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Socioeconomic/health-related factors associated with HPV vaccination initiation/completion among females of paediatric age: A systematic review with meta-analysis

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ABSTRACT

Objectives: To systematically identify, appraise, and summarise published evidence on individual socioeconomic and health-related factors associated with human papillomavirus (HPV) vaccination initiation and completion among females of paediatric age.

Study design: A global systematic review with meta-analysis (PROSPERO: CRD42023445721).

Methods: We performed a literature search in December 2022 and supplemented the search on August 1, 2023. Appropriate data were pooled using an inverse variance, random-effects model and the results were expressed as odds ratios, with 95 % confidence intervals. A statistically significant point pooled increased/decreased odds of 30–69 % was regarded to be strongly associated, and ≥70 % was very strongly associated.

Results: We included 83 cross-sectional studies. Among several significantly associated factors, being an older girl: 1.67 (1.44–1.93), having health insurance: 1.41 (1.16–1.72), and being in a public school: 1.54 (1.05–2.26) strongly increased the odds of vaccination initiation, and nativity in the country of study: 1.82 (1.33–2.50), use of contraception: 2.00 (1.16–3.46), receipt of influenza vaccination: 1.75 (1.54–2.00) and having visited a healthcare provider: 1.85 (1.51–2.28) in the preceding year very strongly increased the odds of vaccination initiation. Likewise, being an older girl: 1.36 (1.23–1.49) and having visited a healthcare provider in the preceding year: 1.46 (1.05–2.04) strongly increased the odds of vaccination series completion, and school-based vaccination: 3.08 (1.05–9.07), having health insurance: 1.72 (1.27–2.33), and receipt of influenza vaccination in the preceding year: 1.72 (1.62–1.83) very strongly increased the odds of vaccination series completion. We made similar observations when the studies were limited to the United States.

Conclusions: Several individual socioeconomic/health-related factors may determine initiating and completing the HPV vaccination series among paediatric females. These factors provide insights that may be key to identifying girls at increased risk of not being vaccinated and may aid targeted public health messaging.

1. Introduction

Human papillomavirus (HPV) infection is the most common sexually transmitted infection in the world [1], with at least one infection during a lifetime in about 80 % of sexually active individuals [2]. While many of the infections are asymptomatic and resolve spontaneously within a couple of years, some persist and develop into cancerous lesions, causing significant morbidity and mortality [3].

Vaccination is an effective and practical strategy for the prevention of high-risk HPV infection. Cervarix® (a bivalent vaccine) protects

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against two high-risk HPV types; 16 and 18, which cause 70 % of cervical cancers. Among females, it is approved for use in 9-45-year-olds and involves administration of one dose followed by another dose one month later, and a third dose six months after the first dose's administration. However, the vaccine may also be administered in a two-dose-only schedule among healthy 9-14-year-olds. Gardasil® (a quadrivalent vaccine) protects against four HPV types; 6 and 11, which cause about 90 % of anogenital warts, as well as 16 and 18, and Gardasil®9 protects against nine HPV types; 6, 11, 16, and 18, in addition to types 31, 33, 45, 52, 58, which cause about 14 % of anogenital cancers. Among females, both vaccines are also approved for use in 9-45-year-olds and involve administration of one dose followed by another dose two months later, and a third dose six months after the first dose's administration. The vaccines may also be administered in a two-dose-only schedule among healthy 9-14-year-olds.

Despite the availability of the HPV vaccine and publicly funded paediatric vaccination programmes in many jurisdictions, initiation of the vaccine and the vaccination series completion rates remain low across jurisdictions. In Canada for example, HPV vaccination initiation rates have been estimated to be around 55.92 % (66.95 % among those ≤18years compared with 13.58 % among those >18years, and 69.62 % among school-based programmes compared with 18.66 % for community-based programmes) [4], which is far below both the WHO and the Canadian national targets of 90 % [5].

Vaccine acceptance is informed by a complex decision-making process [6]. While knowledge and attitudes towards vaccination may influence uptake of a vaccine, some individual socioeconomic and health-related factors could facilitate or hinder vaccine access and uptake. Insights into these potential factors could help in designing better targeted and more effective public health messaging and intervention programmes to optimize HPV vaccination.

While there have been some published systematic reviews of factors that may influence HPV vaccination, they are mostly narrative, focused on qualitative factors, and limited to a few socioeconomic/health-related factors (not extensive) [7–11]. Many of those that included quantitative summaries (meta-analysis) did not utilise stringent and thorough literature screening and inclusion processes, which resulted in the inclusion and pooling of results for actual receipt of vaccine together with results for the willingness to vaccinate, which does not imply uptake of vaccine [12–14]. As such, the findings from many of these systematic reviews may not be entirely accurate and valid for well-informed evidence-based public health decision-making. Further, since publication of these systematic reviews, the evidence on factors associated with HPV vaccination has been accumulating, thus, providing the opportunity to review and summarise a larger body of published evidence for increased precision of pooled effect estimation. Even so, there is a lack of published systematic reviews with meta-analyses of individual socioeconomic and health-related factors that may influence HPV vaccination series completion.

We aimed to address these identified methodological deficiencies across published systematic reviews, and gaps in knowledge, by systematically identifying, appraising, and carefully summarising appropriate published evidence on individual socioeconomic and health-related factors associated with HPV vaccination initiation and vaccination series completion among females, and herein, we report our findings on paediatric females.

2. Methods

We conducted a comprehensive global systematic evidence review with meta-analysis following the Cochrane Handbook for Systematic Reviews of Interventions guidelines [15]. The review protocol was registered in the international prospective register of systematic reviews (PROSPERO: CRD42023445721). Herein, we report our findings following the Meta-analyses Of Observational Studies in Epidemiology (MOOSE) guidelines [16].

2.1. Literature search strategy and study eligibility criteria

An experienced health librarian designed a sensitive search strategy for MEDLINE (Ovid) to identify potentially relevant studies of determinants of human papillomavirus vaccination irrespective of vaccine type. The search strategy was peer-reviewed by an independent health librarian using the Peer Review of Electronic Search Strategies (PRESS) Checklist [17]. Following suggested revisions by the independent librarian, the MEDLINE search strategy was revised and adapted by the experienced health librarian for Embase (Ovid), CINAHL with Full Text, the Cochrane Library, Web of Science Core Collection, and Scopus (**Appendix 1**). A literature search in these bibliographic databases was conducted on December 14, 2022. Further, we searched Google Scholar on August 1, 2023, for any new peer-reviewed publications that met our eligibility criteria, but we found none. All retrieved literature citations were imported into and de-duplicated in EndNote (X9.2) software [18].

The de-duplicated citations were imported into a specially designed Microsoft Access 2016 database (Microsoft Corporation, Redmond, WA, U.S.) for literature sifting and double-screened independently by experienced reviewers with knowledge of the review topic, using a two-stage sifting approach to review the title/abstract, and full-text articles of identified relevant citations. We documented the number of ineligible citations at the title/abstract screening stage and the number and reasons for ineligibility at the full-text article screening stage. The reference lists of all finally included full-text studies were scanned for any potentially relevant studies not captured through the searches. Discrepancies in decisions were discussed and resolved between paired reviewers and, if needed, by involving a third reviewer.

We included peer-reviewed full-text publications of randomized controlled trials (RCT), non-randomized studies (NRS), and cohort, case-control, and cross-sectional studies reporting on individual socioeconomic and/or health-related factors associated with the HPV vaccination initiation and/or vaccination series completion among female paediatric (<18-year-olds) populations. Preprint articles (published online but not peer-reviewed), theses/dissertations, modelling studies, case reports/series, reviews, commentaries/opinion pieces/letters to the editor, and grey literature were excluded. Vaccination initiation was defined as receipt of at least one vaccine dose, and vaccination series completion was defined as receipt of the recommended three-doses of vaccine although the vaccines may also be administered in a two-dose-only schedule among healthy 9-14year-old females, in which case, the two-dose schedule for this population subgroup was also considered as completion of vaccination series. A study had to report multivariable adjusted and complete results (point effect estimate and associated 95 % confidence interval [CI]) of association between HPV vaccination initiation and/or vaccination series completion and individual socioeconomic and/or health-related factors irrespective of whether vaccination was self-reported or determined via medical records (electronic or paper-based).

2.2. Data extraction

A data extraction spreadsheet was designed in MS Excel (Microsoft Corporation, Redmond, WA, U.S.) and piloted on a small selection of studies (n = 5). Data were extracted from the included studies by one reviewer and the extracted data were independently checked and corrected and if any errors were identified.

2.3. Study quality assessment

We assessed the quality of the included studies using the National Institutes of Health (NIH) quality assessment tool for observational cohort and cross-sectional studies [19]. The process was conducted by one reviewer, and the judgments were independently checked and corrected if any errors were identified. The NIH quality assessment tool assesses 14 criteria to determine study quality. A study was judged to be of high quality if all assessed parameters were judged to be satisfactory, of good quality if all but one parameter were judged to be satisfactory, of moderate quality if all but two to four parameters were judged to be satisfactory, and of poor quality if more than four parameters were judged to be unsatisfactory.

2.4. Data synthesis and analysis

Relevant characteristics and quality assessments of the included studies are presented in a tabular form and analysed descriptively. Drawing from our previous similar systematic reviews with meta-analyses on influenza vaccine uptake and adherence to the vaccination [20–23], it was anticipated that most of the included studies in this review would likely have reported adjusted odds ratios and that if any reported adjusted relative risks or prevalence ratios, they would be converted to odds ratios, albeit if enough information for conversion was available. Where not possible, we pooled any adjusted relative risks and prevalence ratios with the odds ratios and then conducted sensitivity analysis excluding the studies. We reported our findings on the sensitivity analysis only if significantly different from the overall analysis.

Where a reverse comparison was needed for uniformity of comparison in a pooled analysis, a study result and its associated 95 % CI were inverted. If a study reported results for more than one comparison on the same characteristic, for example, comparison of 15–17-year-olds and 12–14-year-olds with 9–11-year-olds, the two results were first pooled to represent older compared with younger girls in the study population, using a fixed effects model before being pooled with results of similar comparisons from other studies with different populations, using a random effects model. Further, parent/guardian sociodemographic factors were those for the parent/guardian who participated in a study.

