths identified as male (39.60%), none of the respondents identified as non-binary or third gender. Most respondents identified as partnered (75.11%). Approximately half of the respondents have two children (49.77%). The respondents were fairly well educated with over half (53.4%) having completed at least an associate’s degree. Income was relatively evenly distributed. The three most selected religious affiliation were Christian (non-denominational) (38.91%), Catholic (30.77%) and Baptist (13.12%).
<table>
<thead>
<tr>
<th>Date</th>
<th>Number</th>
<th>Percent of total responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (n = 442)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18-25</td>
<td>38</td>
<td>8.60%</td>
</tr>
<tr>
<td>26-35</td>
<td>170</td>
<td>38.45%</td>
</tr>
<tr>
<td>36-45</td>
<td>173</td>
<td>39.14%</td>
</tr>
<tr>
<td>46-55</td>
<td>37</td>
<td>8.37%</td>
</tr>
<tr>
<td>Over 55</td>
<td>24</td>
<td>5.43%</td>
</tr>
<tr>
<td>Gender (n = 422)</td>
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<td></td>
</tr>
<tr>
<td>Male</td>
<td>175</td>
<td>39.60%</td>
</tr>
<tr>
<td>Female</td>
<td>267</td>
<td>60.4%</td>
</tr>
<tr>
<td>Non-binary/3rd gender</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Prefer not to answer</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Marital status (n = 442)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single</td>
<td>54</td>
<td>12.22%</td>
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<tr>
<td>Partnered</td>
<td>332</td>
<td>75.11%</td>
</tr>
<tr>
<td>Married</td>
<td>19</td>
<td>4.30%</td>
</tr>
<tr>
<td>Divorced</td>
<td>7</td>
<td>1.58%</td>
</tr>
<tr>
<td>Widow/widower</td>
<td>30</td>
<td>6.79%</td>
</tr>
<tr>
<td>Number of Children (n = 442)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>One</td>
<td>130</td>
<td>29.41%</td>
</tr>
<tr>
<td>Two</td>
<td>220</td>
<td>49.77%</td>
</tr>
<tr>
<td>More than Two</td>
<td>92</td>
<td>20.81%</td>
</tr>
<tr>
<td>Education (n = 442)</td>
<td></td>
<td></td>
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<tr>
<td>Have not finished high school</td>
<td>12</td>
<td>2.71%</td>
</tr>
<tr>
<td>Finished high school</td>
<td>115</td>
<td>26.02%</td>
</tr>
<tr>
<td>Some college</td>
<td>79</td>
<td>17.87%</td>
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<tr>
<td>Associate degree</td>
<td>53</td>
<td>12.00%</td>
</tr>
<tr>
<td>Bachelor’s Degree</td>
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<td>19.00%</td>
</tr>
<tr>
<td>Post-baccalaureate</td>
<td>99</td>
<td>22.40%</td>
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<tr>
<td>Income (n = 442)</td>
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<td></td>
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<tr>
<td>Less than $5,000</td>
<td>14</td>
<td>3.17%</td>
</tr>
<tr>
<td>$5,000-$9,999</td>
<td>7</td>
<td>1.58%</td>
</tr>
<tr>
<td>$10,000-$14,999</td>
<td>14</td>
<td>3.17%</td>
</tr>
<tr>
<td>$15,000-$19,999</td>
<td>11</td>
<td>2.49%</td>
</tr>
<tr>
<td>$20,000-$29,000</td>
<td>43</td>
<td>9.72%</td>
</tr>
<tr>
<td>$30,000-$39,999</td>
<td>36</td>
<td>8.14%</td>
</tr>
<tr>
<td>$40,000-$49,999</td>
<td>32</td>
<td>7.24%</td>
</tr>
<tr>
<td>$50,000-$59,999</td>
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<td>8.60%</td>
</tr>
<tr>
<td>$60,000-$74,999</td>
<td>39</td>
<td>8.82%</td>
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<tr>
<td>$75,000-$99,999</td>
<td>55</td>
<td>12.42%</td>
</tr>
<tr>
<td>$100,000-$124,999</td>
<td>49</td>
<td>11.09%</td>
</tr>
<tr>
<td>$125,000-$149,999</td>
<td>48</td>
<td>10.86%</td>
</tr>
</tbody>
</table>
$150,000 or more  56  12.67%
Specific Christian religious affiliation (n = 442)
Anglican/Episcopalian  4  0.90%
Baptist  58  13.12%
Catholic  136  30.77%
Christian (non-denominational)  172  38.91%
Church of Christ/Disciples of Christ  7  1.83%
Congregational  3  0.68%
Jehovah’s Witness  4  0.90%
LDS (Mormon)  3  0.68%
Lutheran  4  0.90%
Methodist/Wesleyan  7  1.58%
Orthodox (Eastern)  4  0.90%
Pentecostal/Charismatic  15  3.39%
Protestant (Other)  20  4.52%
Reformed/Presbyterian  2  0.45%
Seventh-day Adventist  1  0.23%
Other  2  0.45%

3.3. Confirmatory Factor Analysis

Confirmatory factor analysis showed that each latent variable fit the data well. CFA models were run for each structural equation model (see Figure 1A & 1B), for the remaining latent factors used for univariate analyses, and for the combined model. Two items were removed from the latent variable, Positive Attitudes Toward Vaccines, due to lack of fit (“Vaccines often have severe side effects”, and “Vaccines contain dangerous toxins”). The survey section on attitudes toward the HPV vaccine was divided into two latent variables: Fear of HPV Vaccine Side-effects that consisted of items 1, 4, and 5; and Intent to Vaccinate that consisted of items 2, 3, 6, and 7. One item was removed from the latent variable, Vaccine Knowledge, due to lack of fit (“Smallpox has been eliminated because of mass vaccination”). Two items were removed from the latent variable, HPV Knowledge, due to lack of fit (“Only a small minority of people will catch HPV during their lives” and “HPV causes cancer in women but not men”). And one item was removed from the latent variable, Trust in Modern Medicine, due to lack of fit (“Doctors sometimes do not pay attention to or disregard what their patients are telling them”). Fit statistics are shown in Table 2. CFA models are included in the supplementary materials (S2, S3).
Table 1.2. Fit Statistics for Each Measurement Model

<table>
<thead>
<tr>
<th>Model (Latent Variables)</th>
<th>TLI</th>
<th>CFI</th>
<th>SRMR</th>
<th>Chi-square Test X² value</th>
<th>df</th>
<th>p-</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model A (Religious Practice, Pro-Vaccine Religious Views, Trust in Modern Medicine, Vaccine Knowledge, Positive Attitudes Toward Vaccines, Intent to Vaccinate)</td>
<td>.948</td>
<td>.955</td>
<td>.041</td>
<td>.055</td>
<td>5321.84</td>
<td>351</td>
</tr>
<tr>
<td>Model B (Religious Practice, Religious Encouragement of Premarital Abstinence, Beliefs that Religious Adherence Protects Against HPV, HPV Knowledge, Intent to Vaccinate)</td>
<td>.927</td>
<td>.938</td>
<td>.058</td>
<td>.65</td>
<td>4455.42</td>
<td>210</td>
</tr>
<tr>
<td>Model for Remaining Variables (Religious Influence, Religious Hope, Parent/Peer Influence on Sexual Behavior, Fear of HPV Vaccine Side-effects)</td>
<td>.966</td>
<td>.973</td>
<td>.041</td>
<td>.045</td>
<td>2699.05</td>
<td>120</td>
</tr>
<tr>
<td>Combined Model</td>
<td>.902</td>
<td>.991</td>
<td>.042</td>
<td>.065</td>
<td>13280.5</td>
<td>1485</td>
</tr>
</tbody>
</table>

