Comparison of different human papillomavirus (HPV) vaccine types and dose schedules for prevention of HPV-related disease in females and males (Review)

Bergman H, Buckley BS, Villanueva G, Petkovic J, Garrity C, Lutje V, Riveros-Balta AX, Low N, Henschke N

Copyright © 2019 The Authors. Cochrane Database of Systematic Reviews published by John Wiley & Sons, Ltd. on behalf of The Cochrane Collaboration.
TABLE OF CONTENTS

ABSTRACT ........................................................................................................................................................................ 1
PLAIN LANGUAGE SUMMARY .................................................................................................................................................. 3
SUMMARY OF FINDINGS .................................................................................................................................................... 5
BACKGROUND .................................................................................................................................................................. 13
OBJECTIVES ................................................................................................................................................................... 15
METHODS ......................................................................................................................................................................... 15
RESULTS ........................................................................................................................................................................... 18
Figure 1. ............................................................................................................................................................................. 19
Figure 2. ............................................................................................................................................................................. 20
DISCUSSION .................................................................................................................................................................... 27
AUTHORS’ CONCLUSIONS ................................................................................................................................................ 29
ACKNOWLEDGEMENTS .................................................................................................................................................. 30
REFERENCES .................................................................................................................................................................. 31
CHARACTERISTICS OF STUDIES ................................................................................................................................... 39
DATA AND ANALYSES .................................................................................................................................................... 40
Analysis 1.1. Comparison 1 Two versus three doses of HPV vaccines in 9- to 15-year-old females, Outcome 1 Pain at injection site. ............................................................ 71
Analysis 1.2. Comparison 1 Two versus three doses of HPV vaccines in 9- to 15-year-old females, Outcome 2 Swelling at injection site. ............................................................. 72
Analysis 1.3. Comparison 1 Two versus three doses of HPV vaccines in 9- to 15-year-old females, Outcome 3 Redness at injection site. .......................................................... 72
Analysis 1.4. Comparison 1 Two versus three doses of HPV vaccines in 9- to 15-year-old females, Outcome 4 Serious adverse events (overall). .................................................... 73
Analysis 1.5. Comparison 1 Two versus three doses of HPV vaccines in 9- to 15-year-old females, Outcome 5 Deaths. ............................................................... 12
Analysis 2.1. Comparison 2 Two doses of HPV vaccine with longer interval versus two doses of HPV vaccine with shorter interval in 9- to 14-year-olds, Outcome 1 Pain at injection site. ........................................................... 74
Analysis 2.2. Comparison 2 Two doses of HPV vaccine with longer interval versus two doses of HPV vaccine with shorter interval in 9- to 14-year-olds, Outcome 2 Swelling at injection site. ................................................................. 75
Analysis 2.3. Comparison 2 Two doses of HPV vaccine with longer interval versus two doses of HPV vaccine with shorter interval in 9- to 14-year-olds, Outcome 3 Redness at injection site. ................................................................. 75
Analysis 2.4. Comparison 2 Two doses of HPV vaccine with longer interval versus two doses of HPV vaccine with shorter interval in 9- to 14-year-olds, Outcome 4 Serious adverse events (overall). .................................................. 76
Analysis 2.5. Comparison 2 Two doses of HPV vaccine with longer interval versus two doses of HPV vaccine with shorter interval in 9- to 14-year-olds, Outcome 5 Deaths. .............................................................. 76
Analysis 3.1. Comparison 3 Three doses of HPV vaccine with longer interval versus three doses of HPV vaccine with shorter interval in 18- to 25-year-old males, Outcome 1 Adverse events. ................................................................. 77
Analysis 3.2. Comparison 3 Three doses of HPV vaccine with longer interval versus three doses of HPV vaccine with shorter interval in 18- to 25-year-old males, Outcome 2 Serious adverse events (overall). ......................................... 77
Analysis 4.1. Comparison 4 HPV vaccine versus control in males, Outcome 1 External genital lesions (any type). ............................................................. 78
Analysis 4.2. Comparison 4 HPV vaccine versus control in males, Outcome 2 External genital lesions (HPV 6, 11, 16, or 18). .... 78
Analysis 4.3. Comparison 4 HPV vaccine versus control in males, Outcome 3 Anogenital warts. ............................................................. 78
Analysis 4.4. Comparison 4 HPV vaccine versus control in males, Outcome 4 All penile, perianal, or perineal intraepithelial neoplasia lesions. .................................................. 79
Analysis 4.5. Comparison 4 HPV vaccine versus control in males, Outcome 5 Penile, perianal, or perineal intraepithelial neoplasia grade 1 ................................................................. 79
Analysis 4.6. Comparison 4 HPV vaccine versus control in males, Outcome 6 Penile, perianal, or perineal intraepithelial neoplasia grade 2 or 3. ................................................................. 79
Analysis 4.7. Comparison 4 HPV vaccine versus control in males, Outcome 7 Overall local/injection site adverse events. ................................................................. 80
Analysis 4.8. Comparison 4 HPV vaccine versus control in males, Outcome 8 Pain at injection site. ................................................................. 80
Analysis 4.9. Comparison 4 HPV vaccine versus control in males, Outcome 9 Swelling at injection site. ................................................................. 80
Analysis 4.10. Comparison 4 HPV vaccine versus control in males, Outcome 10 Redness at injection site. ................................................................. 81
Analysis 4.11. Comparison 4 HPV vaccine versus control in males, Outcome 11 Overall systemic events and general symptoms. ................................................................. 81
Analysis 4.12. Comparison 4 HPV vaccine versus control in males, Outcome 12 Serious adverse events (overall). ................................................................. 81

Comparison of different human papillomavirus (HPV) vaccine types and dose schedules for prevention of HPV-related disease in females and males (Review)