Where appropriate (at least two applicable results), the adjusted individual study results and their associated 95 % CIs were pooled using an inverse variance, random-effects model (DerSimonian and Laird method) [24], and the pooled results expressed with associated 95 % CIs. A statistically significant point pooled increased/decreased odds of 30 %–69 % was regarded to be strongly associated, and a ≥70 % increased/decreased odds was very strongly associated. Statistical heterogeneity was assessed using the I^2 statistic [25]. Where appropriate (if ≥ 10 contributing results in a pooled analysis), we assessed for publication bias using Egger's regression test [26]. Due to a large proportion of studies from the U.S., we conducted a sensitivity analysis limited to studies from the U.S. Data were managed and analysed using the STATA software (version 16; StataCorp LP, Texas, U.S.).

3. Results

From a total 18,279 retrieved literature citations, we included 83 cross-sectional studies (Fig. 1) [27–109]. Relevant characteristics of these included studies are summarized in Table 1. Most studies (60 %) were from the U.S. There were four studies from Canada [43,71,85,94], three studies each from Denmark [65,93,108], France [35,63,87], and Uganda [27,51,72], two studies each from Brazil [39,40], Germany [92, 96], Netherlands [36,66], Sweden [45,107], Tanzania [73,106], and the United Kingdom (U.K.) [29,95], and one study each from Australia [102], China [62], Ethiopia [53], Haiti [86], Italy [103], India [69], New Zealand [78], and Norway [46]. Study year, age group of focus, and participants' sample size varied across the studies, ranging from 80 persons to 3,690,000 persons for vaccination initiation, and 300 persons to 550,048 persons for vaccination series completion. Seven studies were funded by industry [31,33,35,49,68,69,86], while non-industry

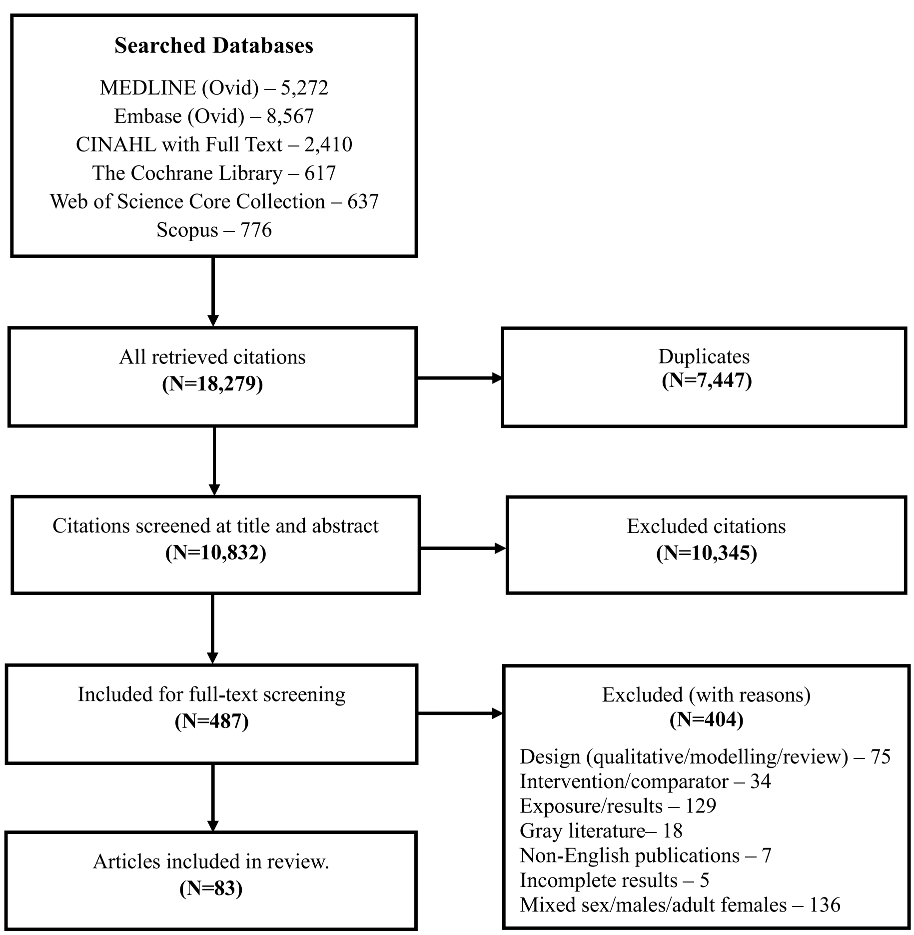

Fig. 1. Summary of literature search and citation screening (Modified PRISMA flow chart).

Table 1
Summary characteristics of the included studies.

Study (country - [region])	Study year (funder)	Age group (sample size - [vaccination])	Outcome(s) (assessed determinant(s))	Effect estimate (adjusted covariates)
Aruho 2022 [27] (Uganda - [Gulu Municipality])	2020 (Not funded)	15–18 years (250 - [Self-reported])	One or more vaccinations (Parent's marital status)	Odds ratio (Not clear)
Bastani 2011 [28] (U.S. - [Los Angeles])	2009 (CDC/NCI UCLA Cancer Prevention and Control Research Network)	9–18 years (490 - [Self-reported])	One or more vaccinations (Age, and parent's educational attainment)	Odds ratio (Not reported)
Bedford 2021 [29] (U.K. - [The four UK regions])	2012 to 2015 (The Economic and Social Research Council and a consortium of U.K. government departments)	14 years (5654 - [Self-reported])	One or more vaccinations (Socioeconomic status, and school type)	Odds ratio (Parental ethnic background, parental religious faith, household income quintile, history of school exclusion, school type, and age at interview in whole years)
Bhatta 2015 [30] (U.S. - [Rural Ohio])	2012 (Not reported)	11–18 years (405 - [Self-reported])	One or more vaccinations (Age)	Odds ratio (Sex, age, ethnicity/race, parents talked about HPV vaccine, and health care provider talked about HPV vaccine)
Chao 2010 [31] (U.S. - [Kaiser Permanente Southern California])	2006 to 2008 (Merck & Co, Inc.)	9–17 years (179,580 - [Medical records])	One or more vaccinations (Ethnicity/race, healthcare provider, and primary care physician's sex)	Relative risk (Demographic variables, provider specialty and gender, primary care provider visits, hospitalizations, emergency room visits, history of influenza vaccination, history of asthma/allergy (combined), and drug allergy. In addition, for young women, obstetric history, history of STDs, and pap smear screening)
Choi 2016 [32] (U.S. - [National])	2012 and 2013 (Not funded)	13–17 years (18,350 - [Medical records])	One or more vaccinations (Age, ethnicity/race, parent's educational attainment, and health insurance)	Odds ratio (14 independent variables (13 socio-demographic variables and survey year) and sex)
Cook 2010 [33] (U.S. - [Florida])	2006 to 2008 (Merck, Inc.)	11–18 years (550,048 - [Medical records])	One or more vaccinations, and completion of vaccination schedule (Age, ethnicity/race, and sexually active)	Odds ratio (Geographic region, Medicaid plan type, number of enrolled months, having any outpatient visit, and month of vaccination)
Cuff 2016 [34] (U.S. - [Virginia])	2014 (The South Carolina Clinical & Translational Research Institute)	11–12 years (907 - [Medical records])	One or more vaccinations (Ethnicity/race, and health insurance)	Odds ratio (Not clear)
Dalon 2021 [35] (France - [National])	2018 (MSD (Merck & Co.) France)	11 years (335,767 - [Medical records])	One or more vaccinations (Use of contraception, visit to healthcare provider, having a chronic condition, and hospitalization)	Odds ratio (Not reported)
de Munter 2021 [36] (Netherlands - [National])	2017 (The Dutch National Institute for Public Health and the Environment)	13 years (96,007 - [Medical records])	One or more vaccinations (Socioeconomic status, and distance to clinic)	Odds ratio (Not clear)
Dorell 2011 [37] (U.S. - [National])	2008 to 2009 (Not reported)	13–17 years (18,228 - [Medical records])	One or more vaccinations, and completion of vaccination schedule (Age, ethnicity/race, area of residence, parent's age, parent's educational attainment, parent's marital status, health insurance, and healthcare facility type)	Prevalence ratio (Survey year and state of residence)
Du 2015 [38] (U.S. - [Connecticut, Massachusetts, Rhode Island, West Virginia, and Wyoming])	2010 (Not reported)	9–17 years (2201 - [Self-reported])	One or more vaccinations, and completion of vaccination schedule (Age, area of residence, annual household income, parent's age, parent's educational attainment, parent's employment status, parent's marital status, visit to healthcare provider, health insurance, and influenza vaccination in the past year)	Odds ratio (Age, sex, seasonal influenza shot, and parent's characteristics)
Faisal-Cury 2020 [39] (Brazil - [National])	2015 (Not funded)	13–17 years (5404 - [Self-reported])	One or more vaccinations (Age, ethnicity/race, living circumstance, school type, parent's educational attainment, and number of sexual partners)	Prevalence ratio (Age, ethnicity, maternal level of education, consumer goods and services score, type of school, having had sexual intercourse, number of sexual partners, age at first intercourse, condom use in most recent encounter, and condom use at first intercourse)
Farias 2016 [40] (Brazil - [Boa Vista, Roraima])	2015 (Universidade Federal de Roraima)	12–14 years (797 - [Self-reported])	One or more vaccinations (School type)	Odds ratio (Not clear)
Gelman 2013 [41] (U.S. - [National])	2008 to 2010 (University of Pittsburgh's Clinical and Translational	15–18 years (872 - [Self-reported])	One or more vaccinations (Ethnicity/Race)	Odds ratio (All of the sociodemographic variables as well as household income and insurance

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Table 1 (*continued*)

