# Provider communication and HPV vaccine uptake: A meta-analysis and systematic review

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ARTICLE INFO

*Keywords:*
HPV vaccines
Provider communication
Meta-analysis
Systematic review

ABSTRACT

Provider communication can be critically important to families as they consider HPV vaccination. We sought to characterize the association of provider communication and HPV vaccine uptake, and when communication better motivates vaccination. We searched four databases for studies published between 2006 and 2019. Eligible studies examined health care provider communication (defined as recommendation or discussion) and HPV vaccine uptake (defined as initiation, completion, or follow-through) in the US. Two coders independently identified eligible studies and coded effect sizes and study characteristics. We pooled effect sizes using random-effects meta-analysis. We identified 59 eligible studies of 265,083 patients. Receiving a provider recommendation was associated with higher HPV vaccine initiation (pooled OR = 10.1, 95% CI: 7.6–13.4). HPV vaccine initiation was 24% for patients without and 60% for patients with a provider recommendation. The pooled effect size for provider recommendation and initiation was smaller for probability samples, clinical records, and NIS-Teen (all $p < 0.002$). Recommendations were equally effective for males and females, for different patient ages, and over time. Provider recommendation was also associated with higher HPV vaccine series completion and follow-through. Provider discussion was similarly associated with higher HPV vaccine initiation (OR = 12.4, 95% CI: 6.3–24.3). In summary, provider communication was robustly associated with HPV vaccination initiation, completion, and follow-through. These findings suggest that US public health efforts to increase HPV vaccine coverage should continue to emphasize provider communication.

## 1. Introduction

Human papillomavirus (HPV) accounts for 5% of new cancer cases globally (de Martel et al., 2017; Plummer et al., 2016). It causes almost all cervical cancers and five other cancers (vaginal, vulvar, oropharyngeal, penile and anal) (Saraiya et al., 2015). In the United States (US), HPV causes an estimated 34,800 new cancers each year (Senkomago et al., 2019). Routine vaccination of adolescents could prevent over 80% of HPV cancers (Senkomago et al., 2019; de Sanjose et al., 2019; de Sanjosé et al., 2018) and precancers, potentially eliminating cervical cancer as a public health problem. The US recommends routine provision of HPV vaccine to adolescents ages 11–12 (Meites et al., 2019). Catch-up HPV vaccination is recommended for ages 13–26 and shared decision making with a provider for ages 27–45. The recommended number of doses increases from two to three doses if HPV vaccination begins at age 15 or older.

As of 2019, 54% of adolescents ages 13–17 in the US had completed HPV vaccine series and were considered up-to-date (Elam-Evans et al., 2020), far short of the Healthy People 2020 goal of 80% (Immunization and Infectious Diseases Objectives, 2020). Therefore, it is critical to identify and understand factors that influence uptake. Numerous studies, including the National Immunization Survey-Teen (NIS-Teen) survey (The National Immunization Survey-Teen, 2021), have shown provider recommendation is an important contributor to HPV vaccination (Newman et al., 2018). However, neither the size of this effect nor boundary conditions are well understood. We sought to characterize the strength of the association between provider communication and HPV vaccine uptake, identify moderators of this relationship, and understand

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https://doi.org/10.1016/j.ypmed.2021.106554
Received 19 August 2020; Received in revised form 6 April 2021; Accepted 11 April 2021
Available online 20 April 2021

provider discussion in influencing vaccine uptake. Understanding the strength and boundary conditions of this association will inform providers and policymakers on the use of provider communication as a public health tool for increasing HPV vaccine coverage in the US.

## 2. Materials and methods

### 2.1. Search strategy

We systematically searched PubMed, CINAHL, Embase, and Web of Science to identify empirical research studies published between January 2006 (when the US first licensed an HPV vaccine) and October 2019. We used the following search terms to identify relevant studies: (human papillomavirus OR human papilloma virus OR HPV) AND (immuniz* OR immunis* OR vaccinat*) AND (acceptance OR initiat* OR (follow through) OR (up to date) OR complet* OR uptake OR coverage* OR dose*). We also searched the references of included studies to identify additional relevant studies.

### 2.2. Study selection

Two reviewers independently screened titles and abstracts and completed full-text reviews of relevant articles. Eligible studies examined provider communication and HPV vaccine uptake among US adolescents ages 11–17 and young adults ages 18–26. Studies of adults ages 27+ were included if the study sample also contained either adolescents, young adults, or both. We limited the review to studies conducted in the US and its territories to limit variability resulting from different healthcare systems and vaccination policies. We included studies that were published in English; were published in peer-reviewed journals; reported primary data (not review, commentary, or editorial); and reported quantitative data on provider communication and HPV vaccine uptake. We excluded any studies that were duplicates or reported multifaceted interventions with other components besides provider communication. We resolved any questions or disagreements among reviewers and the senior author (NB).

### 2.3. Data extraction

Two reviewers independently coded studies after full-text review using a standard form. Reviewers compared their data for agreement and resolved any differences through discussion among reviewers and the senior author (NB). Reviewers coded year, study design, sampling strategy, mode of interview, sample characteristics, response rate, and any reports of missing data for variables. If studies stratified results by age or gender, we analyzed each stratified effect size as a separate study. When studies had missing data, reviewers reached out to the first author of the study to request additional data.

Reviewers coded three types of provider communication: recommendation, discussion, and strength of recommendation. Reviewers coded provider communication as either recommendation, discussion, or strength of recommendation based on the wording of the survey. To be coded as recommendation, the provider must have taken an encouraging stance towards HPV vaccine that went beyond providing background information. Words such as "recommended" or "suggested" around provider communication for HPV vaccination were coded as provider recommendation. Words such as "discussed" or "informed" to describe provider communication were coded as provider discussion. Finally, reviewers coded strength of recommendation when the study assessed the emphasis of recommendation and presented distinct effect estimates for provider recommendation based on "strongly recommended" compared to "not strongly recommended," for example.

Reviewers coded associations of provider communication and three measures of HPV vaccine uptake found commonly in HPV vaccination literature: initiation, completion, and follow-through. We defined *initiation* as having received at least one dose of HPV vaccine (denominator was all study participants). We defined *completion* as having received all recommended doses of the vaccine (denominator was all study participants). We defined *follow-through* as having completed the vaccine series after initiating or receiving at least the first dose (denominator was study participants who initiated the HPV vaccine series). Reviewers coded source of vaccination uptake as self-report (i.e., parent/guardian or patient) or as provider-verified (e.g., medical records, immunization registries). They also coded additional study characteristics, such as location and sampling strategy.

Reviewers extracted sample size and the unadjusted odds ratio (OR). The referent group was individuals who did not receive provider communication about HPV vaccination. Of the identified studies, many used data from the Centers for Disease Control and Prevention's (CDC) NIS-Teen, an annual, nationally representative survey of parent-reported, provider-verified vaccination among adolescents ages 13–17. Given the importance of NIS-Teen as a data source, we requested data directly from the CDC on provider recommendation and HPV vaccination for 2008–2018 for females and 2010–2018 for males. The CDC provided unadjusted odds ratios and 95% CIs for HPV vaccination initiation.

### 2.4. Data synthesis

For outcomes with effect sizes from less than five studies, we synthesized the findings by narrative systematic review. For outcomes with effect sizes from at least five studies, we log transformed the ORs, combined them using random-effects meta-analysis, and then exponentiated the pooled result to yield a pooled OR. For the association between provider recommendation and HPV vaccine initiation, we calculated the weighted percentage of patients who initiated vaccination with and without provider communication. For outcomes with effect sizes from at least 15 studies, we conducted a moderation analysis to examine whether effect size varied by study characteristics. We conducted analyses with Stata Version 16 (StataCorp LLC, 2019) using two-tailed statistical tests and a critical alpha of 0.05. To characterize potential publication bias in the meta-analyses, we constructed funnel plots and conducted quantitative analyses using Egger's test of bias. We also stratified the publication bias analyses for variables identified in the moderation analysis.