Copyright © 2019 The Authors. Cochrane Database of Systematic Reviews published by John Wiley & Sons, Ltd. on behalf of The Cochrane Collaboration.
Analysis 4.13. Comparison 4 HPV vaccine versus control in males, Outcome 13 Deaths. ................................................................. 85
Analysis 5.1. Comparison 5 Nonavalent HPV vaccine versus quadravalent HPV vaccine in 9- to 26-year-olds, Outcome 1 High-grade cervical epithelial neoplasia, adenocarcinoma in situ, and cervical cancer. ................................................................. 88
Analysis 5.2. Comparison 5 Nonavalent HPV vaccine versus quadravalent HPV vaccine in 9- to 26-year-olds, Outcome 2 High-grade cervical, vulval, and vaginal disease. ................................................................. 89
Analysis 5.3. Comparison 5 Nonavalent HPV vaccine versus quadravalent HPV vaccine in 9- to 26-year-olds, Outcome 3 High-grade cervical disease related to HPV 6, 11, 16, or 18. ................................................................................................................................. 89
Analysis 5.4. Comparison 5 Nonavalent HPV vaccine versus quadravalent HPV vaccine in 9- to 26-year-olds, Outcome 4 High-grade vulval and vaginal disease related to HPV 6, 11, 16, or 18. ................................................................................................................................. 89
Analysis 5.5. Comparison 5 Nonavalent HPV vaccine versus quadravalent HPV vaccine in 9- to 26-year-olds, Outcome 5 High-grade cervical disease related to HPV 31, 33, 45, 52, or 58. ................................................................................................................................. 90
Analysis 5.6. Comparison 5 Nonavalent HPV vaccine versus quadravalent HPV vaccine in 9- to 26-year-olds, Outcome 6 High-grade vulval and vaginal disease related to HPV 31, 33, 45, 52, or 58. ................................................................................................................................. 90
Analysis 5.7. Comparison 5 Nonavalent HPV vaccine versus quadravalent HPV vaccine in 9- to 26-year-olds, Outcome 7 Cervical intraepithelial neoplasia 2 related to HPV 6, 11, 16, or 18. ................................................................................................................................. 90
Analysis 5.8. Comparison 5 Nonavalent HPV vaccine versus quadravalent HPV vaccine in 9- to 26-year-olds, Outcome 8 Cervical intraepithelial neoplasia 2 related to HPV 31, 33, 45, 52, or 58. ................................................................................................................................. 91
Analysis 5.9. Comparison 5 Nonavalent HPV vaccine versus quadravalent HPV vaccine in 9- to 26-year-olds, Outcome 9 Cervical intraepithelial neoplasia 3, adenocarcinoma in situ, and cervical cancer related to HPV 6, 11, 16, or 18. ................................................................................................................................. 91
Analysis 5.10. Comparison 5 Nonavalent HPV vaccine versus quadravalent HPV vaccine in 9- to 26-year-olds, Outcome 10 Cervical intraepithelial neoplasia 3, adenocarcinoma in situ, and cervical cancer related to HPV 31, 33, 45, 52, or 58. ................................................................................................................................. 91
Analysis 5.11. Comparison 5 Nonavalent HPV vaccine versus quadravalent HPV vaccine in 9- to 26-year-olds, Outcome 11 Overall local/injection site adverse events. ................................................................................................................................. 92
Analysis 5.12. Comparison 5 Nonavalent HPV vaccine versus quadravalent HPV vaccine in 9- to 26-year-olds, Outcome 12 Pain at injection site. ................................................................................................................................. 92
Analysis 5.13. Comparison 5 Nonavalent HPV vaccine versus quadravalent HPV vaccine in 9- to 26-year-olds, Outcome 13 Swelling at injection site. ................................................................................................................................. 93
Analysis 5.14. Comparison 5 Nonavalent HPV vaccine versus quadravalent HPV vaccine in 9- to 26-year-olds, Outcome 14 Redness at injection site. ................................................................................................................................. 94
Analysis 5.15. Comparison 5 Nonavalent HPV vaccine versus quadravalent HPV vaccine in 9- to 26-year-olds, Outcome 15 Overall systemic events and general symptoms. ................................................................................................................................. 94
Analysis 5.16. Comparison 5 Nonavalent HPV vaccine versus quadravalent HPV vaccine in 9- to 26-year-olds, Outcome 16 Serious adverse events (overall). ................................................................................................................................. 95
Analysis 5.17. Comparison 5 Nonavalent HPV vaccine versus quadravalent HPV vaccine in 9- to 26-year-olds, Outcome 17 Deaths. ................................................................................................................................. 96
Analysis 6.1. Comparison 6 Quadravalent HPV vaccine versus control in people living with HIV, Outcome 1 High-grade anal intraepithelial neoplasia. ................................................................................................................................. 97
Analysis 6.2. Comparison 6 Quadravalent HPV vaccine versus control in people living with HIV, Outcome 2 Recurrence of anogenital warts. ................................................................................................................................. 98
Analysis 6.3. Comparison 6 Quadravalent HPV vaccine versus control in people living with HIV, Outcome 3 Abnormal anal cytology. ................................................................................................................................. 98
Analysis 6.4. Comparison 6 Quadravalent HPV vaccine versus control in people living with HIV, Outcome 4 Overall local/injection site adverse events. ................................................................................................................................. 98
Analysis 6.5. Comparison 6 Quadravalent HPV vaccine versus control in people living with HIV, Outcome 5 Overall systemic event and general symptoms. ................................................................................................................................. 99
Analysis 6.6. Comparison 6 Quadravalent HPV vaccine versus control in people living with HIV, Outcome 6 Serious adverse events (overall). ................................................................................................................................. 99
Analysis 6.7. Comparison 6 Quadravalent HPV vaccine versus control in people living with HIV, Outcome 7 Deaths. ................................................................................................................................. 100
Analysis 7.1. Comparison 7 Bivalent HPV vaccine versus control in 18- to 25-year-old females with HIV, Outcome 1 Pain at injection site. ................................................................................................................................. 100
Analysis 7.2. Comparison 7 Bivalent HPV vaccine versus control in 18- to 25-year-old females with HIV, Outcome 2 Swelling at injection site. ................................................................................................................................. 101
Analysis 7.3. Comparison 7 Bivalent HPV vaccine versus control in 18- to 25-year-old females with HIV, Outcome 3 Serious adverse events (overall). ................................................................................................................................. 101
Analysis 7.4. Comparison 7 Bivalent HPV vaccine versus control in 18- to 25-year-old females with HIV, Outcome 4 Deaths. ................................................................................................................................. 101
Comparison of different human papillomavirus (HPV) vaccine types and dose schedules for prevention of HPV-related disease in females and males (Review)

Copyright © 2019 The Authors. Cochrane Database of Systematic Reviews published by John Wiley & Sons, Ltd. on behalf of The Cochrane Collaboration.
Comparison of different human papillomavirus (HPV) vaccine types and dose schedules for prevention of HPV-related disease in females and males