Study (country - [region])	Study year (funder)	Age group (sample size - [vaccination])	Outcome(s) (assessed determinant(s))	Effect estimate (adjusted covariates)
	Sciences Institute National Institutes of Health through Grants)			status and whether the participant had a usual place for receiving health care)
Gerend 2013 [42] (U.S. - [Southwestern Florida])	2010 (Florida State University College of Medicine Summer Research Fellowship award)	9–18 years (200 - [Self-reported])	One or more vaccinations (Age, and parent's educational attainment)	Odds ratio (Mother's age, daughter's age, mother's education, years in the US for foreign-born, interview language, physician recommendation, heard of HPV, and vaccine beliefs)
Gilbert 2016 [43] (Canada - [National])	2013 (The Public Health Agency of Canada)	12–14 years (5720 - [Self-reported])	One or more vaccinations (Age, and born in the country of study)	Odds ratio (Age, province or territory, place of birth, education of responding parent, total household income, and country of birth of responding parent)
Gowda 2013 [44] (U.S. - [Michigan])	2006 to 2010 (Centers for Disease Control and Prevention)	11–18 years (588,597 - [Medical records])	One or more vaccinations (Age)	Odds ratio (Not reported)
Grandahl 2017 [45] (Sweden - [National])	2014 to 2015 (The Swedish Cancer Society)	Adolescents (391 - [Self-reported])	One or more vaccinations (Parent's educational attainment)	Odds ratio (Not clear)
Hansen 2015 [46] (Norway - [National])	2009 to 2011 (The Cancer Registry of Norway)	12–13 years (90,842 - [Medical records])	One or more vaccinations, and completion of vaccination schedule (Region of residence, annual household income, parent's age, parent's educational attainment, parent's employment status, and parent's marital status)	Odds ratio (Not clear)
Henry 2016 [47] (U.S. - [National])	2011 to 2012 (The Huntsman Cancer Institute Foundation, Primary Children's Hospital Foundation, the Beaumont Foundation, and the University of Utah, School of Medicine)	13–17 years (20,308 - [Medical records])	One or more vaccinations (Age, ethnicity/race, annual household income, poverty level, parent's age, parent's educational attainment, parent's marital status, and health insurance)	Odds ratio (Age, health insurance coverage, mother's education, mother's marital status, mother's age, poverty status, ethnicity/race, provider recommendations, facility type where vaccines were administered, and survey year)
Hirth 2012 [48] (U.S. - [National])	2006 to 2009 (Eunice Kennedy Shriver National Institute of Child Health and Human Development)	≥9 years (271,976 - [Medical records])	Completion of vaccination schedule (Age)	Odds ratio (Provider type and region, and year at first vaccination was included as a continuous variable in one)
Hofstetter 2014 [49] (U.S. - [New York City])	2007 to 2011 (Investigator-Initiated Studies Program of Merck Sharp & Dohme Corp)	11–12 years (Not clear - [Medical records])	One or more vaccinations (Ethnicity/race, and healthcare provider)	Odds ratio (Language, insurance, clinic site, and race)
Inguva 2020 [50] (U.S. - [Mississippi])	2014 to 2018 (Not funded)	9–26 years (18,110 - [Medical records])	Completion of vaccination schedule (Age)	Odds ratio (Age group, race/ethnicity, geographic location in terms of public health region, plan at initiation and provider who initiated the HPV vaccine series)
Isabirye 2020 [51] (Uganda - [National])	2016 (Not funded)	10–14 years (6093 - [Self-reported])	One or more vaccinations (Age, socioeconomic status, and school-based vaccination)	Odds ratio (Not clear)
Johnson 2017 [52] (U.S. - [National])	2013 (Not funded)	13–17 years (7375 - [Medical records])	One or more vaccinations, and completion of vaccination schedule (Age, ethnicity/race, region of residence, federal poverty level, parent's age, parent's educational attainment, parent's marital status, and healthcare facility type)	Odds ratio (Not clear)
Kassa 2021 [53] (Ethiopia - [Minjar-Shenkora Woreda, North Shewa Zone, Amhara Region])	2020 (Not funded)	11–15 years (591 - [Self-reported])	One or more vaccinations (Area of residence, religion, and parent's educational attainment)	Odds ratio (Not reported)
Kepka 2015 [54] (U.S. - [National])	2012 (University of Utah College of Nursing, the Huntsman, Cancer Institute Foundation, the Primary Children's Hospital Foundation, the Beaumont Foundation, and the National Center for Advancing Translational Sciences of the National Institutes of Health)	13–17 years (9376 - [Medical records])	Completion of vaccination schedule (Age, ethnicity/race, annual household income, poverty level, parent's age, parent's educational attainment, parent's marital status, healthcare facility type, and influenza vaccination in the past year)	Odds ratio (Mother's education, poverty status, ethnicity/race, adolescent's age, source of health insurance, facility type, and receipt of other adolescent vaccinations)
Klosky 2013 [55] (U.S. - [St. Jude Children's Research Hospital])	2010 to 2011 (Cancer Center Support grant and American Lebanese Syrian Associated Charities)	9–17 years (300 - [Self-reported])	One or more vaccinations, and completion of vaccination schedule (Age, and family or personal history of cancer)	Odds ratio (Not reported)
Kornides 2019 [56] (U.S. - [National])	Not clear (The Center for Human Papillomavirus Research, funded by the Indiana University–Purdue University Indianapolis)	11–14 years (3261 - [Self-reported])	One or more vaccinations (Age, region of residence, annual household income, parent's age, parent's ethnicity/race, parent's	Odds ratio (Maternal characteristics (age, race/ethnicity, education attainment, vaccination confidence), child characteristics (age, sex, insurance status), and household

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Table 1 (*continued*)

Study (country - [region])	Study year (funder)	Age group (sample size - [vaccination])	Outcome(s) (assessed determinant(s))	Effect estimate (adjusted covariates)
			educational attainment, and health insurance)	characteristics (annual household income, US census region))
Kramer 2012 [57] (U.S. - [National])	2007 (Not reported)	12–17 years (17,264 - [Self-reported])	One or more vaccinations, and completion of vaccination schedule (Age, ethnicity/race, living circumstance, federal poverty level, parent's educational attainment, and health insurance)	Odds ratio (Family poverty status, child's insurance status, medical home, and physician counselling)
Lai 2015 [58] (U.S. - [Intermountain West])	2012 (The University of Utah's College of Nursing, the Huntsman Cancer Institute Foundation, the Primary Children's Hospital Foundation, the Beaumont Foundation, and the National Center for Advancing Translational Sciences of the National Institutes of Health)	13–17 years (1203 - [Medical records])	One or more vaccinations, and completion of vaccination schedule (Age, ethnicity/race, annual household income, poverty level, parent's age, parent's educational attainment, parent's marital status, and influenza vaccination in the past year)	Prevalence ratio (Not clear)
Lau 2012 [59] (U.S. - [National])	2007 (Not reported)	12–17 years (16,462 - [Self-reported])	One or more vaccinations (Ethnicity/race, federal poverty level, and visit to healthcare provider)	Odds ratio (Adolescent's age, insurance status, and US region)
Laz 2012 [60] (U.S. - [National])	2010 (Eunice Kennedy Shriver National Institute of Child Health and Human Development)	11–17 years (2171 - [Self-reported])	One or more vaccinations, and completion of vaccination schedule (Ethnicity/race, federal poverty level, parent's educational attainment, health insurance, visit to healthcare provider, and influenza vaccination in the past year)	Odds ratio (Nor reported)
Lee 2016 [61] (U.S. - [Massachusetts])	Not clear (The National Cancer Institute)	12–17 years (129 - [Self-reported])	One or more vaccinations (Age, and annual household income)	Odds ratio (Age, percent of life in the US, monthly family income, education attended in the US, read English, have heard about HPV, mother's HPV knowledge, how comfortable discussing STDs with daughter)
Li 2013 [62] (China - [Hong Kong])	Not reported (The Family Planning Association, Hong Kong)	Adolescents (1832 - [Self-reported])	One or more vaccinations (Age, born in the country of study, parent's educational attainment, and parent's marital status)	Odds ratio (Grade level, birthplace, mother's education, parental marital status)
Lions 2013 [63] (France - [South-Eastern region])	2007 to 2009 (ARS PACA and the Regional Council (financing of the SIRSE PACA project))	14–16 years (105,327 - [Medical records])	One or more vaccinations, and completion of vaccination schedule (Area of residence, healthcare provider, visit to healthcare provider, and consultation with a specialist)	Relative risk (Not reported)
Lu 2018 [64] (U.S. - [National])	2015 (Not reported)	13–17 years (Not clear - [Self-reported])	One or more vaccinations, and completion of vaccination schedule (Health insurance)	Prevalence ratio (Age, adolescent's race/ethnicity, mother's educational level, mother's marital status, mother's age, adolescent's country of origin, household poverty level, type of health insurance (except among uninsured), number of healthcare provider contacts within past 12 months, provider reported well-child visit at 11–12 years, number of vaccination providers, vaccination facility types (all public, all private, all hospital, all sexually transmitted diseases [STD]/school/teen clinics, others [such as military, women, infants, and children clinics, and pharmacies], and mixed [including adolescents who received vaccines from facilities in more than one of the previously listed categories]), metropolitan statistical area, and US Census region)
Møller 2018 [65] (Denmark - [National])	2008 to 2012 (Not reported)	12–15 years (9065 - [Medical records])	One or more vaccinations (Born in or a citizen of the country of study)	Odds ratio (Income)
Mollers 2014 [66] (Netherlands - [National])	2010 (Not reported)	16–17 years (2989 - [Self-reported])	One or more vaccinations (Religion, alcohol consumption, and use of contraception)	Odds ratio (Not clear)
Monnat 2013 [67] (U.S. - [Nine States and Puerto Rico])	2008 to 2010 (Not reported)	9–17 years (4776 - [Self-reported])	One or more vaccinations, and completion of vaccination schedule (Age, area of residence, annual household income, parent's age,	Odds ratio (Adolescent's age, mother's demographic characteristics, socioeconomic status, family characteristics, mother's access

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Table 1 (*continued*)