## 3. Results

### 3.1. Characteristics of studies

We identified 59 eligible studies that reported provider communication and HPV vaccine uptake ($n = 265{,}083$) (Bednarczyk et al., 2011; Bednarczyk et al., 2017; Berenson et al., 2017; Bhatta and Phillips, 2015; Brewer et al., 2011; Buechel and Connelly, 2018; Casey et al., 2013; Caskey et al., 2009; Cates et al., 2010; Cherven et al., 2019; Colón-López et al., 2016; Curtis et al., 2014; Daley et al., 2010; Donahue et al., 2015; Flores et al., 2019; Fu et al., 2017; Gargano et al., 2013; Gerend et al., 2016a; Gerend et al., 2016b; Gerend et al., 2019; Gerend et al., 2009; Gerend et al., 2013; Gilkey et al., 2016; Gorbach et al., 2017; Gottlieb et al., 2009; Guerry et al., 2011; Hoffman et al., 2012; Klosky et al., 2013; Klosky et al., 2015a; Klosky et al., 2017; Klosky et al., 2015b; Kramer and Dunlop, 2012; Krawczyk et al., 2012; Marchand et al., 2012; McRee et al., 2014; Rahman et al., 2015; Reiter et al., 2014; Reiter et al., 2009; Reiter et al., 2013a; Reiter et al., 2013b; Rosenthal et al., 2011; Savas et al., 2012; Sturm et al., 2017; Suryadevara et al., 2016; Vu et al., 2019; Williams et al., 2013; Wilson et al., 2016; *The 2008 National Immunization Survey-Teen*, 2009; *The 2009 National Immunization Survey-Teen*, 2010; *The 2010 National Immunization Survey-Teen*, 2011; *The 2011 National Immunization Survey-Teen*, 2012; *The 2012 National Immunization Survey-Teen*, 2013; The 2013 National Immunization Survey-Teen, 2014; *The 2014 National Immunization Survey-Teen*, 2015; *The 2015 National Immunization Survey-Teen*, 2016; *The 2016 National*

*Immunization Survey-Teen. U.S*, 2017; *The 2017 National Immunization Survey-Teen*, 2018; *The 2018 National Immunization Survey-Teen*, 2019; Gold et al., 2013). The majority of studies (68%) had less than 2000 participants (Table 1). Studies included adolescents ages 11–17 and adults ages 18+, though most studies (66%) focused on adolescents ages 13–17. Around half of the studies included only females (51%). Most studies used convenience sampling (59%), had a cross-sectional design (92%), and relied on national samples (46%). Studies collected data from 2007 to 2015, with 32% of studies collecting data from 2013 to 2015. One-fourth of studies (24%) did not report response rates; 27% had response rates below 50%; 24% had response rates of 50–75%; and 25% had response rates higher than 75%. The most common source of HPV vaccination data was self-report (66%). The 59 studies yielded 77 effect sizes due to stratified analyses.

### 3.2. Provider recommendation

For the association between provider recommendation and HPV vaccine initiation, 45 studies yielded 59 effect sizes. CDC NIS-Teen surveys reported on females for two years (2008, 2009) and then stratified results by sex in subsequent years. Other studies stratified by gender (Vu et al., 2019), quality of recommendation (Fu et al., 2017; Gilkey et al., 2016), and age (Klosky et al., 2015b). The majority (93%) of effect sizes came from cross-sectional studies. Around 40% relied on medical records and 49% came from studies that used probability sampling.

For recommendation and completion, eight studies yielded eight effect sizes. All of these studies were cross-sectional. Half used probability sampling and verified records for HPV vaccination completion. For recommendation and follow-through, nine studies yielded twelve effect sizes. Gilkey et al. (Gilkey et al., 2016) stratified by strength of recommendation, while Klosky et al. (Klosky et al., 2015b) stratified by age. The majority (92%) of effect sizes came from cross-sectional studies. Meanwhile, about 40% came from studies with probability sampling and approximately one-third used verified records for vaccination data."

#### 3.2.1. Association with initiation

A provider recommendation was associated with higher likelihood of initiating HPV vaccination (pooled OR = 10.1, 95% CI: 7.6, 13.4) in analysis of 59 effect sizes ($n$ = 226,224, Table 2), with ORs ranging from 1.1 to 281.2 (Fig. 1). Only 24% of patients initiated HPV vaccination without provider recommendation, whereas 60% of patients with provider recommendation initiated HPV vaccination, based on available vaccination data corresponding to 57 effect sizes.

The pooled effect size for recommendation-initiation was very heterogenous ($I^2$ = 99%), which was due in part to variation in sampling strategy, source of vaccination data, and NIS-Teen data (Table 3). Provider recommendation had a larger association with HPV vaccine initiation when based on convenience samples versus probability samples (pooled OR = 15.8, 95% CI: 10.0, 25.0 vs. 6.6, 95% CI: 5.0, 12.4). Similarly, self-reported vaccination data yielded a larger association with recommendations when compared to medical records (pooled OR = 15.3, 95% CI: 10.3, 22.7 vs. 5.7, 95% CI: 4.3, 7.5). Finally, NIS-Teen data yielded a smaller association with recommendations than studies using other data sources (pooled OR = 5.8; 95% CI: 4.5, 7.6 vs 14.0, 95% CI: 9.4, 20.9).

#### 3.2.2. Association with completion

Provider recommendation was associated with higher completion (pooled OR = 5.2, 95% CI 1.9, 13.8) in analysis of eight effect sizes ($n$ = 33,282, Table 2). ORs ranged from 1.0 to 128.5, with substantial heterogeneity ($I^2$ = 98%) (Fig. S1).

#### 3.2.3. Association with follow-through

Provider recommendation was associated with higher HPV vaccine series completion after initiation (pooled OR = 1.8, 95% CI: 1.3, 2.5) in analysis of 12 effect sizes ($n$ = 9406, Table 2). Effect sizes included ORs of 0.81 to 6.2, with high heterogeneity ($I^2$ = 71%) (Fig. S2).

### 3.3. Provider discussion

For initiation, nine studies yielded ten effect sizes. Caskey et al. (Caskey et al., 2009) stratified analyses by age group: adolescents and young adults. All ten effect sizes were from cross-sectional studies. Three came from studies with probability sampling, and one came from a study that used verified records. For completion, Wilson et al. (Wilson et al., 2016) conducted a cross-sectional study with convenience sampling and verified records. For follow-through, Gold et al. (Gold et al., 2013) conducted a longitudinal study from the years 2008–2009 using

**Table 1**
Study characteristics (59 studies).

| | No. of studies | % |
|---|---|---|
| **Sample size** | | |
| 0–499 patients | 24 | 41 |
| 500–1999 patients | 16 | 27 |
| 2000–9999 patients | 8 | 14 |
| 10,000+ patients | 11 | 19 |
| **Gender** | | |
| Female only | 30 | 51 |
| Male only | 4 | 7 |
| Mixed | 25 | 42 |
| **Ages** | | |
| 11–12 years | 25 | 42 |
| 13–17 years | 39 | 66 |
| 18–26 years | 22 | 37 |
| 27+ years | 3 | 5 |
| **Year of data collection** | | |
| 2007–2009 | 17 | 29 |
| 2010–2012 | 15 | 25 |
| 2013–2015 | 19 | 32 |
| 2016–2018 | 5 | 8 |
| Not reported | 3 | 5 |
| **Sampling strategy** | | |
| Convenience | 35 | 59 |
| Probability | 24 | 41 |
| **Population** | | |
| Local | 22 | 37 |
| Single state | 6 | 10 |
| Multi-state | 4 | 7 |
| National | 27 | 46 |
| **Source of HPV vaccination data** | | |
| Self-report | 39 | 66 |
| Clinical record | 20 | 34 |
| **Response rate** | | |
| 0–49% | 16 | 27 |
| 50–75% | 14 | 24 |
| 76–100% | 15 | 25 |
| Not reported | 14 | 24 |
| **Study design** | | |
| Cross-sectional | 54 | 92 |
| Longitudinal | 5 | 8 |
| **NIS-Teen** | | |
| No | 44 | 75 |
| Yes | 15 | 25 |

Note. NIS-Teen = National Immunization Survey Teen.