Hanna Bergman, Brian S Buckley, Gemma Villanueva, Jennifer Petkovic, Chantelle Garrity, Vittoria Lutje, Alina Ximena Riveros-Balta, Nicola Low, Nicholas Henschke

1Cochrane Response, Cochrane, London, UK. 2Department of Surgery, University of the Phillipines, Manila, Philippines. 3Bruyère Research Institute, University of Ottawa, Ottawa, Canada. 4Ottawa Methods Centre, Clinical Epidemiology Program, Ottawa Hospital Research Institute, Ottawa, Canada. 5Department of Clinical Sciences, Liverpool School of Tropical Medicine, Liverpool, UK. 6Initiative for Vaccine Research, World Health Organization, Geneva, Switzerland. 7Institute of Social and Preventive Medicine (ISPM), University of Bern, Bern, Switzerland

Contact: Nicholas Henschke, Cochrane Response, Cochrane, St Albans House, 57-59 Haymarket, London, SW1Y 4QX, UK. nhenschke@cochrane.org.

Editorial group: Cochrane Gynaecological, Neuro-oncology and Orphan Cancer Group.

Publication status and date: New, published in Issue 11, 2019.

Citation: Bergman H, Buckley BS, Villanueva G, Petkovic J, Garrity C, Lutje V, Riveros-Balta AX, Low N, Henschke N. Comparison of different human papillomavirus (HPV) vaccine types and dose schedules for prevention of HPV-related disease in females and males. Cochrane Database of Systematic Reviews 2019, Issue 11. Art. No.: CD013479. DOI: 10.1002/14651858.CD013479.

ABSTRACT

Background

Uptake of human papillomavirus (HPV) vaccine remains low in many countries, although the bivalent and quadrivalent HPV vaccines given as a three-dose schedule are effective in the prevention of precancerous lesions of the cervix in women. Simpler immunisation schedules, such as those with fewer doses, might reduce barriers to vaccination, as may programmes that include males.

Objectives

To evaluate the efficacy, immunogenicity, and harms of different dose schedules and different types of HPV vaccines in females and males.

Search methods

We conducted electronic searches on 27 September 2018 in Ovid MEDLINE, the Cochrane Central Register of Controlled Trials (CENTRAL) (in the Cochrane Library), and Ovid Embase. We also searched the WHO International Clinical Trials Registry Platform, and ClinicalTrials.gov (both 27 September 2018), vaccine manufacturer websites, and checked reference lists from an index of HPV studies and other relevant systematic reviews.

Selection criteria

We included randomised controlled trials (RCTs) with no language restriction. We considered studies if they enrolled HIV-negative males or females aged 9 to 26 years, or HIV-positive males or females of any age.
Data collection and analysis

We used methods recommended by Cochrane. We use the term ‘control’ to refer to comparator products containing an adjuvant or active vaccine and ‘placebo’ to refer to products that contain no adjuvant or active vaccine. Most primary outcomes in this review were clinical outcomes. However, for comparisons comparing dose schedules, the included RCTs were designed to measure antibody responses (i.e. immunogenicity) as the primary outcome, rather than clinical outcomes, since it is unethical to collect cervical samples from girls under 16 years of age. We analysed immunogenicity outcomes (i.e. geometric mean titres) with ratios of means, clinical outcomes (e.g. cancer and intraepithelial neoplasia) with risk ratios or rate ratios and, for serious adverse events and deaths, we calculated odds ratios. We rated the certainty of evidence with GRADE.

Main results

We included 20 RCTs with 31,940 participants. The length of follow-up in the included studies ranged from seven months to five years.

Two doses versus three doses of HPV vaccine in 9- to 15-year-old females

Antibody responses after two-dose and three-dose HPV vaccine schedules were similar after up to five years of follow-up (4 RCTs, moderate-to-high certainty evidence). No RCTs collected clinical outcome data. Evidence about serious adverse events in studies comparing dose schedules was of very low-certainty owing to imprecision and indirectness (three doses 35/1159; two doses 36/1158; 4 RCTs). One death was reported in the three-dose group (1/898) and none in the two-dose group (0/899) (low-certainty evidence).

Interval between doses of HPV vaccine in 9- to 14-year-old females and males

Antibody responses were stronger with a longer interval (6 or 12 months) between the first two doses of HPV vaccine than a shorter interval (2 or 6 months) at up to three years of follow-up (4 RCTs, moderate-to-high certainty evidence). No RCTs collected data about clinical outcomes. Evidence about serious adverse events in studies comparing intervals was of very low-certainty, owing to imprecision and indirectness. No deaths were reported in any of the studies (0/1898, 3 RCTs, low-certainty evidence).

HPV vaccination of 10- to 26-year-old males

In one RCT there was moderate-certainty evidence that quadrivalent HPV vaccine, compared with control, reduced the incidence of external genital lesions (control 36 per 3081 person-years; quadrivalent 6 per 3173 person-years; rate ratio 0.16, 95% CI 0.07 to 0.38; 6254 person-years) and anogenital warts (control 28 per 2814 person-years; quadrivalent 3 per 2831 person-years; rate ratio 0.11, 95% CI 0.03 to 0.38; 5645 person-years). The quadrivalent vaccine resulted in more injection-site adverse events, such as pain or redness, than control (537 versus 601 per 1000; risk ratio (RR) 1.12, 95% CI 1.06 to 1.18, 3895 participants, high-certainty evidence). There was very low-certainty evidence from two RCTs about serious adverse events with quadrivalent vaccine (control 12/2588; quadrivalent 8/2574), and about deaths (control 11/2591; quadrivalent 3/2582), owing to imprecision and indirectness.

Nonavalent versus quadrivalent vaccine in 9- to 26-year-old females and males

Three RCTs were included; one in females aged 9- to 15-years (n = 600), one in females aged 16- to 26-years (n = 14,215), and one in males aged 16- to 26-years (n = 500). The RCT in 16- to 26-year-old females reported clinical outcomes. There was little to no difference in the incidence of the combined outcome of high-grade cervical epithelial neoplasia, adenocarcinoma in situ, or cervical cancer between the HPV vaccines (quadrivalent 325/6882, nonavalent 326/6871; OR 1.00, 95% CI 0.85 to 1.16; 13,753 participants; high-certainty evidence). The other two RCTs did not collect data about clinical outcomes. There were slightly more local adverse events with the nonavalent vaccine (905 per 1000) than the quadrivalent vaccine (846 per 1000) (RR 1.07, 95% CI 1.05 to 1.08; 3 RCTs, 15,863 participants; high-certainty evidence). Comparative evidence about serious adverse events in the three RCTs (nonavalent 243/8234, quadrivalent 192/7629; OR 0.60, 95% CI 0.14 to 2.61) was of low certainty, owing to imprecision and indirectness.