Study (country - [region])	Study year (funder)	Age group (sample size - [vaccination])	Outcome(s) (assessed determinant(s))	Effect estimate (adjusted covariates)
			parent's ethnicity/race, parent's educational attainment, parent's marital status, and parent's employment status)	to a personal doctor and receipt of a physical examination in the past year)
Moss 2012 [68] (U.S. - [North Carolina])	2008 to 2010 (Supported in part by an educational grant from GlaxoSmithKline and the Cancer Control Education Program at University of North Carolina Lineberger Comprehensive Cancer Center, with additional support from the National Institutes of Health)	11–17 years (1437 - [Self-reported])	One or more vaccinations (Age, area of residence, school type, visit to healthcare provider and influenza vaccination in the past year)	Odds ratio (Not reported)
Mukherjee 2014 [69] (India - [Mysore])	Not clear (The Investigator Initiated Award from Merck & Co)	11–15 years (778 - [Self-reported])	Completion of vaccination schedule (Parent's age, and parent's educational attainment)	Odds ratio (Parent's age, education, occupation, religion, receipt of other vaccine, and many questions regarding healthcare)
Munn 2019 [70] (U.S. - [Seattle, Washington])	1995 to 2000 (The Centers for Disease Control and Prevention)	13–18 years (12,676 - [Medical records])	Completion of vaccination schedule (School-based vaccination)	Odds ratio (Not clear)
Musto 2013 [71] (Canada - [Calgary])	2008 to 2011 (Not reported)	9–15 years (35,592 - [Medical records])	Completion of vaccination schedule (Age, school-based vaccination, and Hepatitis B virus vaccination)	Odds ratio (Vaccine delivery system, school type, socioeconomic status, HBV vaccination status, and school class grade)
Nabirye 2020 [72] (Uganda - [Mbale District])	Not clear (The Makerere University School of Public Health, and The German Academic Exchange Services, Deutscher Akademischer Austauschdient)	9–15 years (407 - [Self-reported])	One or more vaccinations (Age)	Prevalence ratio (Age group, tribe, religion, and occupation, having many options from which to receive the HPV vaccine, knowing where to report side effects, having received any other vaccines, getting HPV vaccine together with other services, knowing where to report the side effects, and receiving adequate information about the vaccine)
Nhumba 2022 [73] (Tanzania - [Dar es Salaam])	Not reported (Not funded)	12–14 years (389 - [Self-reported])	One or more vaccinations (Age, socioeconomic status, parent's educational attainment, and parent's employment status)	Odds ratio (Not reported)
Niccolai 2011 [74] (U.S. - [National])	2008 to 2009 (The Centers for Disease Prevention and Control)	13–17 years (7606 - [Medical records])	Completion of vaccination schedule (Age, ethnicity/race, region of residence, annual household income, parent's educational attainment, parent's marital status, and health insurance)	Odds ratio (Age, year, ethnicity/race, poverty level, mother's education, mother's marital status, health insurance, well-child visit, and region)
Palli 2012 [75] (U.S. - [National])	2007 t0 2008 (Not reported)	12–17 years (3,690,000 - [Self-reported])	One or more vaccinations (Age, region of residence, federal poverty level, health insurance, and visit to healthcare provider)	Odds ratio (Not reported)
Perkins 2012 [76] (U.S. - [Boston])	2007 to 2009 (American Cancer Society Mentored Research Scholar grant, a Building Interdisciplinary Research Careers in Women's Health grant, and an American Cancer Society Boston University Institutional Research grant)	11–12 years (1371 - [Medical records])	One or more vaccinations, and completion of vaccination schedule (Ethnicity/Race)	Odds ratio (Location of care, number of visits in study period, ethnicity/race, provider documentation of STI or alcohol use, receipt of meningococcal vaccine, and Tdap vaccination)
Pierce 2013 [77] (U.S. - [Virginia])	2008 to 2009 (American College of Obstetrics and Gynecology/Merck & Company, Inc. Immunization Award for Residents and Fellows)	11–12 years (242 - [Medical records])	One or more vaccinations (Ethnicity/race)	Odds ratio (Not reported)
Poole 2012 [78] (New Zealand - [Auckland])	2009 (Not reported)	11–18 years (8665 - [Medical records])	One or more vaccinations (Socioeconomic status, and school type)	Odds ratio (Not reported)
Porsch 2020 [79] (U.S. - [National])	2011 to 2017 (Dean's Dissertation grant from the CUNY Graduate School of Public Health and Health Policy)	15–17 years (Not reported - [Self-reported])	One or more vaccinations (Sexual orientation)	Odds ratio (Ethnicity/race, highest level of education, total household income, and age (for the STD treatment models only))
Pruitt 2010 [80] (U.S. - [Delaware, New York, Oklahoma, Pennsylvania, Texas, and West Virginia])	2008 (Not reported)	13–17 years (1709 - [Self-reported])	One or more vaccinations (Age, ethnicity/race, socioeconomic status, annual household income, parent's educational attainment, and health insurance)	Odds ratio (Individual, state, and county-level factors)
Rahman 2014 [81] (U.S. - [National])	2011 (The Eunice Kennedy Shriver National Institute of Child Health & Human Development)	13–17 years (11,236 - [Medical records])	One or more vaccinations, and completion of vaccination schedule (Age, ethnicity/race, region of residence, federal poverty level, parent's age, health insurance, and	Prevalence ratio (Region, pupil's age, respondent's age, ethnicity/race, family income, eligibility for VFC program, healthcare coverage, moved from different state, provider-

(*continued on next page*)

Table 1 (*continued*)

Study (country - [region])	Study year (funder)	Age group (sample size - [vaccination])	Outcome(s) (assessed determinant(s))	Effect estimate (adjusted covariates)
			influenza vaccination in the past year)	confirmed seasonal influenza vaccination in past 3 years by age 13, and HPV vaccine awareness)
Rahman 2015 [82] (U.S. - [National])	2012 (The National Institutes of Health)	13–17 years (4548 - [Medical records])	Completion of vaccination schedule (Age, ethnicity/race, parent's educational attainment, and influenza vaccination in the past year)	Prevalence ratio (Age, race/ethnicity, mother's education, provider-confirmed seasonal influenza vaccination in past year, provider recommendation of vaccine, and region)
Reiter 2010 [83] (U.S. - [North Carolina])	2008 (Centers for Disease Control and Prevention, the American Cancer Society, and the Cancer Control Education Program at Lineberger Comprehensive Cancer Center)	10–17 years (617 - [Self-reported])	One or more vaccinations (Age, area of residence, have a primary care physician, visit to healthcare provider, and influenza vaccination in the past year)	Odds ratio (Age, having a regular healthcare provider, having preventive health check in last 12 months, received meningococcal vaccine, parent characteristics (employment), received influenza vaccine in the past year, characteristics of county of residence, and percentage of population who speak a language other than English in the home)
Reiter 2011 [84] (U.S. - [North Carolina])	2008 (The Centers for Disease Control and Prevention, the American Cancer Society, and the Cancer Control Education Program at Lineberger Comprehensive Cancer Center)	11–20 years (647 - [Self-reported])	One or more vaccinations (Age)	Odds ratio (Not clear)
Remes 2014 [85] (Canada - [Ontario])	2007 to 2011 (The Ontario Ministry of Health and Long-Term Care Drug Innovation Fund)	13–14 years (144,047 - [Medical records])	One or more vaccinations (Obesity/overweight)	Odds ratio (Income quintiles, vaccination history, health care utilization, medical history, health unit-level characteristics index of area deprivation)
Riviere 2021 [86] (Haiti - [Port-au-Prince])	2016 to 2017 (The MSPP, Partners in Health, and Merck Pharmaceuticals)	9–14 years (1994 - [Self-reported])	Completion of vaccination schedule (Age, and school-based vaccination)	Odds ratio (Age, education level, menarche, having been previously followed as patient in the GHESKIO clinic, neighbourhood distance from GHESKIO clinic, guardian age, and guardian relationship to participant)
Rousset-Jablonski 2021 [87] (France - [Auvergne-Rhone-Alpes and Parisian region])	2018 to 2019 (l'Association Gregory Lemarchal)	9–17 years (113 - [Self-reported])	One or more vaccinations (Age)	Odds ratio (Not clear)
Sadigh 2012 [88] (U.S. - [National])	2006 to 2008 (Not reported)	9–18 years (444 - [Self-reported])	One or more vaccinations (Poverty level, parent's age, parent's educational attainment, and parent's marital status)	Odds ratio (Not reported)
Sara Test 2013 [89] (U.S. - [National])	2007 (Not reported)	12–17 years (15,965 - [Self-reported])	One or more vaccinations (Have a primary care physician)	Odds ratio (Age, race/ethnicity, type of health insurance, region, family nativity, relationship of respondent to child, highest education level of any patent/guardian in household, income, and primary language spoken in household)
Savas 2012 [90] (U.S. - [Texas])	2009 (National Cancer Institute and the Office of Behavioural and Social Science Research of the National Institutes of Health)	9–17 years (80 - [Self-reported])	One or more vaccinations (Ethnicity/Race)	Odds ratio (Not reported)
Schluterman 2011 [91] (U.S. - [University of Maryland Medical Center outpatient clinic])	2006 to 2010 (Not reported)	9–13 years (897 - [Medical records])	One or more vaccinations, and completion of vaccination schedule (Ethnicity/race, and health insurance)	Odds ratio (Not clear)
Schülein 2016 [92] (Germany - [National])	2007 (University of Munich)	9–17 years (1906 - [Self-reported])	One or more vaccinations (Age, annual household income, and parent's educational attainment)	Odds ratio (Age, region of residence, education, and income)
Slåttelid Schreiber 2015 [93] (Denmark - [National])	Not clear (Not reported)	15 years (65,926 - [Medical records])	One or more vaccinations, and completion of vaccination schedule (Born in the country of study, parent's educational attainment, parent's employment status, and parent's marital status)	Odds ratio (Not clear)
Smith 2011 [94] (Canada - [Ontario])	2007 to 2009 (Ontario Ministry of Health and Long-term Care's Drug Innovation Fund and by the Canadian Institutes of Health Research)	12–13 years (2519 (completion, N = 1425) - [Medical records])	One or more vaccinations, and completion of vaccination schedule (Age, Area of residence, and hospitalization)	Odds ratio (Age, neighbourhood income quintile, place of residence, vaccination history, health services utilization, medical history, and vaccination programme year)