**3.4 Structural Equation Modeling**

SEM on model A shows a robust fit as indicated by fit statistics and probability scores (see Table 3). The model indicates that respondents with higher religious practice have a slightly higher intent to vaccinate their children against HPV (+0.158). Respondents with higher religious practice also had higher vaccine knowledge (+0.639). Vaccine knowledge is not a significant predictor of intent to vaccinate. Respondents with higher religious practice have a more negative attitude to vaccines in general (-0.358). Respondents who view vaccines positively have a higher intent to vaccinate their children (+0.590). Lower attitudes toward vaccination negatively impacts intent to vaccinate. Respondents who indicated that their religion views vaccines positively have more trust in modern medicine (+0.615), less vaccine knowledge (-0.245) and have higher attitudes towards vaccines in general (+0.828). There is not a significant relationship between trust in modern medicine and intent to vaccinate. There is also not a significant
relationship between vaccine knowledge and intent to vaccinate. Income positively influences intent to vaccinate (+0.157).

Table 1.3. Fit Statistics for Each Structural Equation Model.

<table>
<thead>
<tr>
<th>Model (Latent Variables)</th>
<th>TLI</th>
<th>CFI</th>
<th>RMSEA</th>
<th>SRMR</th>
<th>Chi-square Test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X^2</td>
<td>df</td>
<td>p-value</td>
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<td></td>
</tr>
<tr>
<td>Model A</td>
<td>.939</td>
<td>.946</td>
<td>.043</td>
<td>.061</td>
<td>5531.44</td>
</tr>
<tr>
<td>Model B</td>
<td>.927</td>
<td>.939</td>
<td>.058</td>
<td>.065</td>
<td>4455.42</td>
</tr>
</tbody>
</table>

In model A, a positive attitude toward vaccines in general is the strongest predictor of intent to vaccinate, religious practice negatively impacts vaccine attitudes, whereas positive religious views on vaccines positively impacts vaccine attitudes.
Figure 1.2 Results of Structural Equation Model A. We hypothesize that religious practice and pro-vaccine religious views affect trust in modern medicine, vaccine knowledge and positive attitudes toward vaccines, which in turn affects parents’ intent to vaccinate against HPV. Bolded lines indicate the relationship is significant, the numbers adjacent to the lines indicate the strength and direction of the relationship. The biggest influence on intent to vaccinate is positive attitudes toward vaccines (+0.590), which is negatively influenced by religious practice (-0.354) and positively influenced by the views of respondent’s religion toward vaccines.

SEM on model B also shows a robust fit as indicated by fit statistics and probability scores (Table 2). The model (Figure 3) indicates that religious practice is a significant predictor of a belief that religious adherence protects against HPV (+0.542). This belief in turn negatively impacts intent to vaccinate (-0.164). Respondents with high religious practice have higher knowledge about HPV (+0.284), which positively impacts intent to vaccinate (+0.784). Respondents whose religion highly emphasizes abstaining from sex before marriage have slightly higher knowledge of HPV (+0.194), which positively influences intent to vaccinate (+0.784). Neither religious practice nor religious encouragement of premarital abstinence has a
direct impact on intent to vaccinate. Knowledge about HPV is the strongest predictor of intent to vaccinate; both religious practice and religious encouragement of abstinence before marriage positively affect knowledge about HPV.

Figure 1.3. Structural Equation Modeling Results Model B Representing the Second Component of our Hypothesis. We hypothesize that religious practice and religious encouragement of premarital abstinence affects the belief that religious adherence protects against HPV, and knowledge about HPV, which in turn both affect intent to vaccinate against HPV. Bolded lines indicate that a relationship is significant, the numbers adjacent to the lines indicate the strength and direction of the relationship.

3.4 Univariate Factor Analysis

Univariate correlation analysis was preformed to determine whether belief in vaccine efficacy and belief in vaccine safety impact respondents’ intent to vaccinate their children against HPV (Figure 4). There is a strong positive correlation between intent to vaccinate and belief in vaccine efficacy ($r=0.3828$, $p<0.00001$). The magnitude of this effect was a change in Intent to vaccinate score of 5. These scores rose from a low median of 12 to a high of 17 with increasing belief in vaccine efficacy. Univariate analysis also indicated that there was a strong
positive correlation between views on the safety of the HPV vaccine and intent to vaccinate (r=-0.3828, p=<0.00001). Intent scores rose from a low of 6 to a high of 14 with increasing confidence in vaccine safety. For both efficacy and safety scores, there was a plateau effect, with approximately the top third of scores having the same median values.

Figure 1.4. Intent to Vaccinate Correlates with Views of Safety and Efficacy: There is a strong correlation between an individual’s intent to vaccinate their children against HPV and their beliefs in the safety and efficacy of HPV vaccines. The y-axis indicates intent to vaccinate, the x-axis indicates beliefs in the safety and efficacy of the vaccine. [A] Individuals who believe that the vaccine is effective have a higher intent to vaccinate their children (r=0.3828, p=<.00001) [B] Individuals who believe that the vaccine is safe have a higher intent to vaccinate their children (r=0.4021, p=<.00001).

Univariate correlation analysis was performed to determine whether vaccine knowledge impacts respondents’ intent to vaccinate their children against HPV (Figure 5). There is a strong positive correlation between intent to vaccinate and vaccine knowledge (r=0.5297, p<0.00001). As individuals have increased knowledge about vaccines in general, their intent to vaccinate their children against HPV increases. Overall intent to vaccinate more than tripled, with median intent to vaccinate rising from 5 to 19 with increasing knowledge of vaccines.
Figure 1.5. Intent to Vaccinate Correlates with General Vaccine Knowledge: There is a strong positive correlation between an individual’s general knowledge about vaccines and their intent to vaccinate their children against Human Papillomavirus. Larger values on the y-axis indicate a higher intent to vaccinate against HPV and larger values on the x-axis indicate more general knowledge about vaccines ($r=0.529658$, $p<0.00001$).

4. Discussion

SEM analysis on the first model (Figure 2) shows that income, religious practice, and positive vaccine attitudes are all predictors of intent to vaccinate against HPV. Positive attitudes toward vaccines, with a value of 0.590, is a far stronger predictor of intent to vaccinate than religious practice or income, with values of 0.158 and 0.157, respectively. If an individual has a generally favorable attitude toward vaccination, it follows that they would choose to consider current health guidelines and vaccinate their children against HPV. If an individual feels that vaccines are ineffective or risky it is unlikely that they would choose to vaccinate their children. Although religious practice has a slight positive impact on intent to vaccinate it has a negative impact on vaccine attitudes. Positive vaccine attitudes are the strongest predictor of intent, so the negative effect of religious practice on vaccine attitudes decreases intent to vaccinate. A subset of our population was highly religious, highly educated and had a high intent to vaccinate, which explains the slight positive relationship between religious practice and intent to vaccinate. The relationship between income and intent to vaccinate could be explained by the assumption that
individuals with higher income have access to superior healthcare and therefore have better HPV vaccine access.