HPV vaccination for people living with HIV

Seven RCTs reported on HPV vaccines in people with HIV, with two small trials that collected data about clinical outcomes. Antibody responses were higher following vaccination with either bivalent or quadrivalent HPV vaccine than with control, and these responses could be demonstrated to have been maintained for up to 24 months in children living with HIV (low-certainty evidence). The evidence about clinical outcomes and harms for HPV vaccines in people with HIV is very uncertain (low-to-very low-certainty evidence), owing to imprecision and indirectness.

Authors’ conclusions

The immunogenicity of two-dose and three-dose HPV vaccine schedules, measured using antibody responses in young females, is comparable. The quadrivalent vaccine probably reduces external genital lesions and anogenital warts in males compared with control. The nonavalent and quadrivalent vaccines offer similar protection against a combined outcome of cervical, vaginal, and vulval precancer lesions or cancer. In people living with HIV, both the bivalent and quadrivalent HPV vaccines result in high antibody responses. For all comparisons of alternative HPV vaccine schedules, the certainty of the body of evidence about serious adverse events reported during the study periods was low or very low, either because the number of events was low, or the evidence was indirect, or both. Post-marketing surveillance is needed to continue monitoring harms that might be associated with HPV vaccines in the population, and this evidence will...
be incorporated in future updates of this review. Long-term observational studies are needed to determine the effectiveness of reduced-dose schedules against HPV-related cancer endpoints, and whether adopting these schedules improves vaccine coverage rates.

**Plain Language Summary**

**Comparison of different human papillomavirus (HPV) vaccines and the number of doses administered to prevent HPV-related disease in females and males**

Human papillomaviruses (HPV) are a group of viruses that infect the skin and mucous membranes. Some types of HPV are sexually transmitted and are common in young people. Most infections will be cleared by the immune system, but some people will experience persistent infection with certain HPV types that go on to cause abnormalities in infected cells. These changes are called 'precancerous' because they can develop into cancers of the cervix, vagina, vulva, anal canal, penis, and head and neck. Infection with other HPV types causes warts in the genital area or around the anus.

Vaccination aims to prevent future HPV infections. Three HPV vaccines are in use – a bivalent one (protects against two HPV types), a quadrivalent one (protects against four HPV types), and a nonavalent one (protects against nine HPV types). In women, three doses of the bivalent or the quadrivalent HPV vaccines protect against precancer of the cervix caused by the HPV types contained in the vaccine. Evidence about the nonavalent vaccine, about the effects of the quadrivalent vaccine in males, and about the effects of HPV vaccines in people with HIV infection, has not yet been reviewed thoroughly. Uptake of HPV vaccines remains low in many countries. Simpler vaccine schedules, or giving the vaccine to both girls and boys, could increase the number of people being vaccinated.

Trials of HPV vaccines are not always designed to collect data about precancer and cancer, for several reasons. Firstly, HPV vaccine is routinely given before girls become sexually active, and it is not ethical to take specimens from the cervix of girls who have not had sex. Secondly, HPV-related precancer and cancer are rare and do not develop until years after HPV infection has occurred. Thirdly, participants in a trial will be offered treatment if precancer develops, so progression to cervical cancer would be even rarer, even without vaccination. An international committee of experts states that, in some circumstances, antibody levels (i.e. showing a strong immune system response), can be used to demonstrate protection against cervical and anal cancer. The antibody levels following vaccination in a trial should not be lower than those found in other studies on adults in whom the vaccine has been shown to protect against severe HPV-related cervical or anal disease.

**Review question(s)**

How effective or harmful are different HPV vaccine schedules (i.e. number and timing of doses) and different HPV vaccines in females and males?

**Main results**

These results are based on research evidence to 27 September 2018. We analysed 20 studies involving 31,940 people.

Studies comparing two doses of HPV vaccine to three doses, or comparing the time interval between doses, focus on immune system responses rather than infection or disease outcomes. Two doses of HPV vaccine result in similar immune system responses to three doses, and a longer interval (up to 12 months) between doses gives a stronger immune system response than a shorter interval. There is insufficient evidence to determine whether there was a difference between the vaccine schedules for serious adverse events and death.

In 16- to 26-year-old men, one study showed evidence of moderate certainty that a quadrivalent HPV vaccine provides better protection against external genital lesions and genital warts than a dummy treatment (control). In 16- to 26-year-old women, one study showed that the nonavalent and quadrivalent vaccines provide the same levels of protection against cervical, vaginal, and vulval precancer lesions and cancer (high-certainty evidence).

There was evidence that the quadrivalent vaccine resulted in more local adverse events (such as pain, swelling, and redness at the injection site) than a control treatment in males, and that the nonavalent vaccine resulted in more local adverse events than the quadrivalent vaccine in males and females. Evidence about serious adverse events and deaths from studies comparing different HPV vaccine types or dose schedules was of low or very low-certainty.

In people living with HIV, HPV vaccines result in reasonable levels of immune system response, but evidence about their effects on persistent HPV infection or HPV-related disease outcomes and harms is limited.

**Certainty of the evidence**

No major issues were identified with the methodological quality of the studies for the measurements of infection and disease outcomes, or for immune system responses. Our certainty in the evidence about serious harms and deaths across all the studies comparing different HPV vaccines and vaccine schedules is low, either because of their low frequency, or because the evidence is indirect, or both. Evidence graded as high certainty means that we were confident that further research is unlikely to change our findings. Moderate-certainty evidence means that there is a possibility that further research may have an important effect on our findings, whilst low-certainty evidence means
that our confidence was limited and further research may have an important impact on our findings. Very low-certainty evidence means that we were uncertain about the result.