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Table 1 (*continued*)

Study (country - [region])	Study year (funder)	Age group (sample size - [vaccination])	Outcome(s) (assessed determinant(s))	Effect estimate (adjusted covariates)
Spencer 2014 [95] (U.K. - [Northwest of England])	Not clear (NHS Cancer Screening Programme)	12–13 years (56,234 - [Medical records])	One or more vaccinations, and completion of vaccination schedule (Ethnicity/race, and socioeconomic status)	Odds ratio (Deprivation and ethnicity)
Stocker 2013 [96] (Germany - [Berlin])	2010 (Not reported)	14–18 years (161 - [Medical records])	One or more vaccinations (Age)	Odds ratio (Not clear, but claimed to have adjusted for statistically significant covariates in the univariable analysis)
Sundaram 2016 [97] (U.S. - [National])	2009 to 2014 (The Office of the Director, National Institutes of Health)	9–18 years (2469 - [Self-reported])	One or more vaccinations, and completion of vaccination schedule (Obesity/overweight)	Relative risk (Ratio of household income to federal poverty level, age group, race/ethnicity and NHANES period)
Swiecki-Sikora 2019 [98] (U.S. - [National])	2012 to 2013 (The National Institutes of Health/National Cancer Institute, the Huntsman Cancer Foundation, the Beaumont Foundation, and the American Cancer Society institutional research, and Fox Chase Cancer Center)	13–17 years (17,596 - [Medical records])	One or more vaccinations, and completion of vaccination schedule (Area of residence)	Odds ratio (Survey year, child's age, type of insurance coverage, mother's education (years), mother's marital status, mother's age, poverty status, ZCTA poverty, and state random effects)
Tiro 2012 [99] (U.S. - [California])	2007 (Not reported)	12–17 years (3615 - [Self-reported])	One or more vaccinations (Ethnicity/race, born in the country of study, federal poverty level, parent's educational attainment, and parent's marital status)	Odds ratio (Ethnicity/race, parent's educational attainment, parent's marital status, household income, time spent in the US, language of survey, healthcare insurance, usual source of health care, past visits with primary care provider)
Tiro 2012 [100] (U.S. - [Texas])	2007 to 2009 (Simmons Cancer Center and American Cancer Society)	11–18 years (700 - [Medical records])	One or more vaccinations (Age, sexually active, and influenza vaccination in the past year)	Odds ratio (Age at index visit, race/ethnicity, insurance status, whether index visit was the first time at clinic, follow-up time, clinic use in the year before index visit, receipt of other adolescent vaccines, influenza vaccination, sexual activity, and chart documentation)
Tsui 2013 [101] (U.S. - [Los Angeles])	2009 (University of California NIH/NCI R25 Cancer Education and Career Development Program and the AHRQ Grants for Health Services Research Dissertation Program)	9–18 years (Not clear - [Self-reported])	One or more vaccinations (Age, health insurance)	Odds ratio (Not clear, but included individual and neighbourhood factors)
Tung 2016 [102] (Australia - [Victoria])	2007 to 2009 (The Victorian Cancer Agency)	11–17 years (320 - [Medical records])	One or more vaccinations (Born in the country of study)	Odds ratio (Childhood vaccinations, country of birth, parental country of birth, main decision maker regarding HPV vaccination and participant age)
Venturelli 2017 [103] (Italy - [Reggio Emilia])	2008 (1996 birth cohort) (Not funded)	11 years (2260 - [Medical records])	One or more vaccinations (Born in or a citizen of the country of study, living circumstance, have siblings, and parent's educational attainment)	Relative risk (Citizenship, educational level, demographics (mother's age at birth, number of pregnancies, marital status) and adherence to screening were performed)
Verdeniusn 2013 [104] (U.S. - [Midwest])	2006 to 2009 (Not funded)	10–17 years (Not clear - [Medical records])	Completion of vaccination schedule (Ethnicity/race, and number of pregnancies or births)	Odds ratio (Ethnicity/race, gravidity, parity, visit type for dose 1 visit, visit type for dose 2 visit, non-HPV4 visits between first and last dose, and other vaccinations at dose 1 visit)
Warner 2017 [105] (U.S. - [National])	2013 (The University of Utah College of Nursing, the Huntsman Cancer Institute Foundation, the Primary Children's Hospital Foundation, the de Beaumont Foundation, and the National Center for Advancing Translational Sciences of the National Institutes of Health)	13–17 years (8256 - [Medical records])	One or more vaccinations, and completion of vaccination schedule (Age, ethnicity/race, annual household income, poverty level, parent's age, parent's educational attainment, parent's marital status, healthcare facility type, and influenza vaccination in the past year)	Prevalence ratio (Parent's age, education, poverty status, marital status (mother), and teens ethnicity/race, age, source of healthcare insurance, facility type for teen's providers, do the providers order vaccine from states/local authorities, influenza vaccination, TDAP, and Meningitis vaccinations)
Watson-Jones 2012 [106] (Tanzania - [Mwanza city and Misungwi district])	2010 to 2011 (Wellcome Trust and a Cervical Cancer Initiative Grant from the Union of International Cancer Control)	11–16 years (404 - [Medical records])	One or more vaccinations (Parent's age)	Odds ratio (Not clear)
Wemrell 2022 [107] (Sweden - [National])	2013 to 2020 (Vetenskapsrådet and FORTE)	10–12 years (311,656 - [Medical records])	One or more vaccinations (Area of residence, socioeconomic status, and parent's educational attainment)	Odds ratio (Not clear)
Widgren 2011 [108] (Denmark - [National])	2009 (Not reported)	12 years (33,838 - [Medical records])	One or more vaccinations (Have siblings, and parent's age)	Relative risk (Place or residence (area), urban/rural (population density), place of origin, age of mother and number of siblings)

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Table 1 (*continued*)

Study (country - [region])	Study year (funder)	Age group (sample size - [vaccination])	Outcome(s) (assessed determinant(s))	Effect estimate (adjusted covariates)
Yiltalo 2013 [109] (U.S. - [National])	2009 (The Robert Wood Johnson Foundation Health and Society Scholars program)	13–17 years (9274 - [Medical records])	One or more vaccinations (Age, ethnicity/race, parent's age, parent's educational attainment, parent's marital status, and health insurance)	Odds ratio (Age, race/ethnicity, mother's education, mother's age, mother's marital status, and type of health insurance, and vaccine recommendation)

U.S. = United States of America; U.K. = United Kingdom; HPV = human papillomavirus; CDC = Centers for Disease Control and Prevention; NCI = National Cancer Institute; UCLA = University of California, Los Angeles; MSD = Merck, Sharp & Dohme; FVC = Vaccines For Children; ARS = L'Agence Régionale de Santé; PACA = Provence-Alpes-Côte d'Azur; SIRSE =Système d'Information Régional en Santé de; MSPP = Ministry of Public Health and of the Population; NHANES = National Health and Nutrition Examination Survey; ZCTA = ZIP Code Tabulation Areas; NIH = National Institutes of Health; FORTE = Forskningsradet for halsa, arbetsliv och valfard.

sources funded the rest of the studies, or they were not supported by funding. Forty of the studies (48 %) utilised self-reported vaccination, whereas vaccination status was obtained from medical records in the rest of the studies (52 %). Seventy-three studies (88 %) reported on vaccination initiation while thirty-one studies (37 %) reported on vaccination series completion. Studies on vaccination series completion were all based on receipt of three-doses of vaccine. Covariate adjustments varied across the studies. Five studies reported relative risk [31,63,97,103,108], eight studies reported prevalence ratio [37,39,58,64,72,81,82,105], and the rest of the studies (n = 70; 84 %) reported odds ratio results. Only eight studies reported study sample size justification [27,36,53,61,72,73,95,106]. The studies were mostly judged to be of considerably good quality although the quality assessment did not cover all domains due to inapplicability of some of the domains to the study type/methodology. As such, the study quality assessment (Table 2) should not be overemphasized.

3.1. Pooled analysis of multivariable-adjusted association between HPV vaccination initiation and individual socioeconomic and health-related factors

Age, annual household income, area of residence, whether born in or are a citizen of the country of study, race, whether having a primary care physician, health insurance, and public or private health insurance, influenza vaccination in the preceding year, body mass index, parent's age, race, and marital status, type of school attended, use of contraception, and visit to a healthcare provider in the preceding year were all found to be associated with vaccination initiation (Table 3). Among these associated individual factors, being an older girl [adjusted OR: 1.67 (1.44–1.93), 26 studies, over 4,950,736 study participants], having health insurance [adjusted OR: 1.41 (1.16–1.72), 13 studies, over 87,578 study participants], and being in a public school versus private school [adjusted OR: 1.54 (1.05–2.26), 5 studies, 21,957 study participants] strongly increased the odds of vaccination initiation, and being born in the country of study [adjusted OR: 1.82 (1.33–2.5), 10 studies, 30,819 study participants], having received the influenza vaccination in the preceding year versus not [adjusted OR: 1.75 (1.54–2.00), 8 studies, 27,821 study participants], use of contraception (any type) [adjusted OR: 2.00 (1.16–3.46), 2 studies, 274,591 study participants], and having visited a healthcare provider in the preceding year [adjusted OR: 1.85 (1.51–2.28), 8 studies, 4,153,982 study participants] very strongly increased the odds of vaccination initiation. Most of these observations were made when limited to those whose vaccination status was determined via medical records (**Appendix 2**). Forest plots for the meta-analyses are presented as **Appendix 2**. There was no evidence of publication bias.