**Table 2**
Provider communication and HPV vaccination uptake.

| | $N$ | $k$ | Pooled OR (95% CI) | $I^2$ |
|---|---|---|---|---|
| Provider recommendation | | | | |
| Initiation | 226,224 | 59 | 10.1 (7.6, 13.4) | 99.4 |
| Completion | 33,282 | 8 | 5.2 (1.9, 13.8) | 98.6 |
| Follow through | 9406 | 12 | 1.8 (1.3, 2.5) | 71.1 |
| Provider discussion | | | | |
| Initiation | 5913 | 10 | 12.4 (6.3, 24.3) | 93.9 |

Note. NIS-Teen = National Immunization Survey Teen. $k$ = number of effect sizes. OR = odds ratio.

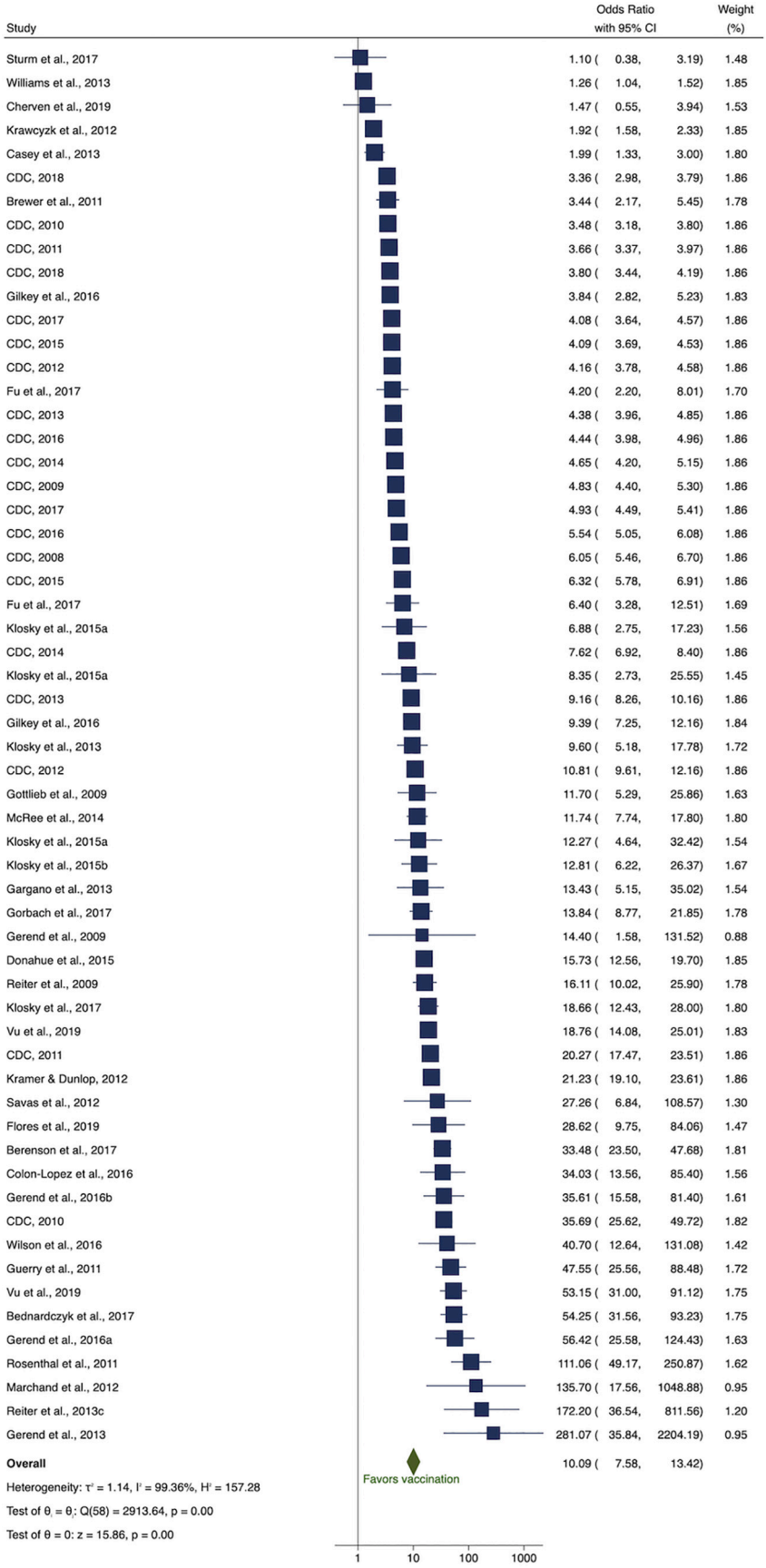


**Fig. 1.** Association of provider recommendation with HPV vaccine initiation.

**Table 3**
Correlates of provider-communication difference in HPV vaccination initiation.

| | n | k | Pooled OR (95% CI) | $I^2$ | p |
|---|---|---|---|---|---|
| Overall | 226,224 | 59 | 10.1 (7.6,13.4) | 99.4 | – |
| Patient characteristics | | | | | |
| Gender | | | | | 0.297 |
| Female only | 128,275 | 34 | 9.0 (6.2, 13.2) | 99.4 | |
| Male only | 91,118 | 14 | 14.6 (8.6, 24.9) | 99.5 | |
| Mixed | 6851 | 11 | 8.5 (4.2, 17.2) | 96.2 | |
| Age | | | | | 0.235 |
| Adolescents (11–17 years) | 215,831 | 40 | 8.6 (6.5, 11.5) | 99.3 | |
| Adults (18–45 years) | 9029 | 14 | 17.4 (7.9, 38.2) | 98.0 | |
| Mixed (11–45 years) | 1384 | 5 | 7.5 (3.2, 17.9) | 81.7 | |
| Study characteristics | | | | | |
| Year of data collection | | | | | 0.623 |
| 2007–2009 | 38,255 | 12 | 10.4 (5.0, 21.7) | 99.3 | |
| 2010–2012 | 63,334 | 12 | 12.7 (5.7, 33.1) | 99.7 | |
| 2013–2015 | 63,048 | 16 | 10.5 (6.3, 17.7) | 99.4 | |
| 2016–2018 | 57,113 | 8 | 6.9 (3.6, 13.3) | 99.6 | |
| Sampling strategy | | | | | 0.002 |
| Convenience | 11,140 | 29 | 15.8 (10.0, 25.0) | 94.5 | |
| Probability | 215,104 | 30 | 6.6 (5.0, 12.4) | 99.4 | |
| Population | | | | | 0.096 |
| Local | 6077 | 18 | 13.3 (7.9, 22.2) | 91.5 | |
| State | 5668 | 8 | 16.5 (6.9, 39.3) | 96.1 | |
| National | 214,499 | 30 | 7.6 (5.4, 10.8) | 99.6 | |
| Source of vaccination data | | | | | <0.001 |
| Self-report | 36,671 | 36 | 15.3 (10.3, 22.7) | 97.0 | |
| Clinical record | 189,573 | 23 | 5.7 (4.3, 7.5) | 99.3 | |
| Study design | | | | | 0.983 |
| Cross-sectional | 224,892 | 55 | 10.2 (7.6, 13.6) | 99.4 | |
| Longitudinal | 1352 | 4 | 10.0 (1.2, 51.7) | 95.5 | |
| NIS-teen data | | | | | <0.001 |
| No | 37,487 | 39 | 14.0 (9.4, 20.9) | 97.2 | |
| Yes | 188,757 | 20 | 5.8 (4.5, 7.6) | 99.2 | |

Note. NIS-Teen = National Immunization Survey Teen. $k$ = number of effect sizes. OR = odds ratio.

convenience sampling and verified records.