SEM analysis on the second model [Figure 3] shows that knowledge about HPV is a strong predictor of parents’ intent to vaccinate their children against HPV with a value of 0.784. If parents understand the possible risk presented by HPV infection it is understandable that they would want to protect their children through vaccination. This interpretation is further supported by univariate factor analysis, which shows that intent to vaccinate is correlated with belief in the safety and efficacy of HPV vaccination [Figure 4]. Religious practice is positively related to vaccine knowledge; this relationship could be explained by the highly religious subset of our sample who are also highly educated. Religious encouragement of premarital abstinence is positively related to HPV knowledge.

SEM analysis also shows that the belief that religious adherence protects against HPV is a negative predictor of intent to vaccinate, with a value of -0.164. Religious parents may feel that HPV vaccination is unnecessary for their children. Religious parents may also fear that HPV vaccination could increase their child’s sexual activity, which would negatively impact their intent to vaccinate if they perceive increased sexual activity as a negative outcome. Although the relationship between intent to vaccinate and a belief that religious adherence protects you from HPV was found to be significant, the relationship is not very strong. However, highly religious individuals are more likely to believe that religious adherence and lifestyle protect against HPV than their less-religious peers. The positive influence of religious practice on this belief could indirectly reduce respondents’ intent to vaccinate. This could also suggest stigmatization of those with HPV, as has been seen elsewhere [76].

SEM analysis on the first model did not show a significant relationship between vaccine knowledge and intent to vaccinate. Univariate analysis shows intent to vaccinate is correlated with general vaccine knowledge. Although these results may appear to contradict, univariate analysis is sometimes better at illuminating the relationship between latent variables than SEM on a complex model. In a complex model the relationships between some variables can be masked by the interaction of other variables. Understanding how vaccines provide protection against various diseases and how vaccines are tested to ensure that they are reasonably safe, could increase confidence in HPV vaccination thereby increasing parental intent to vaccinate.
These findings clarify some of the earlier work on religiosity and HPV [12-15, 21] by taking a two-step approach to how religiosity affects vaccination intent. We explored how religiosity impacts other factors that lead to vaccination decision making, specifically in the context of Christianity in America. Many of these connections are likely to be applicable beyond the United States, since the variables concerning religiosity and security are not unique to the United States. The results could therefore be widely useful wherever religiosity is high and HPV uptake is low.

Future directions

This work will be the basis for future work looking at targeted interventions geared towards improving vaccine attitudes among highly religious people. Specifically, these will be focused on the idea of vulnerability to infection due to a religious expectation of abstinence before marriage, and on vaccine and HPV knowledge. We will also examine other religious traditions.

Strengths/limitations

One of the most important strengths of the study is that it was carried out among a targeted group that has a historically low acceptance of the HPV vaccine. Another strength is that our computer models were able to determine a path where we could examine the effects of variables such as religious practice, or religious teaching on sexual behaviors on other variables that influence vaccine decision making. The ideas we examined can potentially be affected by public health interventions. One of the primary limitations to the study is that it was difficult to find people who fit the inclusion criteria who had not finished high school. This suggests a possible bias in the surveyed population towards more educated, wealthier individuals. Given the COVID-19 pandemic, this is a time of potential flux in vaccine attitudes, as governments and individuals incorporate experience with widespread deadly disease, vaccine requirements, and fatigue for government interventions [77]. Continued research will be necessary to ensure that our findings remain consistent.

5. Conclusion

The novelty of this work lies primarily in the dissection of the interactions between religious factors and vaccine attitudes. We were able to find not just associations, but mechanisms through
which religious practice and teachings about sexuality can affect HPV vaccine attitudes. We found that the more knowledge individuals have about HPV and the better they understand the risks presented by HPV infection the higher their intent to vaccinate their children against HPV. We also found that the individuals who viewed vaccines positively were more willing to vaccinate their children against HPV.

In addition, individuals who believe that religious adherence provides protection against HPV have lower intent to vaccinate their children against HPV, which lowers one’s intent to vaccinate. SEM revealed that this sense of safety, their knowledge about HPV, and their knowledge about vaccines indirectly, rather than directly, influences intent to vaccinate.

Interventions focused on explaining the risks presented by HPV infection and the benefits of vaccination could help increase vaccine acceptance and uptake. Interventions should address general vaccine concerns and highlight testing and safety. Religiosity is associated with the idea that religious beliefs or behaviors will protect a person’s children from infection with HPV. Intervention strategies could therefore focus on the dire or fatal consequences of HPV infection in the event that the children contract the virus, no matter what the circumstances. Other interventions may focus on the high prevalence of the virus and showing that people with which this religious group identifies are commonly infected with HPV.

Supplementary Materials: The following are available online at www.mdpi.com/xxx/s1, Table S1: Survey, Figure S1: Confirmatory factor analysis for model 1, S2: Confirmatory factor analysis for model 2.

Author Contributions: Conceptualization, B.D.P., J.L.J., C.D.S-A.; methodology, B.D.P., J.L.J., C.D.S-A.; formal analysis, D.S.R., J.L.J.; investigation, D.S.R., S.J.H., K.P., D.S.M., J.D.A., T.B.C., L.Z., R.J.B., resources, B.D.P., J.L.J.; data curation, D.R., J.L.J.; writing—original draft preparation, D.R.; writing—review and editing, D.S.R., B.D.P., J.L.J., S.J.H., C.D.S-A.; supervision, B.D.P.; project administration, B.D.P.; funding acquisition, B.D.P., J.L.J., C.D.S.. All authors have read and agreed to the published version of the manuscript.

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Chapter 2

Evaluating the Effectiveness of Religious Focused and Educational Video Interventions on Increasing HPV Vaccine Uptake.

Introduction

Vaccines have drastically reduced the incidence of once common diseases. Smallpox was eradicated and polio has almost been eradicated through vaccination. Despite the past success of vaccination programs there has been a resurgence of infectious diseases[78, 79]. A waning of natural immunity combined with a reduction in vaccination rates due to vaccine hesitancy has allowed infectious diseases that were once fairly well controlled to spread. In addition to permitting previously controlled diseases to reemerge, vaccine hesitancy negatively impacts the effectiveness of newly developed and released vaccines. Effective vaccines have been developed against high-risk HPV subtypes. These new vaccines have sharply reduced the incidence of the strains covered by the vaccine in regions with high uptake[66]. Areas with more vaccine hesitancy have not experienced as much of a decline in HPV rates due to lower vaccine uptake rates.

Vaccine Hesitancy is a somewhat difficult problem to address. There are many factors that impact vaccination attitudes including, education, fear of side-effects, misinformation, relationship with primary care provider etc. We previously identified factors that impact parental intent to vaccinate their children against HPV. We found that the more knowledge parents have about HPV and the better they understand the risks presented by infection, the higher their intent to vaccinate their children against HPV. We also found that parents who feel that religious adherence provides protection against HPV have lower intent to vaccinate [80]. We designed two interventions in the form of short educational films. We then tested the effectiveness of these interventions using a survey.