3.2. Pooled analysis of multivariable-adjusted association between HPV vaccination series completion and individual socioeconomic and health-related factors

Age, race, health insurance, healthcare facility type attended, influenza vaccination in the preceding year, parent's age, region of residence, whether school-based or community-based vaccination, and visit to a healthcare provider in the preceding year were all found to be associated with vaccination series completion (Table 3). Among these individual factors, being an older girl [adjusted OR: 1.36 (1.23–1.49), 14 studies, 946,055 study participants] and having visited a healthcare provider in the preceding year [adjusted OR: 1.46 (1.05–2.04), 3 studies, 109,699 study participants] strongly increased the odds of vaccination series completion, and having health insurance [adjusted OR: 1.72 (1.27–2.33), 7 studies, over 41,375 study participants], having received the influenza vaccination in the preceding year [adjusted OR: 1.72 (1.62–1.83), 7 studies, 38,991 study participants], and school-based vaccination [adjusted OR: 3.08 (1.05–9.07), 3 studies, 50,262 study participants] very strongly increased the odds of vaccination series completion. Most of these observations were made when limited to those whose vaccination status was determined via medical records (**Appendix 3**). Forest plots for the meta-analyses are presented as **Appendix 3**. There was no evidence of publication bias.

3.3. Sensitivity analysis limited to studies from the U.S

When limited to studies from the U.S., age, area of residence, race, whether having a primary care physician, health insurance, and public or private health insurance, influenza vaccination in the preceding year, parent's age, race, and marital status, and visit to a healthcare provider in the preceding year were all found to be associated with vaccination initiation (Table 4). Among these individual factors, having a primary care physician, and having health insurance strongly increased the odds of vaccination initiation, and being an older girl, having received the influenza vaccination in the preceding year, and having visited a healthcare provider in the preceding year very strongly increased the odds of vaccination initiation (Table 4).

Age, race, health insurance, healthcare facility type attended, influenza vaccination in the preceding year, region of residence, and visit to a healthcare provider in the preceding year were all found to be associated with vaccination series completion (Table 4). Among these individual factors, being an older girl and having visited a healthcare provider in the preceding year strongly increased the odds of vaccination series completion, and having health insurance and having received the influenza vaccination in the preceding year very strongly increased the odds of vaccination series completion (Table 4).

4. Discussion

Findings from this comprehensive systematic evidence review with meta-analysis indicate that, irrespective of vaccine type and method of determination of vaccination status, a girl's age, race, parent's age, health insurance, and influenza vaccination and visit to a healthcare provider in the preceding year may determine HPV vaccination initiation and vaccination series completion. The findings also indicate that, in addition to the above, annual household income, area of residence, type of school attended, birth/citizenship of a country of residence,

Table 2
Study quality assessment using the National Institutes of Health quality assessment tool for observational cohort and cross-sectional studies.

Study	Objective stated	Population specified	Participation rate at least 50 %	Participants from same population	Sample size justified	Exposures measured before outcome	Sufficient study time frame	Measured different exposure levels	Consistent exposure measure	Exposure assessed more than once	Consistent outcome measures	Blinded outcome assessment	20 % or less attrition	Confounder adjustment
Aruho 2022 [27]	✔	✔	✔	✔	✔	NA	✔	✔	✔	NA	✔	NA	✔	✔
Bastani 2011 [28]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Bedford 2021 [29]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Bhatta 2015 [30]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Chao 2010 [31]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Choi 2016 [32]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Cook 2010 [33]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Cuff 2016 [34]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Dalon 2021 [35]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
de Munter 2021 [36]	✔	✔	✔	✔	✔	NA	✔	✔	✔	NA	✔	NA	✔	✔
Dorell 2011 [37]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Du 2015 [38]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Faisal-Cury 2020 [39]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Farias 2016 [40]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Gelman 2013 [41]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Gerend 2013 [42]	✔	✔	X	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Gilbert 2016 [43]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Gowda 2013 [44]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Grandahl 2017 [45]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Hansen 2015 [46]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Henry 2016 [47]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Hirth 2012 [48]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Hofstetter 2014 [49]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Inguva 2020 [50]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Isabirye 2020 [51]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Johnson 2017 [52]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔

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Table 2 (*continued*)

Study	Objective stated	Population specified	Participation rate at least 50 %	Participants from same population	Sample size justified	Exposures measured before outcome	Sufficient study time frame	Measured different exposure levels	Consistent exposure measure	Exposure assessed more than once	Consistent outcome measures	Blinded outcome assessment	20 % or less attrition	Confounder adjustment
Kassa 2021 [53]	✔	✔	✔	✔	✔	NA	✔	✔	✔	NA	✔	NA	✔	✔
Kepka 2015 [54]	✔	✔	NA	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Klosky 2013 [55]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Kornides 2019 [56]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Kramer 2012 [57]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Lai 2015 [58]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Lau 2012 [59]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Laz 2012 [60]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Lee 2016 [61]	✔	✔	✔	✔	✔	NA	✔	✔	✔	NA	✔	NA	✔	✔
Li 2013 [62]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Lions 2013 [63]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Lu 2018 [64]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Møller 2018 [65]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Mollers 2014 [66]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Monnat 2013 [67]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Moss 2012 [68]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Mukherjee 2014 [69]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Munn 2019 [70]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Musto 2013 [71]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Nabirye 2020 [72]	✔	✔	✔	✔	✔	NA	✔	✔	✔	NA	✔	NA	✔	✔
Nhumba 2022 [73]	✔	✔	✔	✔	✔	NA	✔	✔	✔	NA	✔	NA	✔	✔
Niccolai 2011 [74]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Palli 2012 [75]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Perkins 2012 [76]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Pierce 2013 [77]	✔	✔	X	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Poole 2012 [78]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Porsch 2020 [79]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Pruitt 2010 [80]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Rahman 2014 [81]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔

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Table 2 (*continued*)

Study	Objective stated	Population specified	Participation rate at least 50 %	Participants from same population	Sample size justified	Exposures measured before outcome	Sufficient study time frame	Measured different exposure levels	Consistent exposure measure	Exposure assessed more than once	Consistent outcome measures	Blinded outcome assessment	20 % or less attrition	Confounder adjustment
Rahman 2015 [82]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Reiter 2010 [83]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Reiter 2011 [84]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Remes 2014 [85]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Riviere 2021 [86]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Rousset-Jablonski 2021 [87]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Sadigh 2012 [88]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Sara Test 2013 [89]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Savas 2012 [90]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Schluterman 2011 [91]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Schülein 2016 [92]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Slåttelid Schreiber 2015 [93]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Smith 2011 [94]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Spencer 2014 [95]	✔	✔	✔	✔	✔	NA	✔	✔	✔	NA	✔	NA	✔	✔
Stocker 2013 [96]	✔	✔	✔	✔	X	NA	✔	✔	✔	✔	✔	NA	✔	✔
Sundaram 2016 [97]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Swiecki-Sikora 2019 [98]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Tiro 2012 [99]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Tiro 2012 [100]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Tsui 2013 [101]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Tung 2016 [102]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Venturelli 2017 [103]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Verdeniusn 2013 [104]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔
Warner 2017 [105]	✔	✔	✔	✔	X	NA	✔	✔	✔	NA	✔	NA	✔	✔

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Table 2 (*continued*)

Study	Objective stated	Population specified	Participation rate at least 50 %	Participants from same population	Sample size justified	Exposures measured before outcome	Sufficient study time frame	Measured different exposure levels	Consistent exposure measure	Exposure assessed more than once	Consistent outcome measures	Blinded outcome assessment	20 % or less attrition	Confounder adjustment
Watson-Jones 2012 [106]	✓	✓	✓	✓	✓	NA	✓	✓	✓	NA	✓	NA	✓	✓
Wemrell 2022 [107]	✓	✓	✓	✓	X	NA	✓	✓	✓	NA	✓	NA	✓	✓
Widgren 2011 [108]	✓	✓	✓	✓	X	NA	✓	✓	✓	NA	✓	NA	✓	✓
Yiltalo 2013 [109]	✓	✓	✓	✓	X	NA	✓	✓	✓	NA	✓	NA	✓	✓

✓ = satisfactory; X = unsatisfactory; NA = not applicable.

parent's race and marital status, body mass index, use of contraception, and having a primary care physician may also determine vaccination initiation while region of residence, whether school-based or community-based vaccination and healthcare facility type may also determine vaccination series completion. These findings were mostly driven by studies from the U.S. Notably, the vaccination programmes in the U.S. differ significantly from the rest of the world in that the primary care office is the centre of health care, rather than schools, or public health vaccination campaigns, leading to different factors influencing vaccine uptake. The observed effects of the factors appeared stronger when data analysis was limited to the U.S. Therefore, our findings may be more applicable to the U.S. and may not be appropriately generalizable. Nevertheless, most pooled effect estimates were generally strong, suggesting that our findings should be given a close attention by public health decision-makers.

It has been suggested that the timing of sexual activity is influenced by age, and personal and social circumstances, and that, among females of paediatric age, unsatisfactory body image, low socioeconomic status, and higher social media use are most strongly associated with early sexual activity [110–113]. This may explain some of our findings; for example, regarding annual household income, body mass index, and parent's marital status. In particular, our finding that being an older girl and use of contraception increased the odds of HPV vaccination initiation may reflect the increased probability of sexual activity with age among the paediatric age group [114,115], although surprisingly, the association between vaccination initiation and sexual activity was not statistically significant. However, this may be due to a lack of adequate power from just two pooled study results. Further, living in an urban area was found to increase the odds of vaccination initiation, and this finding may, in part, be explained by higher health literacy, easier access to healthcare and health information [116–118], and higher socioeconomic status [119].