Conclusion

A two-dose schedule of HPV vaccines in young females results in immune system responses that are comparable with a three-dose schedule. In males, the quadrivalent HPV vaccine appears to be effective in the prevention of external genital lesions and genital warts. Quadrivalent and nonavalent HPV vaccines in young women result in similar levels of protection against cervical, vaginal, and vulval precancer lesions and cancer. Evidence about the efficacy and harms in people living with HIV is limited. Further long-term population-level studies are needed to continue monitoring safety of these vaccines, to determine for how long two doses of vaccine can provide protection against HPV-related disease, the effect against HPV-related cancer, and whether a two-dose immunisation schedule will increase vaccine coverage.
### Summary of findings for the main comparison: Two doses of HPV vaccine compared with three doses of HPV vaccine in 9- to 15-year-old females

**Patient or population:** 9- to 15-year-old females  
**Setting:** community health centres in Africa, Asia Pacific, Europe, Latin America, North America  
**Intervention:** two doses of HPV vaccine (bivalent, quadrivalent, or nonvalent) administered in months 0 and 2, 0 and 6, or 0 and 12  
**Comparison:** three doses of HPV vaccine (bivalent, quadrivalent, or nonvalent) administered in months 0, 2, and 6, or 0, 1, and 6

| Clinical and harms outcomes* | Anticipated absolute effects** (95% CI) | Relative effect (95% CI) | No of participants (studies) | Certainty of the evidence (GRADE) | Comments |
|-----------------------------|----------------------------------------|--------------------------|------------------------------|----------------------------------|----------|
| Antibody response (immunogenicity) | Risk with three doses of HPV vaccine | Risk with two doses of HPV vaccine |                              |                                  |          |
| Two doses of bivalent vaccine had inconclusive non-inferiority for GMTs of HPV 16 and HPV 18 compared with three doses at 60-month follow-up (1 study, 93 participants; see Appendix 5). |                                    |                            |                              | LOW*     | Long-term results (follow-up 36 to 60 months) |
| Two doses of quadrivalent vaccine resulted in non-inferior GMTs for HPV 6, HPV 11 and HPV 16 compared with three doses, while results were inconclusive for HPV 18 at 60-month follow-up (1 study, 101 participants; see Appendix 5). |                                    |                            |                              | LOW*     |          |
| Two doses of nonvalent vaccine resulted in non-inferior GMTs for all HPV genotypes measured except HPV 45 and HPV 52 where non-inferiority was inconclusive, compared with three doses, at 36-month follow-up (1 study, 476 to 511 participants depending on HPV type; see Appendix 5). |                                    |                            |                              | HIGH*    |          |

**High-grade cervical intraepithelial neoplasia, adenocarcinoma in situ, and cervical cancer**  
No studies were identified that reported on this outcome.

**High-grade cervical, vulval, and vaginal disease**  
No studies were identified that reported on this outcome.

**Overall local/injection site adverse events**  
No studies were identified that reported on this outcome. Data for specific local adverse events (pain/swelling/redness at injection site) are presented in the analysis section.
### Overall systemic events and general symptoms

| Event Type                           | Event Details | OR (95% CI) | Number of Events | GRADE | Comment |
|--------------------------------------|---------------|-------------|------------------|-------|---------|
| **Serious adverse events** at up to 5-year follow-up | 30 per 1000 (20 to 49) | 1.03 (0.64 to 1.66) | 2,317 (4 RCTs) | ⊕⊕⊕ ⊝ ⊝ ⊝ | VERY LOW | **Please see Table 1 for a list of events in each RCT.** |
| **Mortality** at up to 5-year follow-up | 1 per 1000 (0 to 9) | 0.33 (0.01 to 8.19) | 1,797 (3 RCTs) | ⊕⊕ ⊝ | LOW | One death was reported in the three-dose group (nonavalent vaccine). |

*Certainty of the evidence (GRADE) for immunogenicity outcomes are presented in detail in Appendix 5.

**The risk in the intervention group** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI).

CI: confidence interval; GMT: geometric mean titre; HPV: human papillomavirus; OR: odds ratio; RCT: randomised controlled trial

---

**GRADE Working Group grades of evidence**

**High certainty**: we are very confident that the true effect lies close to that of the estimate of the effect

**Moderate certainty**: we are moderately confident in the effect estimate: the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different

**Low certainty**: our confidence in the effect estimate is limited: the true effect may be substantially different from the estimate of the effect

**Very low certainty**: we have very little confidence in the effect estimate: the true effect is likely to be substantially different from the estimate of effect

---

1 Downdgraded two levels for serious imprecision: few events and a wide 95% confidence interval that incorporated a potential large beneficial effect and a potential large harmful effect.

2 Downd graded one level for indirectness: this outcome is a composite measure of events which may or may not be clinically relevant, may or may not be related to the vaccine and may occur outside a biologically plausible time frame relative to vaccine exposure. This outcome is considered to provide indirect evidence about vaccine safety.

---

**Summary of findings 2.** Two doses of HPV vaccine with longer interval compared with two doses of HPV vaccine with shorter interval in 9- to 14-year-old females and males

| Two doses of HPV vaccine with longer interval compared with two doses of HPV vaccine with shorter interval in 9- to 14-year-old females and males |
|---|
| **Patient or population:** 9- to 14-year-old females and males |
| **Setting:** community health centres in Africa, Asia Pacific, Europe, Latin America, North America |
| **Intervention:** two doses of bivalent or nonavalent HPV vaccine with longer interval (months 0 and 6 or 12) |
| **Comparison:** two doses of bivalent or nonavalent HPV vaccine with shorter interval (months 0 and 2 or 6) |
### Anticipated absolute effects** (95% CI)