Survey Description

The survey was composed of 4 sections. The survey section was demographic information. The second section of the survey assessed participant views and attitudes pre-intervention including subsections assessing knowledge about HPV, general vaccine attitudes, religiosity, views on sex, and attitudes towards modern medicine. The third section of the survey was an embedded intervention video. There are three intervention videos which were randomly
assigned to participants. The first video was a control and contained information on an adenovirus. The second video was a religious intervention and contained an interview with a religious cervical cancer survivor who discussed her experiences and advocated for getting vaccinated. The third video was an educational intervention and contained scientific facts about human papillomaviruses, the diseases they cause, how they are transmitted, and how vaccination protects against them. The final section of the survey assessed participants views and attitudes post-intervention and repeated the questions contained in the second section.

Results
Figure 2.1 Population Demographics: Most (83.8%) of our survey participants were between 25 and 45 years old. This is reasonable age range because of our selection criteria was parents with children younger than 11 who identify as Christian. Our population is predominantly white, but all ethnicities were represented. The average number of children that survey participants have is 2. The majority (65%) of our sample population is female. The majority (62.3%) of participants are married, this is somewhat higher than the national average but not unusual based on our selection criteria. Less than half (57.86%) of our population have completed a college degree. The level of education is fairly representative of the national education level. The national median household income ~$67,000, so our sample income is also fairly representative of the national average.
Figure 2.2 Approximate Geographical Distribution of Survey Respondents: Approximate latitude and longitude were collected automatically from survey participants. This data was used to plot the approximate location of participants. There are regional differences in HPV vaccine uptake with some states consistently reporting low vaccination rates. The geographical distribution of our respondents mirrors the population density of the United States where the east is much more populous and the population in the west is clustered around a handful of cites.
Figure 2.3 Change in Intent to Vaccinate Post Intervention: Responses for the six survey items representing the latent variable “Intent to vaccinate” were summed to determine if participants were Accepting, Neutral or Hesitant about HPV vaccinations. Post-intervention attitudes were also calculated. Three graphs were created for the different interventions based on pre-intervention attitudes. Most survey participants did not have a change of attitude post-intervention. The Religious and educational interventions appear to be more effective at increasing intent to vaccinate than the control. Participants where initially vaccine hesitant were most likely to change attitudes post intervention.

Figure 2.4: Alluvial Diagram Displaying Change in Intent (Control Intervention). Survey participants were asked to indicate how the felt about the statement “I am likely to vaccinate my children against HPV OR I have already vaccinated my eligible children against HPV.” before and after viewing the intervention video. This figure shows participants who viewed the control video which contained facts about adenovirus. Data for participants who indicated no change in
attitude were removed for this figure. The colors correspond to participant attitudes post intervention. The control intervention has somewhat mixed results.

Figure 2.5: Alluvial Diagram Displaying Change in Intent (Religious Intervention). Survey participants were asked to indicate how the felt about the statement “I am likely to vaccinate my children against HPV OR I have already vaccinated my eligible children against HPV.” before and after viewing the intervention video. This figure shows participants attitudes after viewing the religious intervention video. Data for participants who indicated no change in attitude were removed for this figure. The religious intervention appears to have had a positive effect on participants who already agreed with the statement strengthened their intent to vaccinate. The intervention also appears to have been effective on at increasing intent to vaccinate in a portion of participant who were neutral, disagreed, or strongly disagreed before with the statement.
Concernedly the largest portion of participants with low intent to vaccinate post intervention had high intent to vaccinate before the intervention.

Figure 2.6: Alluvial Displaying Change in Intent. Survey participants were asked to indicate how they felt about the statement “I am likely to vaccinate my children against HPV OR I have already vaccinated my eligible children against HPV.” before and after viewing the intervention video. This figure shows participants who attitudes after viewing the educational intervention. This intervention appears to be somewhat effective at improving the intent of participants who had neutral views before viewing the intervention. More than half of the participants who strongly disagreed with the statement before the intervention indicated that they agree or strongly agreed after the intervention which is very positive.
Chapter 3

Utah Parents Displaying Cautious Sexual Attitudes have Lower Intent to Vaccinate their Children Against HPV then Their less Cautious Peers.

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Abstract

Although most Human papillomavirus (HPV) infections are mild and are cleared relatively quickly by the immune system some high-risk HPV strains can cause various cancers. Vaccines have been developed which protect against high-risk HPV strains. HPV vaccines have been approved for use by the CDC (Centers for Disease Control and Prevention) and are recommended for everyone age 11-26. Despite the availability of safe and effective vaccines uptake is low. HPV vaccine uptake has been extensively studied on a national and international level, but less is known about vaccine acceptance on a state or local level. In this study we identified factors that impact the intent of Utah parents to vaccinate their children against HPV. A survey was distributed electronically to Utah residents. Survey results were analyzed using confirmatory factor analysis, structural equation modeling, and univariate analysis. Knowledge about HPV and positive vaccine attitudes had the greatest positive effect on intent to vaccinate children against HPV. Cautious sexual attitudes and high religious practice were found to have a negative impact on intent to vaccinate. Overall, our sample population viewed HPV vaccination positively.

1. Introduction

Human papillomaviruses (HPV) are a family of over 150 related human viruses. HPV are non-enveloped double stranded DNA viruses. HPV have co-evolved with humans over millions of years, and are therefore well adapted, often causing cause minimal symptoms or are completely asymptomatic [44]. HPV infects cutaneous and mucosal stratified epithelial cells. In order to replicate, HPV promotes cell cycle progression within infected cells. Modulation of the cell cycle can cause increased cell proliferation resulting in growths called warts or papillomas [46]. Although most HPV infections are mild and typically clear on their own within a few
months to a few years, persistent HPV infections are strongly associated with the development of various cancers [45, 81]. HPV causes 99% of cervical cancers, 90% of anal cancers 50% - 65% of vulvar and vaginal cancers, and between 45% and 90% of oropharyngeal cancers [82]. HPV is responsible for approximately 5% of the world’s total cancer burden [62].

HPV is the most commonly sexually transmitted infection. Between 50-80% of individuals will be infected with HPV sometime during their life [45, 61]. HPV is generally transmitted through skin to skin or sexual contact. Although HPV is generally sexually transmitted evidence suggests that HPV can also be transmitted on surfaces or medical implements [82]. HPV is resistant to many common clinical disinfectants and can remain active on surfaces even after cleaning [49].

Due to the potential harm that HPV can cause, significant effort was made to develop preventative vaccines. Three vaccines have been approved for use in the United States by the Food and Drug administration (FDA). All three vaccines provide protection against the oncogenic HPV strains 16 and 18, which are responsible for 70% of HPV induced cervical cancers [45]. Multiple studies have shown that HPV vaccines are safe for human use, and effective at reducing infection with high-risk HPV strains. [62]. There has been measurable reduction in the incidence and transmission of HPV strains covered by vaccines [52, 83].

Despite the effectiveness of HPV vaccines at preventing HPV infection and progression into various cancers, vaccine uptake is low. In 2018 global HPV vaccine uptake was estimated 12.2% for 15 year-old females. Significant variation in vaccination rates was observed between wealthy and developing nations, with wealthy nations reporting higher vaccination rates [84]. Although HPV vaccination rates in the United States are higher than the global average, vaccine uptake has been modest. A 2016 study reported that 60% of adolescents 13-17 have received at least 1 vaccine dose and that only 37% have completed the vaccine series [85]. Young adults (18-26) have an even lower vaccination rate than adolescents. The US department of health and Human Services (HHS) estimates that half of young adults have received at least 1 vaccine dose and less than 22% have completed a vaccine series [69].