#### 3.3.1. Association with HPV vaccine initiation

Individuals who discussed HPV vaccine with their providers had a higher likelihood of initiating vaccination (pooled OR = 12.4, 95% CI: 6.3, 24.3) in analysis of 10 effect sizes ($n$ = 5913, Table 2). ORs ranged from 2.2 to 112.3, with substantial heterogeneity ($I^2$ = 94%) (Fig. S3).

#### 3.3.2. Association with other outcomes

We systematically reviewed the remaining data because too few effect sizes were available to support meta-analyses. Wilson et al. (Wilson et al., 2016) examined HPV vaccine completion among women ages 18–26. Women who discussed the vaccine with a provider were more likely to complete the HPV vaccine series compared to those who did not (OR = 264.9, 95% CI: 35.4, 1979.9) (Wilson et al., 2016). Examining HPV vaccine follow-through, Gold et al. (Gold et al., 2013) stratified provider discussion by topic: (1) provider discussed benefits of receiving the HPV vaccine, and (2) provider discussed coming back for more shots. Discussing the need to come back for more shots was associated with increased likelihood of follow-through (relative risk = 1.55, 95% CI: 1.18, 2.03), but discussing the benefits of vaccination was not (relative risk = 1.06, 95% CI: 0.90, 1.25) (Gold et al., 2013).

### 3.4. Quality of recommendation

Studies yielded five effect sizes for the association of the quality of provider recommendation with HPV vaccination (Donahue et al., 2015; Fu et al., 2017; Gilkey et al., 2016; Rosenthal et al., 2011; Wilson et al., 2016). Studies were conducted between 2008 and 2016. Only two studies used probability samples. Most studies, with the exception of Fu et al. (Fu et al., 2017), were cross-sectional. Each study examined the effect of quality of recommendation on initiation. In addition to initiation, Wilson et al. (Wilson et al., 2016) included completion as an outcome while Gilkey et al. (Gilkey et al., 2016) included follow-through. Studies defined quality of recommendation in different ways. Gilkey et al. (Gilkey et al., 2016) measured quality using a validated index evaluating provider recommendation on three components: strength of vaccine endorsement, use of messaging regarding cancer prevention, and urgency (defined as same-day recommendation). The remaining studies relied on the patient's subjective evaluation of the strength of provider recommendation (Donahue et al., 2015; Rosenthal et al., 2011).

#### 3.4.1. Association with HPV vaccine initiation

Gilkey et al. (Gilkey et al., 2016) found that patients who received a high-quality recommendation were more likely to initiate the vaccine as compared to those with no recommendation (adjusted OR = 9.3, 95% CI: 7.1, 12.2). Those who received a low-quality recommendation were also more likely to initiate the vaccine as compared to those with no recommendation (adjusted OR = 4.13, 95% CI: 3.0, 5.7). Similarly, Rosenthal et al. (Rosenthal et al., 2011) found that insured women ages 19–26 who received a very strong recommendation had a higher likelihood of initiation compared to those receiving a weak recommendation (adjusted OR = 1.41, 95% CI: 1.06, 1.88). Donahue et al. (Donahue et al., 2015) found that a strong recommendation for girls ages 9–13 was associated with higher HPV vaccine initiation compared to those receiving an average recommendation (OR = 2.0, 95% CI: 1.5, 2.6). Fu et al. (Fu et al., 2017) found that among children ages 10–12 with African American parents, those with a provider who "very strongly" recommended the vaccine reported higher initiation compared to those with a provider who "not very strongly" recommended it. Finally, Wilson et al. (Wilson et al., 2016) found that among women ages 18–26, stronger recommendations were associated with higher initiation (OR = 1.86, 95% CI: 1.46–2.35).

#### 3.4.2. Association with other outcomes

Wilson et al. (Wilson et al., 2016) reported that quality of recommendation predicted series completion, but did not quantify this association. Gilkey et al. (Gilkey et al., 2016) found that, compared to no recommendation, a high-quality recommendation was associated with HPV vaccine follow-through (OR = 9.31, 95% CI: 7.10–12.22), but low-quality recommendations were not better than no recommendation in predicting follow-through.

### 3.5. Publication bias

The funnel plot for provider recommendation and initiation (Fig. S4) showed asymmetry, suggesting that publication bias may be present. Egger's test of bias also suggested publication bias ($p < 0.001$). Stratification of the recommendation-initiation funnel plots by sampling strategy, source of vaccination data, and NIS-Teen data again showed asymmetry (Figs. S5–S7), as did stratified Egger's tests (all $p < 0.01$). For recommendation-completion and recommendation-follow-through, analyses indicated no asymmetry, either in funnel plots (Figs. S8–S9) or Egger's test (both $p > 0.29$). Finally, we found no evidence of publication bias for discussion and initiation, either through the funnel plot (no asymmetry, Fig. S10), or through Egger's test ($p = 0.31$).

## 4. Discussion

Provider communication had consistently large associations with HPV vaccine uptake in studies of over 265,000 US patients. The association of recommendation with initiation was robust, being equally strong across age and gender. Higher-quality studies (i.e., studies using probability sampling or clinical records as source of vaccination data) had smaller effect sizes for initiation, but these studies still showed large

effects. Effect sizes were also smaller, but still large, for probability samples and provider-verified vaccination. These results are in keeping with the stainless-steel law of evaluation that higher quality evaluations identify smaller effects (Rossi, 1987) and may explain why the NIS-Teen, which uses both methods, reliably yielded smaller estimates (Cheung and Slavin, 2016). Our review's findings confirm the unique importance of provider communication in ensuring high HPV vaccine coverage.

The robustness of the impact of provider recommendation – across patient age, patient gender, and year of study – is encouraging. Despite trends of lower HPV vaccine coverage in males (Stokley et al., 2014), provider recommendation was associated with HPV vaccine uptake for males and females and across age groups. In previous studies, providers have reported that they expected HPV vaccine communication to be uncomfortable due to HPV being sexually transmitted (Kumar et al., 2019). Providers also cited bad publicity around HPV vaccine as one of the barriers to communication (Kumar et al., 2019). Interventions providing provider education on HPV vaccine, especially as cancer prevention, have improved vaccination uptake (Dempsey et al., 2018; Perkins et al., 2015). Provider recommendation of HPV vaccination has also varied across age group and gender. While most pediatricians (85%) recommended HPV vaccine for adolescents ages 11–12, nearly 100% recommended it for ages 13 and older (Kempe et al., 2019). Many national organizations – including the CDC, American Cancer Society, and American Academy of Pediatrics – have compiled resources to encourage providers to recommend HPV vaccination (*HPV You Are Key 2018 | Vaccine Education | CDC*, 2020; *HPV Champion Toolkit*, 2021; *Human Papillomavirus Vaccine (HPV)*, 2021; National HPV Roundtable, 2021). Over time, provider recommendation for HPV vaccination has increased in the US (Stokley et al., 2014), likely a driver for national increases in vaccine coverage (Markowitz et al., 2018).

Provider recommendation may have a larger effect on HPV vaccine initiation than on completion and follow-through. Completion may depend more on the patients' ability to overcome barriers to completing the vaccine series, such as transportation or difficulty remembering when to return for the next dose. Studies have found that patient reminders increased completion of the HPV vaccine series (Bar-Shain et al., 2015; Chao et al., 2015; Kharbanda et al., 2011; Szilagyi et al., 2013). Two of these studies demonstrated that reminders had little to no effect on HPV vaccination initiation (Kharbanda et al., 2011; Szilagyi et al., 2013). Providers may also have difficulty remembering when the patient needs to receive the next dose, which may result in less robust provider recommendation. An intervention that prompted providers through the electronic medical record showed greater timely completion of the vaccine series (Ruffin et al., 2015). Finally, an intervention that gave providers feedback on rates and reminders for subsequent doses increased vaccination completion and had a much larger effect when they added patient reminders (Fiks et al., 2013).