| Risk with two doses of HPV vaccine with shorter interval | Risk with two doses of HPV vaccine with longer interval |
|---------------------------------------------------------|--------------------------------------------------------|
| Antibody response (geometric mean titre)               |                                                        |
| Longer intervals between the first two doses of bivalent vaccine resulted in higher and non-inferior GMTs for HPV 16 (n = 971) and HPV 18 (n = 986) compared with shorter intervals in 9- to 14-year-old females at short-term follow-up (2 studies; moderate- to high-certainty evidence, see Appendix 6). |                                                        |
| A longer interval between the first two doses of nonavalent vaccine resulted in higher and non-inferior GMTs than a shorter interval for all HPV vaccine genotypes in girls and boys at short-term follow-up (1 study, number of participants ranged from 778 to 815 depending on HPV type; high-certainty evidence, see Appendix 6). |                                                        |
| Longer intervals between the first two doses of bivalent vaccine resulted in higher and non-inferior GMTs for HPV 16 (n = 817) and HPV 18 (n = 794) compared with shorter intervals in 9- to 14-year-old females at 36 months follow-up (1 study; high-certainty evidence, see Appendix 6). |                                                        |
| A longer interval between the first two doses of nonavalent vaccine resulted in higher and non-inferior GMTs than a shorter interval for all HPV vaccine genotypes in girls and boys at seven and 36 months follow-up (1 study, number of participants ranged from 236 to 263 depending on HPV type; high-certainty evidence, see Appendix 6). |                                                        |
| Invasive cervical, vaginal, anal, or penile cancer       |                                                        |
| No studies were identified that reported on this outcome. |                                                        |
| High-grade cervical, vulval, vaginal, penile, or anal intraepithelial neoplasia |                                                        |
| No studies were identified that reported on this outcome. |                                                        |
| Overall local/injection site adverse events             |                                                        |
| No studies were identified that reported on this outcome. Data for specific local adverse events (pain/swelling/redness at injection site) are presented in the analysis section. |                                                        |
| Overall systemic events and general symptoms             |                                                        |
| No studies were identified that reported on this outcome. |                                                        |

### Relative effect (95% CI)

| Risk with two doses of HPV vaccine with shorter interval | Risk with two doses of HPV vaccine with longer interval |
|---------------------------------------------------------|--------------------------------------------------------|
| Bivalent vaccine (0 and 2 months)                       | Bivalent vaccine (0 and 6 months)                      |
| OR 1.15                                                 | OR 1.04                                                |
| (0.55 to 2.41)                                          | (0.67 to 1.58)                                         |

### Comments

- MODERATE/ HIGH*: Short-term results (follow-up one month after final dose)
- HIGH*: Long-term results (follow-up 36 months)
- VERY LOW: Please see Table 1 for list of Cochrane Library Trusted evidence. Informed decisions. Better health.
Comparison of different human papillomavirus (HPV) vaccine types and dose schedules for prevention of HPV-related disease in females and males (Review)

| Vaccine Type | Dose Schedule | Rate per 1000 (95% CI) | OR (95% CI) | Grade |
|--------------|---------------|------------------------|-------------|-------|
| Bivalent     | (0 and 6 months) | 67 (33 to 130) | 1.63 (0.89 to 2.99) | VERY LOW 1,2 |
|              | (0 and 12 months) | 58 (32 to 101) |            |       |
| Nonavalent   | (0 and 6 months) | 20 (8 to 52) | 0.80 (0.31 to 2.07) | LOW 3 |
|              | (0 and 12 months) | 20 (8 to 52) |            |       |

| Mortality | Bivalent vaccine (0 and 2 months) | Bivalent vaccine (0 and 6 months) | Not estimable | 481 (1 RCT) | LOW 3 |
|-----------|----------------------------------|----------------------------------|---------------|-------------|-------|
|           | 0 per 1000                        | 0 per 1000 (0 to 0)               |               |             |       |
|           | Bivalent vaccine (0 and 6 months) | Bivalent vaccine (0 and 12 months) | Not estimable | 965 (1 RCT) | LOW 3 |
|           | 0 per 1000                        | 0 per 1000 (0 to 0)               |               |             |       |
|           | Nonavalent vaccine (0 and 6 months) | Nonavalent vaccine (0 and 12 months) | Not estimable | 452 (1 RCT) | LOW 3 |
|           | 0 per 1000                        | 0 per 1000 (0 to 0)               |               |             |       |

*Certainty of the evidence (GRADE) for immunogenicity outcomes are presented in detail in Appendix 6.

**The risk in the intervention group** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI).

CI: confidence interval; GMT: geometric mean titre; HPV: human papillomavirus; OR: odds ratio; RCT: randomised controlled trial

GRADE Working Group grades of evidence

- **High certainty:** we are very confident that the true effect lies close to that of the estimate of the effect
- **Moderate certainty:** we are moderately confident in the effect estimate: the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different
- **Low certainty:** our confidence in the effect estimate is limited: the true effect may be substantially different from the estimate of the effect
- **Very low certainty:** we have very little confidence in the effect estimate: the true effect is likely to be substantially different from the estimate of effect
Comparison of different human papillomavirus (HPV) vaccine types and dose schedules for prevention of HPV-related disease in females and males (Review)

1Downgraded two levels for serious imprecision: few events and a wide 95% confidence interval that incorporates a potential large beneficial effect and a potential small harmful effect.
2Downgraded one level for indirectness: this outcome is a composite measure of events which may or may not be clinically relevant, may or may not be related to the vaccine and may occur outside a biologically plausible time frame relative to vaccine exposure. This outcome is considered to provide indirect evidence about vaccine safety.
3Downgraded two levels for serious imprecision: no events reported, the studies were not powered to detect a difference in mortality.

Summary of findings 3. Three doses HPV vaccine compared with control in 10- to 26-year-old males

| Outcomes                          | Anticipated absolute effects* (95% CI) | Relative effect (95% CI) | No of participants (studies) | Certainty of the evidence (GRADE) | Comments     |
|-----------------------------------|---------------------------------------|--------------------------|------------------------------|----------------------------------|--------------|
|                                   | Risk/rate with control                | Risk/rate with HPV vaccine|                             |                                  |              |
| Invasive anal or penile cancer    |                                        |                          |                              |                                  |              |
| No studies were identified that reported on this outcome |                                      |                          |                              |                                  |              |
| Penile or anal intraepithelial neoplasia at up to 3-year follow-up | 3/2824 person-years | 0/2833 person-years | Rate ratio 0.17 (0.01 to 3.27) | 2805 participants (5657 person-years) | ⊕⊕⊝ LOW 2 |
| External genital lesions (any genotype) at up to 3-year follow-up | 36/3081 person-years | 6/3173 person-years | Rate ratio 0.16 (0.07 to 0.38) | 2545 participants (6254 person-years) | ⊕⊕⊕ MODERATE 1 |
| Anogenital warts at up to 3-year follow-up | 28/2814 person-years | 3/2831 person-years | Rate ratio 0.11 (0.03 to 0.38) | 2805 participants (5645 person-years) | ⊕⊕⊕ MODERATE 1 |
| Overall local/injection site adverse events at 15-day follow-up | 537 per 1000 (569 to 634) | 601 per 1000 | RR 1.12 (1.06 to 1.18) | 3895 (1 RCT) | ⊕⊕⊕⊕ HIGH 3 |