There have been many studies assessing HPV vaccine uptake at a national level but there is has been little research done about what impacts HPV vaccination rates at a state level. For the past 5 years, the percentage of Utah adolescents who have received the recommended number of
HPV vaccine doses has been persistently among the lowest in the country [60, 84]. The studies on HPV vaccination in Utah that have been performed focused primarily on health care providers. [86, 87]. In one of these studies health care providers consider parental misconceptions to be the strongest barrier to HPV vaccination in Utah [59]. Another Utah study found that religious young women are underinformed about HPV and are under-vaccinated [59]. To better understand what factors, impact parental intent to vaccinate their children we surveyed Utah parents directly.

2. Materials and Methods

2.1 Survey of Utah Residents.

Utah residents were invited to participate in a cross-sectional study by completing a survey designed to assess attitudes toward HPV vaccination. The survey was distributed through an online portal by Qualtrics (Provo, UT, USA). Initial inclusion criteria required participants to be a current resident of Utah. Survey results were later filtered so only parents, with a child 15 or under, were included in our sample. Filters were applied to collect responses from educational backgrounds consistent with census data for Utah.

2.2 Survey Description

The survey contained 80 questions in total. Some questions were clarifying questions and were only shown if certain responses were chosen on previous questions. The questions were divided into 10 sections. The first section contained questions about demographics. The second section assessed primary sources of news. The third section and fourth sections assessed trust in government and modern medicine respectively. In the fifth section participants were asked about their religious practice. The sixth section assessed aspirations for their children. In the seventh section, participants were asked about their sexual attitudes and what they intended to teach their children about sex. The eighth section assessed knowledge about HPV. The ninth section assessed participants attitudes towards vaccines in general. The final section contained outcome questions which tested the attitudes of parents toward HPV and their intent to vaccinate their children against it. Prior to distribution the study received ethical approval from the institutional review board of Brigham Young University (IRB# IRB2022-165).

2.3 Confirmatory Factor Analysis and Structural Equation Modeling
To validate our survey, confirmatory factor analysis (CFA) was used to confirm the latent variables we were testing were accurately represented by the questions we chose to include in the survey. We preformed structural equation modeling (SEM) to test the relationship between variables. Before starting analysis we cleaned and organized the data using Excel (Microsoft 2022 Redmond, WA, USA) and SPSS statistics software (IBM 2021 Armonk, NY, USA). The first step of cleaning the data was removing participants who indicated that they did not have children, because we wanted to look at what factors impacted parental intent to vaccinate their children. Next we removed data determined to be incomplete or low quality. Mplus software, ver 8 (Muthen and Muthen, 1998-2001, Los Angeles, CA, USA) was used to perform CFA and SEM on the measurement and structural portion of our model. Latent variables were represented by three or more survey items. CFA was performed with a request for modification indices. Survey items representing latent variables were removed until fit indices (root mean square error approximation), comparative fit index (CFI), Tucker-Lewis index (TLI) and standardized root mean square residual (SRMR) were found to be acceptable. SEM was performed on a complete model comprised of all the validated latent variables with age, gender, income and education as covariates. The validated latent variables were divided to form two hypothetical models, the first to test the relationship between trust in medical professionals and religious practices on intent to vaccinate through general vaccine attitudes; and the second to test the relationship between knowledge of HPV and religious practice on intent to vaccinate through sexual attitudes; SEM was performed on the hypothetical models.

2.4 Univariate Analysis

Univariate analysis and data visualization were preformed to further explore the factors that impact intent to vaccinate identified by structural equation modeling. To illustrate our sample populations attitude toward HPV vaccination we created stacked bar charts of our outcome variables using the likert, tidyverse and ggplot2 libraries in R. We used the corrrplot and psych R libraries to create a series of correlation matrixes to determine which variables were correlated with intent to vaccinate. We created count plots to display individual correlation between intent to vaccinate and variables identified using correlation matrixes. The R code used to analyze data and create the figures is available in our supplementary materials.
3. Results

3.1 Demographic Characteristics of Survey Respondents

We summarized demographic characteristics of our sample (Table 1), before beginning formal analysis of our dataset. We selected our dataset so that only respondents with children were included. Most respondents had 1 or 2 children (68.5%). The vast majority of respondents were between 26 and 45 years old (82%). Approximately one third of our sample identified as male (31.1%) and two thirds identified as female (68.9%). Participants had the ability to select “Non-binary/third gender” or “I prefer not to answer” for Gender, 1 participant declined to answer and no participants selected Non-binary/third gender choices were removed from the table for clarity. The vast majority of participants selected white (83%) as their ethnicity. More than half of the participants indicated that they were married (68.4%). Almost all of the participants in our study have completed high school (97.5%) but less than half have completed a college degree (44.65%). A vast majority of participants of our participants have a yearly household income less than $100,000 (82.4%). In our sample 37.6% participants identified as republican, 33.5% identified as independent, and 19.0% identified as Democrat. Political leanings on social issues had a relatively even distribution, with the largest portions (36.7) of respondents indicating that they are neither liberal nor conservative leaning. A majority of respondents in our sample indicated they were Christian (57.81%) the second largest group indicated that they had no religious affiliation (27.67%)

Table 3.1. Demographic Characteristics

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<tr>
<td>Less than $25,000</td>
<td>46</td>
<td>12.64%</td>
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<tr>
<td>$25,000 - $50,000</td>
<td>97</td>
<td>26.65%</td>
</tr>
<tr>
<td>$50,000 - $100,000</td>
<td>157</td>
<td>43.13%</td>
</tr>
<tr>
<td>$100,000 - $150,000</td>
<td>48</td>
<td>13.19%</td>
</tr>
<tr>
<td>$150,000 - $200,000</td>
<td>15</td>
<td>4.12%</td>
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<tr>
<td>More than $200,000</td>
<td>1</td>
<td>0.27%</td>
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<table>
<thead>
<tr>
<th>Political affiliation</th>
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<tbody>
<tr>
<td>Democrat</td>
<td>69</td>
<td>19.0%</td>
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<tr>
<td>Republican</td>
<td>137</td>
<td>37.6%</td>
</tr>
<tr>
<td>No political affiliation</td>
<td>122</td>
<td>33.5%</td>
</tr>
<tr>
<td>I prefer not to answer</td>
<td>27</td>
<td>7.4%</td>
</tr>
<tr>
<td>Other</td>
<td>9</td>
<td>2.5%</td>
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<table>
<thead>
<tr>
<th>Political leanings on social issues</th>
<th>n = 365</th>
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</thead>
<tbody>
<tr>
<td>Very Liberal</td>
<td>25</td>
<td>6.8%</td>
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<tr>
<td>Liberal</td>
<td>29</td>
<td>7.9%</td>
</tr>
<tr>
<td>Somewhat Liberal</td>
<td>37</td>
<td>10.1%</td>
</tr>
<tr>
<td>Neither Liberal nor Conservative</td>
<td>134</td>
<td>36.7%</td>
</tr>
<tr>
<td>Somewhat Conservative</td>
<td>61</td>
<td>16.7%</td>
</tr>
<tr>
<td>Conservative</td>
<td>54</td>
<td>14.8%</td>
</tr>
<tr>
<td>Strongly Conservative</td>
<td>25</td>
<td>6.8%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Religious Affiliation</th>
<th>n = 364</th>
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<tbody>
<tr>
<td>Religion</td>
<td>Count</td>
<td>Percentage</td>
</tr>
<tr>
<td>------------------</td>
<td>-------</td>
<td>------------</td>
</tr>
<tr>
<td>Buddhism</td>
<td>2</td>
<td>0.82%</td>
</tr>
<tr>
<td>Christianity</td>
<td>211</td>
<td>57.81%</td>
</tr>
<tr>
<td>Hinduism</td>
<td>3</td>
<td>0.82%</td>
</tr>
<tr>
<td>Islam</td>
<td>1</td>
<td>0.27%</td>
</tr>
<tr>
<td>Judaism</td>
<td>3</td>
<td>0.82%</td>
</tr>
<tr>
<td>Other</td>
<td>43</td>
<td>11.78%</td>
</tr>
<tr>
<td>No Religious Affiliation</td>
<td>101</td>
<td>27.67%</td>
</tr>
</tbody>
</table>