One limitation of our study is the reliance on peer-reviewed articles and NIS-Teen data. The study does not include information from studies not published in peer-reviewed articles or grey literature. In turn, we recognize that our findings may suffer from publication bias, when statistically significant associations are more likely to be published in peer-reviewed journals. Another limitation is the reliance on retrospective cross-sectional studies with self-reported provider communication and vaccination status, which may inflate the magnitude of the association. Several cross-sectional studies took more rigorous approaches to measuring vaccination outcomes with provider-verified responses. One study relied on audio recordings of the provider-patient interaction. However, the remaining studies relied on self-report by adult patients and parents or guardians. Conclusions based on our findings should be made tentatively, recognizing the possibility of inflated estimates, especially when information relies on participant recall.

The accuracy of participants' memories of these conversations is unknown. Having been vaccinated may cue individuals to recall a conversation with their providers about vaccination, which would overstate the association. In addition, definitions of recommendation and discussion varied across studies, with most "discussion" definitions being inclusive of provider recommendation. It is thus not fully satisfying to compare provider discussion versus recommendation across studies due to the non-mutually exclusive nature of their operationalizations. Future research should clearly define and differentiate discussion versus recommendation to assess whether discussion alone is as effective in influencing vaccine uptake as explicit recommendation.

While our review focused on studies of provider communication, we did not distinguish estimates based on type of health care worker, such as physicians versus other members of the primary care team. As the literature stands, it is not clear whether the type of health care worker affects the association between communication and HPV vaccine uptake. Other health care workers (e.g., physician assistants) may be well-positioned to discuss HPV vaccination with parents and adolescents and indeed, may already have this role. These other workers also may have more time to build rapport and trust with patients and their parents before recommending HPV vaccine (Macdonald, 2016). Additionally, these other health care workers may be important in recommending vaccination in non-traditional settings, such as school health centers and school-located mass vaccination days (Kempe et al., 2018; Hansen et al., 2017). School nurses may play an important role in disseminating information and establishing norms surrounding HPV vaccine (Rosen et al., 2016; Rosen et al., 2015). Future research should explore whether recommendation impact varies by the type of health care worker.

Our review focused on studies of the US and its territories, where vaccination typically happens in primary care clinics. We focused on this setting because of its prevalence in the existing literature, the country's unique health care context, and the heterogeneity in vaccination policies and availability in other countries (LaMontagne et al., 2017; Nickel et al., 2017). Provider recommendation may have different meaning in other countries that provide HPV vaccine through school programs or clinical programs run by nurses. Thus, the generalizability of our findings to other countries remains to be established.

A last topic to consider is the meaning of the association of provider communication and vaccine receipt. When a provider recommends adolescents receive HPV vaccine in the US, it is generally available at the clinic, with the cost covered through insurance or the Vaccines for Children program, and the vaccine is delivered by the end of the visit. Thus, the time span for researchers to study vaccination uptake is brief. Cross-sectional studies will always suffer from problems with causal inference, including recall errors described above. Longitudinal studies also run into methodological problems because they follow patients who do not receive the vaccine in the same visit as the provider communication, which may reflect a distinct population that is less likely to receive the vaccine. Thus, longitudinal studies may underestimate the effect of provider communication even as they account for lingering benefits over time. Real-time observations of provider-patient interactions and resulting vaccination (Sturm et al., 2017; Fenton et al., 2018; Shay et al., 2016) are a promising area for research that can offer new insights into the impact and dynamics of a provider communication about vaccines.

In summary, our findings demonstrate a robust association between provider communication and HPV vaccination uptake. Our study suggests that provider recommendation and discussion play an important role in HPV vaccination uptake. Policymakers and health care administrators should consider how they can continue to support and encourage providers to communicate with patients about HPV vaccination through educational resources, training on communication, and tools to address patient hesitancy. Multiple interventions are available to increase HPV vaccine uptake (Brewer et al., 2017), and provider communication should be a central part of any such efforts in the US.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ypmed.2021.106554.

## Funding source

This work was supported by the Lineberger Comprehensive Cancer Center at the University of North Carolina.

## Declaration of Competing Interest

Dr. Brewer has served as a paid advisor for Merck, CDC, and the World Health Organization. The other authors declared no conflicts of interest.

## Acknowledgments

The authors would like to acknowledge Drs. Teri Malo, Parth Shah, William Spencer, and Dongyu Zhang for their contributions in the early stages of this work. The authors would also like to thank Dr. Jennifer Spencer for her guidance on extraction and data analysis. Finally, the authors thank Dr. Tanja Walker, Benjamin Fredua, and Dr. Shannon Stokley for providing data from the National Immunization Survey—-Teen for our review.

## References

Bar-Shain, D.S., Stager, M.M., Runkle, A.P., Leon, J.B., Kaelber, D.C., 2015. Direct messaging to parents/guardians to improve adolescent immunizations. J. Adolesc. Health 56 (5, S), S21–S26. https://doi.org/10.1016/j.jadohealth.2014.11.023.

Bednarczyk, R.A., Birkhead, G.S., Morse, D.L., Doleyres, H., McNutt, L.-A., 2011. Human papillomavirus vaccine uptake and barriers: association with perceived risk, actual risk and race/ethnicity among female students at a New York state university, 2010. Vaccine. 29 (17), 3138–3143. https://doi.org/10.1016/j.vaccine.2011.02.045.

Bednarczyk, R.A., Whitehead, J.L., Stephenson, R., 2017. Moving beyond sex: assessing the impact of gender identity on human papillomavirus vaccine recommendations and uptake among a national sample of rural-residing LGBT young adults. Papillomavirus Res. 3, 121–125. https://doi.org/10.1016/j.pvr.2017.04.002.

Berenson, A.B., Brown, V.G., Fuchs, E.L., Hirth, J.M., Chang, M., 2017. Relationship between maternal experiences and adolescent HPV vaccination. Human Vaccines Immunother. 13 (9), 2150–2154. https://doi.org/10.1080/21645515.2017.1332551.

Bhatta, M.P., Phillips, L., 2015. Human papillomavirus vaccine awareness, uptake, and parental and health care provider communication among 11- to 18-year-old adolescents in a rural Appalachian Ohio County in the United States: HPV vaccine uptake among Appalachian adolescents. J. Rural. Health 31 (1), 67–75. https://doi.org/10.1111/jrh.12079.

Brewer, N.T., Gottlieb, S.L., Reiter, P.L., et al., 2011. Longitudinal predictors of human papillomavirus vaccine initiation among adolescent girls in a high-risk geographic area. Sex. Transm. Dis. 38 (3), 197–204. https://doi.org/10.1097/OLQ.0b013e3181f12dbf.

Brewer, N.T., Chapman, G.B., Rothman, A.J., Leask, J., Kempe, A., 2017. Increasing vaccination: putting psychological science into action. Psychol. Sci. Public Interest 18 (3), 149–207. https://doi.org/10.1177/1529100618760521.

Buechel, J.J., Connelly, C.D., 2018. Determinants of human papillomavirus vaccination among U.S. Navy Personnel. Nurs. Res. 67 (4), 341–346. https://doi.org/10.1097/NNR.0000000000000282.

Casey, B.R., Crosby, R.A., Vanderpool, R.C., Dignan, M., Bates, W., 2013. Predictors of initial uptake of human papillomavirus vaccine uptake among rural Appalachian Young women. J. Prim. Prev. 34 (1–2), 71–80. https://doi.org/10.1007/s10935-013-0295-2.

Caskey, R., Lindau, S.T., Alexander, G.C., 2009. Knowledge and early adoption of the HPV vaccine among girls and Young women: results of a National Survey. J. Adolesc. Health 45 (5), 453–462. https://doi.org/10.1016/j.jadohealth.2009.04.021.

Cates, J.R., Shafer, A., Carpentier, F.D., et al., 2010. How parents hear about human papillomavirus vaccine: implications for uptake. J. Adolesc. Health 47 (3), 305–308. https://doi.org/10.1016/j.jadohealth.2010.04.003.