Data for specific local adverse events (pain, swelling, redness at injection)
| Event Type                                      | Group                        | Rate        | OR (95% CI)         | N (RCTs) | GRADE | Evidence Quality |
|-----------------------------------------------|------------------------------|-------------|---------------------|----------|-------|------------------|
| **Overall systemic events and general symptoms at 15-day follow-up** | Control                     | 11 per 1000 |                     |          |       |                  |
|                                               | Bivalent vaccine             | 17 per 1000 (2 to 141) | OR 1.48 (0.15 to 14.46) | 270      | ⊕⊕⊕⊕⊝ | VERY LOW 2,4      |
|                                               | Quadrivalent vaccine         | 3 per 1000 (1 to 7)    | OR 0.69 (0.29 to 1.66) | 5162     | ⊕⊕⊕⊕⊝ | VERY LOW 2,4      |
| **Serious adverse events at up to 3-year follow-up** | Control                     | 4 per 1000 |                     |          |       |                  |
|                                               | Bivalent vaccine              | see comment |                     |          |       |                  |
|                                               | Quadrivalent vaccine          | see comment |                     |          |       |                  |
| **Mortality at up to 3-year follow-up**       | Control                      | see comment |                     |          |       |                  |
|                                               | Bivalent vaccine              | see comment |                     |          |       |                  |
|                                               | Quadrivalent vaccine          | 1 per 1000 (0 to 4)    | OR 0.30 (0.09 to 1.01) | 5173     | ⊕⊕⊕     | LOW 2            |

*The risk in the intervention group (and its 95% confidence interval) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI).*

CI: confidence interval; HPV: human papillomavirus; OR: odds ratio; RCT: randomised controlled trial; RR: risk ratio

**GRADE Working Group grades of evidence**

- **High certainty:** we are very confident that the true effect lies close to that of the estimate of the effect
- **Moderate certainty:** we are moderately confident in the effect estimate: the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different
- **Low certainty:** our confidence in the effect estimate is limited: the true effect may be substantially different from the estimate of the effect
- **Very low certainty:** we have very little confidence in the effect estimate: the true effect is likely to be substantially different from the estimate of effect

1Downgraded one level for imprecision: few events.
Summary of findings 4. Nonavalent HPV vaccine compared with quadrivalent HPV vaccine in 9- to 26-year-old females and males

| Outcomes | Anticipated absolute effects* (95% CI) | Relative effect (95% CI) | № of participants (studies) | Certainty of the evidence (GRADE) | Comments |
|----------|----------------------------------------|--------------------------|-----------------------------|---------------------------------|----------|
|          | Risk with quadrivalent HPV vaccine | Risk with non-avalent HPV vaccine |                       |                                 |          |
| High-grade cervical intraepithelial neoplasia, adenocarcinoma in situ, and cervical cancer at up to 4.5-year follow-up | 47 per 1000 (41 to 55) | 47 per 1000 (41 to 55) | OR 1.00 (0.85 to 1.16) | 13,753 (1 RCT) | ⊕⊕⊕⊕ HIGH1 | No studies were identified which reported on invasive anal or penile cancer in males |
| High-grade cervical, vulval, and vaginal disease at up to 4.5-year follow-up | 49 per 1000 (42 to 56) | 48 per 1000 (42 to 56) | OR 0.99 (0.85 to 1.15) | 14,054 (1 RCT) | ⊕⊕⊕⊕ HIGH1 | No studies were identified which reported on penile or anal intraepithelial neoplasia in males |
| Overall local/injection site adverse events at 15-day follow-up | 846 per 1000 (888 to 914) | 905 per 1000 (888 to 914) | RR 1.07 (1.05 to 1.08) | 15,863 (3 RCTs) | ⊕⊕⊕⊕ HIGH | Data for specific local adverse events (pain, swelling, redness at injection site) are presented in the analysis section. |
| Overall systemic events and general symptoms | 543 per 1000 (532 to 565) | 548 per 1000 (532 to 565) | RR 1.01 (0.98 to 1.04) | 15,863 (3 RCTs) | ⊕⊕⊕ MODERATE3 |
Comparison of different human papillomavirus (HPV) vaccine types and dose schedules for prevention of HPV-related disease in females and males (Review)

Copyright © 2019 The Authors. Cochrane Database of Systematic Reviews published by John Wiley & Sons, Ltd. on behalf of The Cochrane Collaboration.

| Serious adverse events at 15-day follow-up | 25 per 1000 (4 to 63) | OR 0.60 (0.14 to 2.61) | 15,863 (3 RCTs) | ⊕⊕⊝⊝ LOW 2,3 |
|------------------------------------------|------------------------|------------------------|-----------------|----------------|

Please see Table 1 for list of events in each RCT. Numbers of events/number of participants (%) were: in 16- to 26-year-old females receiving nonavalent vaccine, 242/7686 (3.1%) vs quadrivalent vaccine, 184/7078 (2.6%) over a period of 4.5 years follow-up; in 16- to 26-year-old males receiving nonavalent vaccine, 0/249 (0%) vs quadrivalent vaccine, 6/251 (2.4%) over 7 months follow-up; in 9- to 15-year-old females receiving nonavalent vaccine, 1/299 (0.3%) vs quadrivalent vaccine, 2/300 (0.7%) over 7 months follow-up.

| Mortality at up to 4.5-year follow-up | 1 per 1000 (0 to 3) | OR 1.20 (0.37 to 3.94) | 15,248 (3 RCTs) | ⊕⊕⊝⊝ LOW 4 |
|--------------------------------------|---------------------|------------------------|-----------------|----------------|

*The risk in the intervention group (and its 95% confidence interval) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI).

CI: confidence interval; HPV: human papillomavirus; OR: odds ratio; RCT: randomised controlled trial; RR: risk ratio; SAE: serious adverse event

**GRADE Working Group grades of evidence**

High certainty: we are very confident that the true effect lies close to that of the estimate of the effect.

Moderate certainty: we are moderately confident in the effect estimate: the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different.

Low certainty: our confidence in the effect estimate is limited: the true effect may be substantially different from the estimate of the effect.