3.2 Confirmatory Factor Analysis

CFA models were run for the latent variables included in the hypothetical structural models used for SEM. Items 4.1.1 (“I always vote in national elections”) and 4.1.2 (“I always vote in local elections”) were removed from the latent variable “trust in government” because they measured whether participants vote rather than their trust in government. Two items were removed from the latent variable “trust in health professionals” due to lack of fit (5.1.3 “Natural remedies such as essential oils are as effective at treating most conditions as prescription drugs” and 5.1.5 “Natural remedies are often a better treatment for minor ailments than modern medicine”). No items were removed from “religious practice.” The questions included in “aspirations for children” do not form a single latent variable and therefore were not included in CFA or SEM. Items 8.1 (“As a parent, I emphasize certain rules or cautions about sexual behavior”) and 8.6 (“Sexually transmitted infections are very concerning to me”) did not fit with the latent variable “cautious sexual attitudes” and were therefore removed. Item 9.1.3 “HPV causes cancer in women but not men” was removed from the latent variable “high HPV knowledge” due to lack of fit. Survey item 9.2 (“Vaccines often have severe side effects”) was removed from the latent variable “Positive vaccine attitudes” due to lack of fit. All the items used to determine “intent to vaccinate”, fit the model with acceptable fit statistics (see Table 2; Figure 1).
Figure 3.1 Hypothetical Structural Models: (A) We hypothesize that trust in health professionals and high religious practice influence positive vaccine attitudes which in turn influences intent to vaccinate. We also hypothesize that trust in health professionals and high religious practice may influence intent to vaccinate directly. (B) We hypothesize that high HPV knowledge and high religious practice influence cautious sexual attitudes which in turn influences intent to vaccinate. We also hypothesize that high HPV knowledge and high religious practice could influence intent to vaccinate directly. (C) We hypothesize that the latent variables trust in government, trust in health professionals, high religious practice, cautious sexual attitudes, high HPV knowledge, and positive vaccine attitudes may directly influence intent to vaccinate. We also hypothesize that the covariates age, gender, income, education and political leanings may impact intent to vaccinate.

Table 3.2: Fit Statistics for Full Measurement Model

<table>
<thead>
<tr>
<th>Model (latent variables)</th>
<th>TLI</th>
<th>CFI</th>
<th>RMSEA</th>
<th>SRMR</th>
<th>( \chi^2 )</th>
<th>Chi-square test df</th>
<th>( p )-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combined model</td>
<td>0.886</td>
<td>0.900</td>
<td>0.057</td>
<td>0.076</td>
<td>887.029</td>
<td>408</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

3.3 Structural Equation Modeling
All the Latent variables verified by CFA were combined into a single model with the covariates income, education, age, gender, and political leanings on social issues (Figure 2). SEM on the combined model shows a robust fit, as indicated by fit statistics and probability scores (see Table 3) Structural equation modeling was used to determine which covariates and latent variables influenced intent to vaccinate in the combined model. The combined model indicates that respondents with more cautious sexual attitudes have lower intent to vaccinate (-0.199). The model also indicates that participants with high knowledge about HPV and positive attitudes towards vaccination have a higher intent to vaccinate (0.282, 0.553, respectively) Positive vaccine attitudes had the greatest effect on intent to vaccinate of all the latent variables tested in the combined model. In the combined model there is not a significant relationship between trust in government, trust in health professionals, high religious practice, and intent to vaccinate. The covariates age, gender, income, education, and political leanings on social issues did not significantly impact intent to vaccinate in the combined model.

**Table 3.3.** Fit Statistics for Structural Equation Models

<table>
<thead>
<tr>
<th>Model (Latent variables)</th>
<th>TLI</th>
<th>CFI</th>
<th>RMSEA</th>
<th>SRMR</th>
<th>$\chi^2$</th>
<th>Chi-Square df</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combined model</td>
<td>0.885</td>
<td>0.902</td>
<td>0.050</td>
<td>0.067</td>
<td>1013.133</td>
<td>528</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Model A</td>
<td>0.916</td>
<td>0.929</td>
<td>0.070</td>
<td>0.062</td>
<td>398.635</td>
<td>143</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Model B</td>
<td>0.928</td>
<td>0.943</td>
<td>0.071</td>
<td>0.055</td>
<td>268.436</td>
<td>95</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>
Figure 3.2: Full Structural Model. Latent Variables and Covariates were combined into a full structural model. Structural equation modeling was performed to determine which factors impact parental intent to vaccinate their children against HPV. More cautious sexual attitudes lead to lower intent. Higher knowledge about HPV leads to higher intent to vaccinate. The more positively parents view vaccines the higher their intent to vaccinate their children against HPV. All other Latent variables and covariates were not significantly predictive of intent to vaccinate in the full structural model.
SEM on model A shows a robust fit, as indicated by fit statistics (see Table 3). The model (figure 4) indicates that high trust in health professionals leads to more positive vaccine attitudes (+0.620) which increases intent to vaccinate (+0.665). The indirect effect through positive vaccine attitudes explains 96% of the effect of trust in health professionals on intent to vaccinate. High religious practice does not affect general vaccine attitudes, but it does have a direct negative impact on intent to vaccinate against HPV. This indicates that in our sample, high religious practice impacts general intent to vaccinate and intent to vaccinate against HPV differently.

Figure 3.3: Trust in Medical Professionals is Predictive of Intent to Vaccinate by Means of Increased Trust in Vaccines in General. The latent variables “Trust in Health Professionals”, “High religious practice”, “Positive vaccine attitudes”, and “Intent to vaccinate” were combined in a structural model. Trust in health professionals leads to more positive vaccine attitudes, which increased intent to vaccinate. High religious practice does not affect general vaccine attitudes, but it does have a direct negative impact on intent to vaccinate against HPV.

SEM on Model B also shows a robust fit, as indicated by fit statistics (Table 3). The model (Figure 4) indicates that higher knowledge about HPV has no effect on sexual attitudes but does directly impact intent to vaccinate against HPV. In this model the impact of religious
practice on intent to vaccinate against HPV which was shown in the previous model was found to be mediated through the effect of high religious practice on cautious sexual attitudes (+0.591) which negatively impacts intent to vaccinate (-0.215). In other words, the higher a participant’s religious practice, the more cautious they are about sex, and the more cautious they are, the less likely they are to vaccinate against HPV. The indirect effect of cautious sexual attitudes explains 99% of the impact of religious practice on intent to vaccinate against HPV.