Chao, C., Preciado, M., Slezak, J., Xu, L., 2015. A randomized intervention of reminder letter for human papillomavirus vaccine series completion. J. Adolesc. Health 56 (1), 85–90. https://doi.org/10.1016/j.jadohealth.2014.08.014.

Cherven, B., Castellino, S.M., Chen, Y., et al., 2019. Intent and subsequent initiation of human papillomavirus vaccine among young cancer survivors. Cancer. 125 (21), 3810–3817. https://doi.org/10.1002/cncr.32379.

Cheung, A.C.K., Slavin, R.E., 2016. How methodological features affect effect sizes in education. Educ. Res. 45 (5), 283–292. https://doi.org/10.3102/0013189X16656615.

Colón-López, V., Toro-Mejías, L.M.D., Conde-Toro, A., et al., 2016. Views on HPV and HPV vaccination: the experience at a Federal Qualified Clinic in Puerto Rico. J. Health Care Poor Underserved 27 (3), 1411–1426. https://doi.org/10.1353/hpu.2016.0126.

Curtis, C.R., Dorell, C., Yankey, D., et al., 2014. National human papillomavirus vaccination coverage among adolescents aged 13-17 years-National Immunization Survey–teen, United States, 2011. MMWR Suppl. 63 (2), 61–70.

Daley, E.M., Vamos, C.A., Buhi, E.R., et al., 2010. Influences on human papillomavirus vaccination status among female college students. J. Women's Health 19 (10), 1885–1891. https://doi.org/10.1089/jwh.2009.1861.

de Martel, C., Plummer, M., Vignat, J., Franceschi, S., 2017. Worldwide burden of cancer attributable to HPV by site, country and HPV type: worldwide burden of cancer attributable to HPV. Int. J. Cancer 141 (4), 664–670. https://doi.org/10.1002/ijc.30716.

de Sanjosé, S., Serrano, B., Tous, S., et al., 2018. Burden of Human Papillomavirus (HPV)-Related Cancers Attributable to HPVs 6/11/16/18/31/33/45/52 and 58. JNCI Cancer Spectr. 2 (4) https://doi.org/10.1093/jncics/pky045 pky045.

de Sanjose, S., Brotons, M., LaMontagne, D.S., Bruni, L., 2019. Human papillomavirus vaccine disease impact beyond expectations. Curr. Opin. Virol. 39, 16–22. https://doi.org/10.1016/j.coviro.2019.06.006.

Dempsey, A.F., Pyrznawoski, J., Lockhart, S., et al., 2018. Effect of a health care professional communication training intervention on adolescent human papillomavirus vaccination: a cluster randomized clinical trial. JAMA Pediatr. 172 (5), e180016 https://doi.org/10.1001/jamapediatrics.2018.0016.

Donahue, K.L., Hendrix, K.S., Sturm, L.A., Zimet, G.D., 2015. Human papillomavirus vaccine initiation among 9–13-year-olds in the United States. Prev. Med. Rep. 2, 892–898. https://doi.org/10.1016/j.pmedr.2015.10.003.

Elam-Evans, L.D., Yankey, D., Singleton, J.A., et al., 2020. National, Regional, State, and Selected Local Area Vaccination Coverage Among Adolescents Aged 13–17 Years — United States, 2019. MMWR Morb. Mortal. Wkly Rep. 69 (33), 1109–1116. https://doi.org/10.15585/mmwr.mm6933a1.

Fenton, A.T., Eun, T.J., Clark, J.A., Perkins, R.B., 2018. Indicated or elective? The association of providers' words with HPV vaccine receipt. Hum Vaccin Immunother. 14 (10), 2503–2509. https://doi.org/10.1080/21645515.2018.1480237.

Fiks, A.G., Grundmeier, R.W., Mayne, S., et al., 2013. Effectiveness of decision support for families, clinicians, or both on HPV vaccine receipt. Pediatrics. 131 (6), 1114–1124. https://doi.org/10.1542/peds.2012-3122.

Flores, Y.N., Salmerón, J., Glenn, B.A., Lang, C.M., Chang, L.C., Bastani, R., 2019. Clinician offering is a key factor associated with HPV vaccine uptake among Mexican mothers in the USA and Mexico: a cross-sectional study. Int J Public Health. 64 (3), 323–332. https://doi.org/10.1007/s00038-018-1176-5.

Fu, L.Y., Zimet, G.D., Latkin, C.A., Joseph, J.G., 2017. Associations of trust and healthcare provider advice with HPV vaccine acceptance among African American parents. Vaccine. 35 (5), 802–807. https://doi.org/10.1016/j.vaccine.2016.12.045.

Gargano, L.M., Herbert, N.L., Painter, J.E., et al., 2013. Impact of a physician recommendation and parental immunization attitudes on receipt or intention to receive adolescent vaccines. Vaccines 9 (12), 2627–2633. https://doi.org/10.4161/hv.25823.

Gerend, M.A., Weibley, E., Bland, H., 2009. Parental response to human papillomavirus vaccine availability: uptake and intentions. J. Adolesc. Health 45 (5), 528–531. https://doi.org/10.1016/j.jadohealth.2009.02.006.

Gerend, M.A., Zapata, C., Reyes, E., 2013. Predictors of human papillomavirus vaccination among daughters of low-income Latina mothers: the role of acculturation. J. Adolesc. Health 53 (5), 623–629. https://doi.org/10.1016/j.jadohealth.2013.06.006.

Gerend, M.A., Shepherd, M.A., Lustria, M.L.A., Shepherd, J.E., 2016a. Predictors of provider recommendation for HPV vaccine among young adult men and women: findings from a cross-sectional survey: table 1. Sex. Transm. Infect. 92 (2), 104–107. https://doi.org/10.1136/sextrans-2015-052088.

Gerend, M.A., Madkins, K., Phillips, G., Mustanski, B., 2016b. Predictors of human papillomavirus vaccination among young men who have sex with men. Sex. Transm. Dis. 43 (3), 185–191. https://doi.org/10.1097/OLQ.0000000000000408.

Gerend, M.A., Stephens, Y.P., Kazmer, M.M., Slate, E.H., Reyes, E., 2019. Predictors of human papillomavirus vaccine completion among low-income Latina/o adolescents. J. Adolesc. Health 64 (6), 753–762. https://doi.org/10.1016/j.jadohealth.2018.12.001.

Gilkey, M.B., Calo, W.A., Moss, J.L., Shah, P.D., Marciniak, M.W., Brewer, N.T., 2016. Provider communication and HPV vaccination: the impact of recommendation quality. Vaccine. 34 (9), 1187–1192. https://doi.org/10.1016/j.vaccine.2016.01.023.

Gold, R., Naleway, A., Riedlinger, K., 2013. Factors predicting completion of the human papillomavirus vaccine series. J. Adolesc. Health 52 (4), 427–432. https://doi.org/10.1016/j.jadohealth.2012.09.009.

Gorbach, P.M., Cook, R., Gratzer, B., et al., 2017. Human Papillomavirus Vaccination Among Young Men Who Have Sex With Men and Transgender Women in 2 US Cities, 2012–2014. Sex. Transm. Dis. 44 (7), 436–441. https://doi.org/10.1097/OLQ.0000000000000626.

Gottlieb, S.L., Brewer, N.T., Sternberg, M.R., et al., 2009. Human papillomavirus vaccine initiation in an area with elevated rates of cervical Cancer. J. Adolesc. Health 45 (5), 430–437. https://doi.org/10.1016/j.jadohealth.2009.03.029.

Guerry, S.L., De Rosa, C.J., Markowitz, L.E., et al., 2011. Human papillomavirus vaccine initiation among adolescent girls in high-risk communities☆. Vaccine. 29 (12), 2235–2241. https://doi.org/10.1016/j.vaccine.2011.01.052.