Ethnicity/race correlates with many individual socioeconomic and health-related factors associated with preventive care and overall wellbeing. Healthcare access and utilization, including access to vaccination services, have been found to be influenced by ethnicity/race [120,121], education [122,123], and income [124,125], all of which have also been shown to correlate with having health insurance [126,127]. The non-significant difference in odds of vaccination initiation between Black and White girls was therefore surprising although, the effect may have been diluted by most of the girls being in a public school and having received school-based vaccination, both of which provide most of the HPV vaccinations for young people and were also found in this review to be associated with an increased odds of vaccination initiation and vaccination series completion, respectively. However, compared with being White, being Black was found to be associated with decreased odds of vaccination series completion, and while being Asian compared with White was also found to be associated with decreased odds of vaccination initiation, the opposite was observed with being Hispanic. However, the definition/measure of ethnicity/race likely differed between studies, especially when self-reported. Further, in line with expectations, having health insurance, a primary care physician, and a visit to the healthcare provider in the preceding year all had strongly increased odds of both vaccination initiation and vaccination series completion, as was receipt of the influenza vaccination in the preceding year. These findings suggest that increased contact with the health system may increase the likelihood of receipt of preventive services and, potentially, better healthcare, as studies have also shown [128–130]. The findings may suggest that a mandatory well-child visit could help drive initiation of the HPV vaccination, and potentially, other recommended vaccines for school-age pupils, and they therefore require the attention of public health decision-makers.

A paucity of published systematic reviews directly comparable with our review meant that we could only compare our findings with the findings from a few reviews. Nevertheless, comparable to our findings, a similar systematic review with meta-analysis of factors associated with

Table 3
Meta-analysis of associations between individual socioeconomic and health-related factors, and human papillomavirus vaccination initiation and vaccination series completion among paediatric females globally.

Individual factors	Comparison	Vaccination initiation				Completion of vaccination series			
		No. of studies	Population size	Pooled adjusted odds ratios (95 % CI)	I [2] statistic (%)	No. of studies	Population size	Pooled adjusted odds ratios (95 % CI)	I [2] statistic (%)
Age	Older versus younger girls	26	4,950,736+	**1.67 (1.44–1.93)**	91.7	14	946,055	**1.36 (1.23–1.49)**	95.2
	Increase in age as a continuous variable	10	30,819	**1.22 (1.07–1.40)**	97.2	4	25,459	1.09 (0.89–1.35)	90.6
Alcohol consumption	Drinkers versus non-drinkers	1	2989	1.3 (1.00–1.6)	–	–	–	–	–
Annual household income	Higher versus lower income	10	134,591	**1.14 (1.02–1.27)**	70.3	7	124,260	1.04 (0.99–1.11)	0
Area of residence	Urban versus rural	10	464,948	**1.18 (1.05–1.32)**	87	6	149,553	0.98 (0.88–1.1)	71
Born in or a citizen of the country of study	Not born versus born in the country of study	5	77,413	**0.55 (0.40–0.75)**	74.8	–	–	–	–
	Non-citizens versus citizens	2	11,325	**0.79 (0.40–0.95)**	0	–	–	–	–
Chronic medical condition	Have versus have no condition(s)	1	335,767	**0.79 (0.73–0.86)**	–	–	–	–	–
Ethnicity/race	Blacks versus Whites	21	921,547+	0.98 (0.91–1.05)	79.5	12	676,978+	**0.74 (0.60–0.91)**	89
	Asians versus Whites	4	256,213	**0.92 (0.89–0.95)**	43.5	3	76,633	0.87 (0.62–1.22)	68.6
	Native Americans versus Whites	2	34,690	1.65 (0.80–3.36)	80.2	1	18,228	1.00 (0.78–1.27)	–
	Hispanics versus Whites	16	865,951	**1.21 (1.09–1.33)**	90.6	11	637,311	0.96 (0.85–1.09)	76.5
	Multiracial versus Whites	2	72,696	1.29 (0.40–4.20)	91.4	1	56,234	0.98 (0.50–1.91)	–
	Hispanics versus Blacks	3	2654	1.33 (0.98–1.81)	31	3	11,950	1.17 (1.00–1.38)	0
Federal poverty level (FPL)	More versus less than 100 % FPL	6	3,740,748	0.94 (0.75–1.18)	77.5	3	30,671	0.93 (0.75–1.15)	35.6
	More versus less than 100%–200 % FPL	1	7375	1.20 (0.93–1.55)	–	2	24,639	1.14 (0.78–1.65)	26.5
	More versus less than 200%–300 % FPL	–	–	–	–	1	17,264	**1.75 (1.09–2.82)**	–
Have a primary care physician	Have versus no primary care physician	2	16,582	**1.38 (1.01–1.90)**	0	–	–	–	–
Have siblings	Have versus have no sibling(s)	2	36,098	0.97 (0.88–1.06)	16.9	–	–	–	–
Health insurance	Insured (any type) versus no insurance	13	87,578+	**1.41 (1.16–1.72)**	79.8	7	41,375+	**1.72 (1.27–2.33)**	61.6
	Public versus private insurance	7	3,774,321	**1.19 (1.10–1.30)**	0	4	43,995	1.14 (0.94–1.40)	73.8
Healthcare facility type	Hospital or public versus private facilities	3	33,859	0.90 (0.72–1.11)	56.9	4	43,235	**0.85 (0.77–0.94)**	0
Healthcare provider	Family physicians versus paediatricians	2	179,580+	0.74 (0.47–1.16)	29.2	–	–	–	–
	Internists versus paediatricians	1	179,580	0.93 (0.87–1.00)	–	–	–	–	–
Hospitalization	Hospitalised versus not hospitalised	2	274,121	0.98 (0.67–1.44)	92.5	–	–	–	–
Influenza vaccination in the past year	Influenza vaccination in past year versus no vaccination	8	27,821	**1.75 (1.54–2.00)**	69.1	7	38,991	**1.72 (1.62–1.83)**	0
Living circumstance	Living with one versus both parents	2	22,668	1.12 (0.83–1.51)	65.1	–	–	–	–
	Living with one versus no parents	1	2260	1.10 (1.00–1.20)	–	–	–	–	–
Obesity/overweight/underweight Body Mass Index (BMI)	Being underweight versus a normal BMI	1	2469	**0.45 (0.26–0.79)**	–	–	–	–	–
	Being obese/overweight versus a normal BMI	2	146,516	1.03 (0.81–1.31)	88	–	–	–	–
Parent's age	More versus less than 35 years old	12	203,609	**0.79 (0.73–0.86)**	83.9	8	58,653	1.01 (0.87–1.17)	77.1
	45 years or more versus 35–44 years	3	118,525	**0.87 (0.78–0.96)**	46	–	–	–	–
	Increase in age as a continuous variable	2	8037	1.00 (0.99–1.01)	0	1	4776	**1.02 (1.01–1.03)**	–
Parent's educational attainment	Higher versus lower or no education	27	600,322	1.02 (0.94–1.11)	91.1	14	240,550	1.05 (0.96–1.15)	64.2
Parent's employment status	Unemployed versus employed	5	164,134	1.02 (0.80–1.28)	85	4	163,745	0.91 (0.77–1.06)	46.4
Parent's ethnicity	Blacks versus Whites	2	8037	1.39 (0.76–2.56)	90.9	–	–	–	–
	Hispanics versus Whites	2	8037	1.42 (0.82–2.43)	91	–	–	–	–
	Asians versus Whites	1	3261	**2.59 (1.34–4.99)**	–	–	–	–	–
Parent's marital status	Unmarried/separated/divorced/widowed versus married/cohabiting	14	234,530	**1.08 (1.01–1.15)**	65.7	9	124,947	0.97 (0.87–1.08)	82.4

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Table 3 (*continued*)

Individual factors	Comparison	Vaccination initiation				Completion of vaccination series			
		No. of studies	Population size	Pooled adjusted odds ratios (95 % CI)	I [2] statistic (%)	No. of studies	Population size	Pooled adjusted odds ratios (95 % CI)	I [2] statistic (%)
Poverty level	Below versus above poverty threshold	4	30,211	1.14 (0.96–1.35)	67	3	18,835	1.05 (0.93–1.19)	0
Region of residence	Southern versus Northern U.S. region	4	3,711,872	0.98 (0.79–1.21)	59.2	2	18,611	**0.83 (0.75–0.92)**	0
	Western versus Northern U.S. region	3	3,708,611	0.87 (0.65–1.17)	66.1	3	26,217	**0.79 (0.67–0.94)**	69.1
	Western versus Southern U.S. region	2	10,636	0.89 (0.56–1.40)	84	1	7606	0.87 (0.76–1.00)	–
School type	Public versus private schools	5	21,957	**1.54 (1.05–2.26)**	80.1	–	–	–	–
School-based vaccination	School-based versus community vaccination	–	–	–	–	3	50,262	**3.08 (1.05–9.07)**	99.4
Sexually active	Sexually active versus inactive	2	550,748	1.33 (0.94–1.89)	56.5	–	–	–	–
Socioeconomic status	Lower versus higher socioeconomic status	9	630,454	0.87 (0.74–1.03)	96.1	–	–	–	–
Use of contraception	Use versus no use of contraception	2	274,591	**2.00 (1.16–3.46)**	94.6	–	–	–	–
Visit to healthcare provider	Visit versus no visit within past year	8	4,153,982	**1.85 (1.51–2.28)**	65.3	3	109,699	**1.46 (1.05–2.04)**	75.5

U.S. = United States of America; CI = confidence interval; No = number; Bold = statistically significant; + = one study sample size not reported; Parent = the responsible parent for the surveys.

HPV vaccination initiation and completion, however, among adult females irrespective of vaccine type and method of determination of vaccination status also showed that age, race, health insurance, and influenza vaccination and visit to a healthcare provider in the preceding year may determine HPV vaccination initiation and vaccination series completion among adult females [131]. Similarly, the review also indicated that, in addition to the above, annual household income, birth/citizenship of a country of residence, use of contraception, and having a primary care physician may also determine HPV vaccination, particularly, the series completion [131]. This suggests a potentially strong influence of these factors on HPV vaccination among females irrespective of age. Another systematic review with meta-analysis found increased age (OR:1.55; 95 % CI 1.09–2.21), having a usual source of care (OR: 1.70; 95 % CI 1.20–2.41) and health insurance (OR: 1.87; 95 % CI 1.26–2.80) to be significantly associated with increased odds of initiating and completing HPV vaccination [132]. However, this was specifically among ethnic minority adolescent girls. Further, the meta-analysis combined vaccination initiation and completion and involved a few studies; three studies for age and two for usual source of care and health insurance. Unlike our finding of no difference in the odds of vaccination initiation between Blacks and Whites, a systematic review with meta-analysis of results from thirteen studies found that Black young women were less likely to initiate HPV vaccination when compared with White young women (OR: 0.89, 95 % CI: 0.82–0.97), and that, when limited to the U.S., young women without health insurance were less likely to initiate HPV vaccination (OR: 0.56, 95 % CI: 0.40–0.78) [133]. However, over half of the pooled results for each of the analyses were unadjusted. We did not identify any systematic review and meta-analysis to compare directly with our findings for vaccination series completion among paediatric females.