Figure 3.4: Cautious Sexual Attitudes Negatively Impact Intent for HPV Vaccination. The latent variables “High HPV Knowledge”, “High Religious Practice”, “Cautious Sexual Attitudes” and “Intent to vaccinate” were combined in a structural model. Higher HPV knowledge has no significant effect on sexual attitudes but does directly impact intent to vaccinate. Religious practice does not directly impact intent to vaccinate when combined with the other latent variables in this model. Religious practice influences sexual attitudes which negatively influences intent to vaccinate.
3.4 Univariate analysis

Figure 3.5: Outcome Variables. Five survey items were used to measure attitudes toward the HPV vaccine and intent to vaccinate. The majority of respondents agree with the statements “I intend to vaccinate my children against HPV OR I have already vaccinated my children against HPV”, I will (or would) vaccinate both my sons and my daughters against HPV”, and “vaccination would protect my children against HPV infection in the case of sexual assault”. The majority of respondents disagreed with the statements “The potential side effects of the HPV vaccine will prevent me from vaccinating my children against HPV”, and “Because HPV is sexually transmitted I will not vaccinate my children against it.”
To determine which factors impacted intent to vaccinate a correlation matrix was created from the complete survey. Survey items were compared to question 11.1.1 “I intend to vaccinate my children against HPV OR I have already vaccinated my children against HPV” which was used to represent parental intent to vaccinate their children against HPV. Questions 11.1.2, 11.1.3, 11.1.4, and 11.1.5 were excluded from analysis because they belong to the same latent variable as question 11.1.1 and are therefore highly correlated. Seven survey items were determined to be individually correlated with intent to vaccinate (figure 5).

![Survey Items Correlated With Intent to Vaccinate](image)

**Figure 3.6: Survey Items Correlated With Intent to Vaccinate.** A correlation matrix of the complete survey was created. Non-significant results and results with a low degree of correlation were removed to create an abbreviated correlation matrix. Blue coloration indicates a positive correlation with question 11.1.1 “I intend to vaccinate my children against HPV OR I have..."
already vaccinated my children against HPV”, purple indicates a negative correlation, blank cells indicate that a result was not significant.

Table 3.4. Survey Items Moderately Correlated with Intent to Vaccinate

<table>
<thead>
<tr>
<th>Question</th>
<th>Text</th>
<th>PCC</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1.7</td>
<td>I trust in public health guidelines provided by the CDC (CDC)</td>
<td>0.31</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>8.2</td>
<td>Sexual education is a necessary part of school curriculum</td>
<td>0.31</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>9.1.4</td>
<td>The HPV vaccine is effective at preventing almost all cancers caused by HPV</td>
<td>0.29</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>10.1.1</td>
<td>Vaccines are more helpful than harmful</td>
<td>0.30</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>10.1.4</td>
<td>Vaccines are extensively tested to ensure their safety</td>
<td>0.38</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>10.1.5</td>
<td>Vaccines contain dangerous toxins</td>
<td>-0.31</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>10.1.7</td>
<td>Vaccination efforts have considerably reduced the</td>
<td>0.30</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td>transmission of infectious diseases in the United States</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 3.7: Intent to Vaccinate is Positively Correlated with Trust in Public Health Guidelines.

[A] A majority (53.5%) of respondents agree or strongly agree with the statement “I trust in public health guidelines provided by the CDC (Centers for Disease Control and Prevention)” [B] Linear regression comparing survey item 4.1.7 trust in CDC public health guidelines with item
11.1.1 intent to vaccinate children against HPV. Responses were scored on a Likert scale where one indicates “Strongly Agree” and five indicates “Strongly Disagree”. The graph shows a positive correlation (0.317) between trusting in CDC public health guidelines and intent to vaccinate.

Figure 3.8: Intent to Vaccinate is Positively Correlated with Views that Sexual Education is Important. [A] A majority (72.8%) of respondents agree or strongly agree with the statement “Sexual education is a necessary part of school curriculum” [B] Linear regression comparing survey item 8.2 sexual education is a necessary part of school curriculum with item 11.1.1 intent to vaccinate children against HPV. Responses were scored on a Likert scale where one indicates “Strongly Agree” and five indicates “Strongly Disagree”. The graph shows a positive correlation (0.307) between views that sexual education is necessary and intent to vaccinate.
4. Discussion

4.1 General Attitudes Toward Vaccines are Predictive of Intent to Vaccinate.

In both the combined structural model and partial structural model A, positive vaccine attitudes are the greatest predictor of intent to vaccinate (Figure 2, Figure 3). Correlation matrix analysis supports this finding; survey items 10.1.1, 10.1.4, 10.1.5, and 10.1.7, which makeup the latent variable “positive vaccine attitudes”, were all correlated with intent to vaccinate. (Figure 5) Both structural equation modeling and correlation matrix analysis show that positive vaccine attitudes increase parental intent to vaccinate against HPV, which is consistent with previous findings. In a previous study on Christian parents completed by our lab, we found that positive attitudes toward vaccines were the greatest predictor of parental intent to vaccinate their children against HPV[80]. Parents who already feel positively about vaccines are probably comfortable
giving their children all vaccines which are recommended by the CDC even if they do not feel that their children have a very high risk of contracting high-risk HPV. It also follows that parent who feel less positively about vaccines would have lower intent to vaccinate their children against HPV especially if they don’t feel that HPV poses a very high risk to their children. If parents who feel positively about vaccines have concerns about the HPV vaccine they are more likely than their vaccine hesitant peers to seek information from authoritative sources such as the CDC website or discuss their concerns with a pediatrician and/or primary care provider. In partial model A, trust in healthcare professionals positively impacts vaccine attitudes, which increases intent to vaccinate. The indirect effect of trust in healthcare professionals through positive vaccine attitudes explains 96% of trusts influence on intent to vaccinate, which means trust in healthcare professionals has an indirect effect on intent to vaccinate by influencing positive attitudes. Parents who trust in their primary care providers are probably more likely to follow their recommendations and get their children vaccinated against HPV. Because HPV vaccines are relatively new, parents may not be aware that they exist and of the benefits they provide; If primary care providers have a good relationship with parents they will have an easier time educating and recommending HPV vaccination.

4.2 High Religious Practice Negatively Impacts Intent to Vaccinate by Influencing Sexual Attitudes.

In structural model A (Figure 3), high religious practice was seen to negatively impact intent to vaccinate against HPV. Structural model B (Figure 4) explains this effect by showing that high religious practice positively influences cautious sexual attitudes which negatively impacts intent to vaccinate. The indirect effect of high religious practice through cautious sexual attitudes explains 99% of the variance, this means that 99% of the negative impact of high religious practice on intent to vaccinate is due to the influence of high religious practice on cautious sexual attitudes. Parents with cautious sexual attitudes may not feel that it is necessary to vaccinate their kids against HPV because the vaccine only protects against sexually transmitted strains, and they may feel like the risk of their Children contracting sexually transmitted HPV is low. Alternatively, parents who have cautious attitudes toward sex may not do much research on sexually transmitted diseases and consequently not be aware of harm HPV infection can cause. The Church of Jesus Christ of Latter-day Saints (LDS), which is the
predominant Church in Utah, advocates for sexual abstinence before marriage and fidelity within marriage [88]. The LDS Church’s stance on sexual relations could partially explain why parents in our study with high religious practice had more cautious sexual attitudes. A significant portion of our population identified as LDS and are therefore more likely to be cautious about sex and encourage their children to abstain from sex until marriage.