Hansen, C.E., Okoloko, E., Ogunbajo, A., North, A., Niccolai, L.M., 2017. Acceptability of school-based health centers for human papillomavirus vaccination visits: a mixed-methods study. J. Sch. Health 87 (9), 705–714. https://doi.org/10.1111/josh.12540.

Hoffman, L., Okcu, M.F., Dreyer, Z.E., Suzawa, H., Bryant, R., Middleman, A.B., 2012. Human papillomavirus vaccination in female pediatric cancer survivors. J. Pediatr. Adolesc. Gynecol. 25 (5), 305–307. https://doi.org/10.1016/j.jpag.2012.05.004.

HPV Champion Toolkit. Accessed October 29, 2020. https://www.aap.org/en-us/advocacy-and-policy/aap-health-initiatives/immunizations/HPV-Champion-Toolkit/Pages/HPV-Champion-Toolkit.aspx.

HPV You Are Key 2018 | Vaccine Education | CDC. Published on April 11, 2018. Accessed October 29, 2020. https://www.cdc.gov/vaccines/ed/vaccine-communication/you-are-key-2018.html.
Human Papillomavirus Vaccine (HPV). Accessed October 29, 2020. https://www.aafp.org/family-physician/patient-care/prevention-wellness/immunizations-vaccines/disease-pop-immunization/human-papillomavirus-vaccine-hpv.html.
Immunization and Infectious Diseases Objectives, 2020. Healthy People. Accessed August 3, 2020. https://www.healthypeople.gov/2020/topics-objectives/topic/immunization-and-infectious-diseases/objectives.
Kempe, A., Allison, M.A., Daley, M.F., 2018. Can school-located vaccination have a major impact on human papillomavirus vaccination rates in the United States? Acad. Pediatr. 18 (2), S101–S105. https://doi.org/10.1016/j.acap.2017.08.010.
Kempe, A., O'Leary, S.T., Markowitz, L.E., et al., 2019. HPV vaccine delivery practices by primary care physicians. Pediatrics 144 (4). https://doi.org/10.1542/peds.2019-1475.
Kharbanda, E.O., Stockwell, M.S., Fox, H.W., Andres, R., Lara, M., Rickert, V.I., 2011. Text message reminders to promote human papillomavirus vaccination. Vaccine. 29 (14), 2537–2541. https://doi.org/10.1016/j.vaccine.2011.01.065.
Klosky, J.L., Russell, K.M., Canavera, K.E., et al., 2013. Risk factors for non-initiation of the human papillomavirus vaccine among adolescent survivors of childhood cancer. Cancer Prev. Res. 6 (10), 1101–1110. https://doi.org/10.1158/1940-6207.CAPR-13-0127.
Klosky, J.L., Favaro, B., Peck, K.R., et al., 2015a. Prevalence and predictors of human papillomavirus (HPV) vaccination among young women surviving childhood cancer. J. Cancer Surviv. 10 (3), 449–456. https://doi.org/10.1007/s11764-015-0495-2.
Klosky, J.L., Russell, K.M., Simmons, J.L., et al., 2015b. Medical and sociodemographic factors associated with human papillomavirus (HPV) vaccination adherence among female survivors of childhood cancer: HPV vaccination in cancer survivors. Pediatr. Blood Cancer 62 (9), 1630–1636. https://doi.org/10.1002/pbc.25539.
Klosky, J.L., Hudson, M.M., Chen, Y., et al., 2017. Human papillomavirus vaccination rates in Young Cancer survivors. JCO. 35 (31), 3582–3590. https://doi.org/10.1200/JCO.2017.74.1843.
Kramer, M.R., Dunlop, A.L., 2012. Inter-state variation in human papilloma virus vaccine coverage among adolescent girls in the 50 US states, 2007. Matern. Child Health J. 16 (S1), 102–110. https://doi.org/10.1007/s10995-012-0999-6.
Krawczyk, A.L., Perez, S., Lau, E., et al., 2012. Human papillomavirus vaccination intentions and uptake in college women. Health Psychol. 31 (5), 685–693. https://doi.org/10.1037/a0027012.
Kumar, M.M., Boies, E.G., Sawyer, M.H., Kennedy, M., Williams, C., Rhee, K.E., 2019. A brief provider training video improves comfort with recommending the human papillomavirus vaccine. Clin. Pediatr. (Phila) 58 (1), 17–23. https://doi.org/10.1177/0009922818805217.
LaMontagne, D.S., Bloem, P.J.N., Brotherton, J.M.L., Gallagher, K.E., Badiane, O., Ndiaye, C., 2017. Progress in HPV vaccination in low- and lower-middle-income countries. Int. J. Gynecol. Obstet. 138, 7–14. https://doi.org/10.1002/ijgo.12186.
Macdonald, L.M., 2016. Expertise in everyday nurse-patient conversations: the importance of small talk. Glob Qual Nurs Res. 3 https://doi.org/10.1177/2333393616643201, 2333393616643201.
Marchand, E., Glenn, B.A., Bastani, R., 2012. Low HPV vaccine coverage among female community college students. J. Community Health 37 (6), 1136–1144. https://doi.org/10.1007/s10900-012-9572-x.
Markowitz, L.E., Gee, J., Chesson, H., Stokley, S., 2018. Ten years of human papillomavirus vaccination in the United States. Acad. Pediatr. 18 (2S), S3–S10. https://doi.org/10.1016/j.acap.2017.09.014.
McRee, A.-L., Katz, M.L., Paskett, E.D., Reiter, P.L., 2014. HPV vaccination among lesbian and bisexual women: findings from a national survey of young adults. Vaccine. 32 (37), 4736–4742. https://doi.org/10.1016/j.vaccine.2014.07.001.
Meites, E., Szilagyi, P.G., Chesson, H.W., Unger, E.R., Romero, J.R., Markowitz, L.E., 2019. Human papillomavirus vaccination for adults: updated recommendations of the advisory committee on immunization practices. MMWR Morb. Mortal. Wkly Rep. 68 (32), 698–702. https://doi.org/10.15585/mmwr.mm6832a3.
National HPV Roundtable, 2021. The official website of the National HPV Vaccination Roundtable. https://hpvroundtable.org/. (Accessed 29 October 2020).
Newman, P.A., Logie, C.H., Lacombe-Duncan, A., et al., 2018. Parents' uptake of human papillomavirus vaccines for their children: a systematic review and meta-analysis of observational studies. BMJ Open 8 (4), e019206. https://doi.org/10.1136/bmjopen-2017-019206.
Nickel, B., Dodd, R.H., Turner, R.M., et al., 2017. Factors associated with the human papillomavirus (HPV) vaccination across three countries following vaccination introduction. Prev. Med. Rep. 8, 169–176. https://doi.org/10.1016/j.pmedr.2017.10.005.
Perkins, R.B., Zisblatt, L., Legler, A., Trucks, E., Hanchate, A., Gorin, S.S., 2015. Effectiveness of a provider-focused intervention to improve HPV vaccination rates in boys and girls. Vaccine. 33 (9), 1223–1229. https://doi.org/10.1016/j.vaccine.2014.11.021.
Plummer, M., de Martel, C., Vignat, J., Ferlay, J., Bray, F., Franceschi, S., 2016. Global burden of cancers attributable to infections in 2012: a synthetic analysis. Lancet Glob. Health 4 (9), e609–e616. https://doi.org/10.1016/S2214-109X(16)30143-7.
Rahman, M., Laz, T.H., McGrath, C.J., Berenson, A.B., 2015. Correlates of human papillomavirus vaccine completion among adolescent girl initiators. Clin. Pediatr. (Phila) 54 (14), 1328–1333. https://doi.org/10.1177/0009922815579687.
Reiter, P.L., Brewer, N.T., Gottlieb, S.L., McRee, A.-L., Smith, J.S., 2009. Parents' health beliefs and HPV vaccination of their adolescent daughters. Soc. Sci. Med. 69 (3), 475–480. https://doi.org/10.1016/j.socscimed.2009.05.024.
Reiter, P.L., Katz, M.L., Paskett, E.D., 2013a. Correlates of HPV vaccination among adolescent females from Appalachia and reasons why their parents do not intend to vaccinate. Vaccine. 31 (31), 3121–3125. https://doi.org/10.1016/j.vaccine.2013.04.068.