While there are a few limitations in this review, our findings provide a strong evidence-based insight on several individual socioeconomic/health-related factors that may influence HPV vaccination, knowledge which may be key to identifying girls who may be at increased risk of not being vaccinated against the HPV, particularly in the U.S. from which most of the evidence has been published, and knowledge which could aid public health and HPV vaccination programmatic planning, and targeted public health sensitization messaging to optimize the effectiveness of HPV vaccination programmes. The inability to obtain additional data from some authors to enable conversion of some of the reported relative risks and prevalence ratios to the mostly reported odds ratios for appropriate pooling of results meant that these estimates had to be treated as and pooled together with the odds ratios. Nevertheless, there were only a few of such instances, and we conducted a sensitivity analysis excluding such results and confirmed that their inclusion did not significantly impact the overall pooled analyses. Although there were high levels of heterogeneity in some of the meta-analyses, this was not surprising considering that some pooled results were first derived from pooling categorized results reported in studies (collapsing categories) before pooling with other results. Further, there were potential differences in the studied populations other than age, and differences in the methods of effect estimations. As such, the observed high heterogeneity, especially in the context as described above does not necessarily imply that data is inconsistent and should therefore not be overemphasized in interpreting the results [134].

We followed known guidelines and standards in the conduct and reporting of this review. A detailed review protocol was duly registered and made publicly accessible and, as recommended, a health librarian developed our literature search strategies and an independent health librarian reviewed them using the PRESS checklist [17]. As such, the likelihood of missing relevant literature was slim. Additionally, we carefully included only studies that evaluated actual HPV vaccination and not willingness to accept vaccine, which some of the previous systematic reviews appeared to have misinterpreted as actual receipt of vaccine. Compared with previous systematic reviews on the same topic, this present review is the most detailed and most comprehensive. Even so, we summarized the evidence for individual socioeconomic and health-related determinants of HPV vaccination series completion, which has been lacking.

5. Conclusions

Several potentially related individual factors may determine initiation and completion of the HPV vaccination series among females of paediatric age. These factors provide insights that could aid public health planning and targeted messaging and may be key to identifying girls who may be at increased risk of not being vaccinated, particularly in the U.S. from which most of the evidence has been published. While our findings may not necessarily be generalizable, they may help in optimising the effectiveness of HPV vaccination programmes across

Table 4
Meta-analysis of associations between individual socioeconomic and health-related factors, and human papillomavirus vaccination initiation and vaccination series completion among paediatric females in the U.S.

Individual factors	Comparison	Vaccination initiation				Completion of vaccination series			
		No. of studies	Population size	Pooled adjusted odds ratios (95 % CI)	I [2] statistic (%)	No. of studies	Population size	Pooled adjusted odds ratios (95 % CI)	I [2] statistic (%)
Age	Older versus younger girls	20	4,930,891+	**1.82 (1.51–2.20)**	91.8	13	910,463	**1.48 (1.24–178)**	95.5
	Increase in age as a continuous variable	6	26,120	1.14 (0.98–1.33)	97.8	2	22,040	1.20 (0.95–1.50)	93.1
Annual household income	Higher versus lower income	8	41,843	1.12 (0.97–1.28)	75.8	6	33,418	1.04 (0.97–1.11)	0
Area of residence	Urban versus rural	6	44,855	**1.11 (1.01–1.22)**	43.5	4	42,801	0.98 (0.88–1.07)	35
Born in the country of study	Not born versus born in a country	1	3615	**0.70 (0.52–0.94)**	–	–	–	–	–
Ethnicity/race	Blacks versus Whites	19	859,909+	0.98 (0.91–1.05)	66.2	11	620,744+	**0.71 (0.57–0.88)**	88.8
	Asians versus Whites	3	199,979	**0.93 (0.91–0.96)**	0	2	20,399	0.73 (0.52–1.03)	9
	Native Americans versus Whites	2	34,690	1.65 (0.80–3.36)	80.2	1	18,228	1.00 (0.78–1.27)	–
	Hispanics versus Whites	16	865,951	**1.21 (1.09–1.33)**	90.6	11	637,311	0.96 (0.85–1.09)	76.5
	Multiracial versus Whites	1	16,462	**2.43 (1.32–4.47)**	–	–	–	–	–
	Hispanics versus Blacks	3	2654	1.33 (0.98–1.81)	31	3	11,950	1.17 (1.00–1.38)	0
Federal poverty level (FPL)	More versus less than 100 % FPL	6	3,740,748	0.94 (0.75–1.18)	77.5	3	30,671	0.93 (0.75–1.15)	35.6
	More versus less than 100%–200 % FPL	1	7375	1.20 (0.93–1.55)	–	2	24,639	1.14 (0.78–1.65)	26.5
	More versus less than 200%–300 % FPL	–	–	–	–	1	17,264	**1.75 (1.09–2.82)**	–
Have a primary care physician	Have versus no primary care physician	2	16,582	**1.38 (1.01–1.90)**	0	–	–	–	–
Health insurance	Insured (any type) versus no insurance	13	87,578+	**1.41 (1.16–1.72)**	79.8	7	41,375+	**1.72 (1.27–2.33)**	61.6
	Public versus private insurance	7	3,774,321	**1.19 (1.10–1.30)**	0	4	43,995	1.14 (0.94–1.40)	73.8
Healthcare facility type	Hospital or public versus private facilities	3	33,859	0.90 (0.72–1.11)	56.9	4	43,235	**0.85 (0.77–0.94)**	0
Healthcare provider	Family physicians versus paediatricians	2	179,580+	0.74 (0.47–1.16)	29.2	–	–	–	–
	Internists versus paediatricians	1	179,580	0.93 (0.87–1.00)	–	–	–	–	–
Influenza vaccination in the past year	Influenza vaccination in past year versus no vaccination	8	27,821	**1.75 (1.54–2.00)**	69.1	7	38,991	**1.72 (1.62–1.83)**	0
Obesity/overweight/underweight Body Mass Index (BMI)	Being underweight versus a normal BMI	1	2469	**0.45 (0.26–0.79)**	–	–	–	–	–
	Being obese/overweight versus a normal BMI	2	146,516	1.03 (0.81–1.31)	88	–	–	–	–
Parent's age	More versus less than 35 years old	9	78,525	**0.76 (0.68–0.85)**	80	7	57,875	0.98 (0.84–1.15)	78.5
	45 years or more versus 35–44 years	2	27,683	**0.92 (0.85–0.98)**	0	–	–	–	–
	Increase in age as a continuous variable	2	8037	1.00 (0.99–1.01)	0	1	4776	**1.02 (1.01–1.03)**	–
Parent's educational attainment	Higher versus lower or no education	17	119,003	0.98 (0.87–1.10)	86.4	11	83,064	1.06 (0.94–1.20)	72.3
Parent's employment status	Unemployed versus employed	2	6977	1.07 (0.92–1.23)	85	2	6977	1.05 (0.87–1.26)	0
Parent's ethnicity	Blacks versus Whites	2	8037	1.39 (0.76–2.56)	90.9	–	–	–	–
	Hispanics versus Whites	2	8037	1.42 (0.82–2.43)	91	–	–	–	–
	Asians versus Whites	1	3261	**2.59 (1.34–4.99)**	–	–	–	–	–
Parent's marital status	Unmarried/separated/divorced/widowed versus married/cohabiting	10	75,680	**1.13 (1.06–1.20)**	39.5	8	59,021	1.00 (0.93–1.08)	34.4
Poverty level	Below versus above poverty threshold	4	30,211	1.14 (0.96–1.35)	67	3	18,835	1.05 (0.93–1.19)	0
Region of residence	Southern versus Northern U.S. region	4	3,711,872	0.98 (0.79–1.21)	59.2	2	18,611	**0.83 (0.75–0.92)**	0
	Western versus Northern U.S. region	3	3,708,611	0.87 (0.65–1.17)	66.1	3	26,217	**0.79 (0.67–0.94)**	69.1
	Western versus Southern U.S. region	2	10,636	0.89 (0.56–1.40)	84	1	7606	0.87 (0.76–1.00)	–
School type	Public versus private schools	1	1437	**2.08 (1.28–3.33)**	–	–	–	–	–

(*continued on next page*)

Table 4 (*continued*)

Individual factors	Comparison	Vaccination initiation				Completion of vaccination series			
		No. of studies	Population size	Pooled adjusted odds ratios (95 % CI)	I [2] statistic (%)	No. of studies	Population size	Pooled adjusted odds ratios (95 % CI)	I [2] statistic (%)
School-based vaccination	School-based versus community vaccination	–	–	–	–	1	12,676	**1.37 (1.19–1.58)**	–
Sexually active	Sexually active versus inactive	2	550,748	1.33 (0.94–1.89)	56.5	–	–	–	–
Socioeconomic status	Lower versus higher socioeconomic status	1	1709	**1.50 (1.10–1.80)**	–	–	–	–	–
Visit to healthcare provider	Visit versus no visit within past year	6	3,712,888	**1.98 (1.45–2.70)**	67.5	2	4372	**1.58 (0.75–3.36)**	84.3

U.S. = United States of America; CI = confidence interval; No = number; Bold = statistically significant; + = one study sample size not reported.

jurisdictions.

Statements and declarations

All authors declare that they have no perceived conflicts of interest. The corresponding author affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned have been explained.

Data sharing

All data for this study are presented in the manuscript and as supplementary information.

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Appendix A. Supplementary data

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