4.3 Knowledge about HPV Increases Intent to Vaccinate, and sex Education can Increase HPV Knowledge

High HPV knowledge was shown to be predictive of intent to vaccinate in the complete structural model and in partial structural model B (Figure 2, Figure 4). This shows that in our sample parents who understand the risks of HPV infection intend to protect their children against HPV through vaccination. Educating parents and caregivers about HPV may be an effective mechanism for increasing intent to vaccinate and increase overall HPV vaccination rates. In our study we observed that a majority (72.8%) of respondents agree or strongly agree with the statement “Sexual education is a necessary part of school curriculum.” Intent to vaccinate is also positively correlated with belief that sexual education is a necessary part of school curriculum (figure 8). Knowledge of HPV is a predictor of intent to vaccinate, and sexual education in a medium whereby information about HPV can be delivered. Sexual education curriculum usually focusses on reducing the risk of pregnancy and infection through education. If parents feel that sexual education is a necessary part of school curriculum, it follows they are fairly aware of the risks that their children may encounter and strive to protect their children through various means including education and vaccination.

4.4 HPV Vaccination is Viewed Positively in our Sample Population.

A majority (70%) of our sample agree or strongly agree with the statement “I intend to vaccinate my Children against HPV or I have already vaccinated my children against HPV” (Figure 5). This is a promising outcome because it shows that there is high intent in our population to vaccinate against HPV. The HPV vaccine was originally only recommended for females, the CDC later changed their recommendation to include everyone. Seventy one percent of our sample indicated that they would vaccinate both their sons and their daughters. this indicates that the initial recommendation that the HPV vaccine only be administered to females does not impact current intent of parents to vaccinate all their children. The eight percent of
respondents who disagreed with the statement “I will (or would) vaccinate both my sons and daughters against HPV” likely do not intend to vaccinate any of their children against HPV for reasons unrelated to gender. Half of our sample indicate that they would vaccinate their children despite potential side effects. This could indicate that they feel that HPV presents a far greater risk to their children than the potential risk posed by receiving the vaccine. Thirty-one percent of respondents indicated that they neither agree nor disagree with the statement "The potential side effects of the HPV vaccine will prevent me from vaccinating my children against HPV.” Most parents do not know the frequency of adverse reactions to the HPV vaccine. Uncertainty about the frequency of adverse reactions could explain why a large portion of the sample is unsure if they agree or disagree with the statement about vaccinating their children despite potential side effects. Educating parents about the potential risks of vaccination and the frequency of adverse effects could help increase vaccination rates as they learn that adverse reactions are uncommon, and the risk of potential side effects is low.

4.5 Trust in Health Guidelines Increases Intent to Vaccinate

A majority (53.5%) of survey participants agree or strongly agree with the statement “I trust in public health guidelines provided by the CDC”. Trust in CDC public health guidelines is also positively correlated with intent to vaccinate (Figure 7). As of June, 2022, the Centers for Disease Control and Prevention (CDC) recommends that everyone be vaccinated against HPV at age 11-12. The CDC also recommends vaccination for everyone 26 and younger who were not adequately vaccinated when they were younger. Vaccination can be administered after 26 for high-risk individuals, or on the recommendation of a clinician [89]. Most HPV infections are mild and rarely cause life threatening complications therefore few parents are worried about their children contracting HPV. There is little discussion or public awareness about HPV and societal pressure supporting vaccination is low, therefore institutions like the CDC are often the only organizations promoting HPV vaccination. Because the CDC is the national agency responsible for health in the United States, trust in the CDC can reflect a broader trust in research and medical institutions. Trust in public health guidelines such as vaccine recommendations from the CDC can directly impact intent to vaccinate because the CDC and state and local health departments are often the only organizations encouraging people to get vaccinated against HPV.

4.5 Belief that Vaccination Protects Against HPV Induced Cancer, Increases Intent to Vaccinate
There is a positive correlation between intent to vaccinate and the belief that the HPV vaccine is effective against preventing HPV induced cancer. This observation is consistent with the Health Belief Model, which is that if the perceived benefits are high (the prevention of cancer), the desire to perform the behavior (intent to vaccinate) is also high. Interestingly, only 15.1% of participants strongly agreed that the HPV vaccine prevents cancer, suggesting the lack of certainty about the causation and prevention of cancer. It is possible that if this sample was more educated about the ability of HPV to cause cancer, the intent to vaccinate would be higher.

5. Conclusion

In this study we were able to identify factors that influence the intent of Utah parents to vaccinate their children against HPV, and we were also able to determine the mechanisms by which these factors affect intent. This study shows that in Utah, positive attitudes about vaccines in general and knowledge about HPV have the greatest positive impact on the intent of parents to vaccinate children against HPV. We also found that high religious practice and cautious sexual attitudes have a negative impact on parental intent to vaccinate.

Parents who already feel positively about vaccination view the HPV vaccine as an effective method of protecting their kids from HPV, trust in health care professionals increased positive views of vaccination which increases intent to vaccinate. Parents who are knowledgeable about HPV understand the risks presented by infection which increases their intent to vaccinate and protect their children from infection. Parents with cautious sexual attitudes may feel that their children are unlikely to be exposed to the sexually transmitted strains of HPV that vaccines protect against, therefore they may feel that it is unnecessary to vaccinate their children against HPV. High religious practice has a negative effect on intent to vaccinate because of its considerable impact on cautious sexual attitudes.

Interventions focused on educating Utah residents about the risks HPV infection poses could improve HPV vaccine uptake. Interventions focused on addressing general concerns about vaccines would likely also improve HPV vaccine uptake.
Summary

The results of three Cross-sectional studies are illustrated in this manuscript. In the first study we investigated what factors influenced intent to vaccinate in Christian parents. We determined that general vaccine attitudes have the greatest impact on parental intent to vaccinate. Using random forest analysis, we also found High vaccine knowledge is predictive of positive intent to vaccinate. We also found that individuals who feel that religious adherence protects against HPV have lower intent to vaccinate.

We designed interventions in the form of short educational videos based on our findings in the first study. We designed an education focused intervention and a religious focused intervention. We tested the effectiveness of this intervention with a second cross-sectional study. In the study we assessed intent to vaccinate both pre and post intervention. We found that the religious-focused intervention and the education-focused had a more positive impact on intent to vaccinate than the control intervention.

In the third study we investigated what factors influenced what factors impacted Utah residents’ intent to vaccinate. We found that positive vaccine attitudes are predictive of intent to vaccinate confirming our earlier study. We found that high religious practice had a negative impact on intent to vaccinate. Through further investigation we were able to determine why high religious practice and intent to vaccinate are negatively correlated; high religious practice is correlated with careful sexual attitudes which has a negative impact on intent to vaccinate. Parents who encourage their children to be careful about sex feel that their children have a lower chance of contracting HPV.
Bibliography