Reiter, P.L., McRee, A.-L., Pepper, J.K., Gilkey, M.B., Galbraith, K.V., Brewer, N.T., 2013b. Longitudinal predictors of human papillomavirus vaccination among a National sample of adolescent males. Am. J. Public Health 103 (8), 1419–1427. https://doi.org/10.2105/AJPH.2012.301189.
Reiter, P.L., Gupta, K., Brewer, N.T., et al., 2014. Provider-verified HPV vaccine coverage among a National Sample of Hispanic adolescent females. Cancer Epidemiol. Biomark. Prev. 23 (5), 742–754. https://doi.org/10.1158/1055-9965.EPI-13-0979.
Rosen, B.L., Goodson, P., Thompson, B., Wilson, K.L., 2015. School Nurses' knowledge, attitudes, perceptions of role as opinion leader, and professional practice regarding human papillomavirus vaccine for youth. J. Sch. Health 85 (2), 73–81. https://doi.org/10.1111/josh.12229.
Rosen, B.L., Ashwood, D., Richardson, G.B., 2016. School Nurses' professional practice in the HPV vaccine decision-making process. J. Sch. Nurs. 32 (2), 138–148. https://doi.org/10.1177/1059840515583312.
Rosenthal, S.L., Weiss, T.W., Zimet, G.D., Ma, L., Good, M.B., Vichnin, M.D., 2011. Predictors of HPV vaccine uptake among women aged 19–26: importance of a physician's recommendation. Vaccine. 29 (5), 890–895. https://doi.org/10.1016/j.vaccine.2009.12.063.
Rossi, P.H., 1987. The iron law of evaluation and other metallic rules. In: Research in Social Problems and Public Policy, Vol 4. JAI Press, Inc, pp. 3–20.
Ruffin, M.T., Plegue, M.A., Rockwell, P.G., Young, A.P., Patel, D.A., Yeazel, M.W., 2015. Impact of an electronic health record (EHR) reminder on human papillomavirus (HPV) vaccine initiation and timely completion. J. Am. Board Fam. Med. 28 (3), 324–333. https://doi.org/10.3122/jabfm.2015.03.140082.
Saraiya, M., Unger, E.R., Thompson, T.D., et al., 2015. US assessment of HPV types in cancers: implications for current and 9-valent HPV vaccines. J. Natl. Cancer Inst. 107 (6) https://doi.org/10.1093/jnci/djv086 djv086.
Savas, L.S., Fernández, M.E., Jobe, D., Carmack, C.C., 2012. Human Papillomavirus Vaccine. Am. J. Prev. Med. 43 (6), S490–S496. https://doi.org/10.1016/j.amepre.2012.09.003.
Senkomago, V., Henley, S.J., Thomas, C.C., Mix, J.M., Markowitz, L.E., Saraiya, M., 2019. Human Papillomavirus–Attributable Cancers — United States, 2012–2016. MMWR Morb. Mortal. Wkly Rep. 68 (33), 724–728. https://doi.org/10.15585/mmwr.mm6833a3.
Shay, L.A., Street, R.L., Baldwin, A.S., et al., 2016. Characterizing safety-net providers' HPV vaccine recommendations to undecided parents: a pilot study. Patient Educ. Couns. 99 (9), 1452–1460. https://doi.org/10.1016/j.pec.2016.06.027.
Stokley, S., Jeyarajah, J., Yankey, D., et al., 2014. Human papillomavirus vaccination coverage among adolescents, 2007-2013, and postlicensure vaccine safety monitoring, 2006-2014–United States. MMWR Morb. Mortal. Wkly Rep. 63 (29), 620–624.
Sturm, L., Donahue, K., Kasting, M., Kulkarni, A., Brewer, N.T., Zimet, G.D., 2017. Pediatrician-parent conversations about human papillomavirus vaccination: an analysis of audio recordings. J. Adolesc. Health 61 (2), 246–251. https://doi.org/10.1016/j.jadohealth.2017.02.006.
Suryadevara, M., Bonville, J.R., Kline, R.M., et al., 2016. Student HPV vaccine attitudes and vaccine completion by education level. Human Vaccines Immunother. 12 (6), 1491–1497. https://doi.org/10.1080/21645515.2015.1123359.
Szilagyi, P.G., Albertin, C., Humiston, S.G., et al., 2013. A randomized trial of the effect of centralized reminder/recall on immunizations and preventive care visits for adolescents. Acad. Pediatr. 13 (3), 204–213. https://doi.org/10.1016/j.acap.2013.01.002.
The 2008 National Immunization Survey-Teen, 2009. U.S. Department of Health and Human Services (DHHS), National Center for Health Statistics, Centers for Disease Control and Prevention, Hyattsville, MD.
The 2009 National Immunization Survey-Teen, 2010. U.S. Department of Health and Human Services (DHHS), National Center for Health Statistics, Centers for Disease Control and Prevention, Hyattsville, MD.
The 2010 National Immunization Survey-Teen, 2011. U.S. Department of Health and Human Services (DHHS), National Center for Health Statistics, Centers for Disease Control and Prevention, Hyattsville, MD.
The 2011 National Immunization Survey-Teen, 2012. U.S. Department of Health and Human Services (DHHS), National Center for Health Statistics, Centers for Disease Control and Prevention, Hyattsville, MD.
The 2012 National Immunization Survey-Teen, 2013. U.S. Department of Health and Human Services (DHHS), National Center for Health Statistics, Centers for Disease Control and Prevention, Hyattsville, MD.
The 2013 National Immunization Survey-Teen, 2014. U.S. Department of Health and Human Services (DHHS), National Center for Health Statistics, Centers for Disease Control and Prevention, Hyattsville, MD.
The 2014 National Immunization Survey-Teen, 2015. U.S. Department of Health and Human Services (DHHS), National Center for Health Statistics, Centers for Disease Control and Prevention, Hyattsville, MD.
The 2015 National Immunization Survey-Teen, 2016. U.S. Department of Health and Human Services (DHHS), National Center for Health Statistics, Centers for Disease Control and Prevention, Hyattsville, MD.
The 2016 National Immunization Survey-Teen. U.S, 2017. Department of Health and Human Services (DHHS), National Center for Health Statistics, Centers for Disease Control and Prevention, Hyattsville, MD.
The 2017 National Immunization Survey-Teen, 2018. U.S. Department of Health and Human Services (DHHS), National Center for Health Statistics, Centers for Disease Control and Prevention, Hyattsville, MD.

The 2018 National Immunization Survey-Teen, 2019. U.S. Department of Health and Human Services (DHHS), National Center for Health Statistics, Centers for Disease Control and Prevention, Hyattsville, MD.
The National Immunization Survey-Teen, 2021. Centers for Disease Control and Prevention.
Vu, M., Bednarczyk, R.A., Escoffery, C., Getachew, B., Berg, C.J., 2019. Human papillomavirus vaccination among diverse college students in the state of Georgia: who receives recommendation, who initiates and what are the reasons? Health Educ. Res. 34 (4), 415–434. https://doi.org/10.1093/her/cyz014.
Williams, W.W., Lu, P.-J., Saraiya, M., et al., 2013. Factors associated with human papillomavirus vaccination among young adult women in the United States. Vaccine. 31 (28), 2937–2946. https://doi.org/10.1016/j.vaccine.2013.04.041.
Wilson, A.R., Hashibe, M., Bodson, J., et al., 2016. Factors related to HPV vaccine uptake and 3-dose completion among women in a low vaccination region of the USA: an observational study. BMC Womens Health 16 (1), 41. https://doi.org/10.1186/s12905-016-0323-5.