Very low certainty: we have very little confidence in the effect estimate: the true effect is likely to be substantially different from the estimate of effect.

1 Evidence from this outcome was not downgraded: the included trial was a large multi-national trial with low risk of bias and precise estimates.
2 Downgraded one level for imprecision: pooled estimate has a wide 95% confidence interval that incorporates a potential large beneficial effect and a potential large harmful effect.
3 Downgraded one level for indirectness: this outcome is a composite measure of events which may or may not be clinically relevant, may or may not be related to the vaccine and may occur outside a biologically plausible time frame relative to vaccine exposure. This outcome is considered to provide indirect evidence about vaccine safety.
4 Downgraded two levels for serious imprecision: few events and a wide 95% confidence interval that incorporates a potential large beneficial effect and a potential large harmful effect.
BACKGROUND

Description of the condition

Human papillomavirus (HPV) is the most common viral infection of the reproductive tract in women and men (WHO 2017). Although most HPV infections resolve spontaneously, persistent infections can lead to precancerous lesions and cancer of the cervix, vagina, vulva, anus, penis, and head and neck. HPV-related cancers accounted for an estimated 4.5% of all cancers worldwide in 2012 (de Martel 2017). When stratified by sex, these represent 8.6% of cancers in women and 0.8% of cancers in men, and by development status, 6.7% of all cancers in low- and middle-income countries and 2.8% in high-income countries (de Martel 2017). In 2012, of an estimated 636,000 HPV-related cancers worldwide, 530,000 were cervical cancer, 35,000 anal cancer, 8500 vulval cancer, 13,000 penile cancer, and 37,000 head and neck cancers (de Martel 2017).

Amongst women with normal cytological findings, the worldwide prevalence of infection with any HPV genotype has been estimated in a meta-analysis to be 11.7%, with higher prevalence in sub-Saharan Africa, Latin America, the Caribbean, south-east Asia and eastern Europe (Bruni 2010). Amongst heterosexual men assessed at baseline in a multicentre trial in 18 countries in Africa, Asia-Pacific, Europe, Latin America and North America, penile infection with any HPV genotype was found in 18.7%, scrotal infection in 13.1%, perianal infection in 7.9% and infection at any site in 21.0%. Prevalence was highest in Africa and lowest in the Asia-Pacific region (Vardas 2011). Prevalence of HPV infections in general is higher in men with HIV infection, men who have sex with men (MSM), and highest in MSM with HIV infection (Schim van der Loeff 2014; Smith 2011).

The main types of lesions associated with anogenital HPV infection are anogenital warts (condylomata acuminata) and intraepithelial neoplasia of the cervix (cervical intraepithelial neoplasia, CIN), vulva, vagina, anal canal/perianal area, and penis. Intraepithelial neoplasia is a precursor of some of these cancers, although it can regress at earlier stages and does not progress to invasive cancer in most affected people. A study that followed up women with inadequately treated CIN3 found that 31.3% (95% CI 22.7 to 42.3) developed invasive cancer after 30 years (McCredie 2008). HPV is also associated with squamous cell cancer of the head and neck (HNSSC). Of all head and neck cancers globally in 2012 (534,000), about 7% (37,000) were attributable to HPV, including 29,000 of 96,000 (31%) cases of oropharyngeal cancer (de Martel 2017). The incidence of cancers of the oropharynx has increased over time, more amongst men than women (Gillison 2015). It is likely that HPV is a main contributor to the increase in men, whilst smoking dominates the rise in women (Gillison 2015).

The International Agency for Research on Cancer classifies HPV genotypes according to oncogenic potential, with HPV genotypes 16, 18, 31, 33, 35, 39, 45, 51, 52, 56, 58, and 59 considered as high-risk genotypes (Bouvard 2009). HPV 16 and 18 are the most common genotypes in women worldwide and are associated with most cases of invasive cervical cancer; combined, HPV 16, 18, 31, 33, 45, 52 and 58 cause approximately 90% of all HPV-positive squamous cell carcinomas of the cervix (Alemayehu 2014; Bruni 2010; de Sanjose 2010). HPV 16 and 18 are also the cause of 90% of all anal cancers (Bosch 2002). HPV 16 is found in around 80% of HPV-related anal squamous cell cancers, in 52% of invasive penile squamous cell carcinoma, and in 90% of penile intraepithelial neoplasia (Krustup 2005; Schim van der Loeff 2014). In a meta-analysis, HPV was detected in 22% of HNSSC, with 86.7% of those being attributed to HPV 16, although HPV 6 and 11 were also detected in a minority of cases (Syrrijen 2010). HPV 6 and 11 account for up to 90% of anogenital warts (Greer 1995; Sturegard 2013).

Description of the intervention

Three prophylactic HPV vaccines, given by intramuscular injection, are available. All three vaccines are made by genetic technologies and are non-infectious because they do not contain viral DNA. They are made from purified L1 capsid proteins, which form virus-like particles that resemble the structure of specific genotypes of HPV. Each vaccine is directed against two or more high-risk HPV genotypes. All three vaccines contain L1 proteins of two HPV genotypes; 16 and 18. The quadrivalent vaccine contains L1 proteins of four HPV genotypes; 16 and 18, plus HPV 6 and 11, which cause genital warts. The nonavalent vaccine is the most recent vaccine and contains L1 proteins of nine HPV genotypes; 16, 18, 31, 33, 45, 52 and 58, plus HPV 6 and 11. All three vaccines contain adjuvants (Table 2). In addition to the licensed vaccines, as of September 2018, there are three vaccines in stage 2 to 3 development, two bivalent vaccines manufactured by Innovax and Walvax in China, and a quadrivalent vaccine manufactured by the Serum Institute of India (LaMontagne 2017).

To prevent HPV infection, all HPV vaccines are intended to be administered, where possible, before the first exposure to HPV, that is, before onset of sexual activity. All national HPV vaccination programmes involve girls, and some countries have extended their programme to boys. According to most modelling studies, HPV vaccination programmes for preadolescent girls will be cost-effective for the prevention of cervical cancer, particularly in settings in which infrastructure for cervical cancer screening is poor (WHO 2017). HPV vaccination of females gives indirect protection to males. These so-called herd effects mean that, at the population level, female-only vaccination programmes have resulted in reductions in HPV infections in both men and women (Drolet 2019). However, herd effects from female-only vaccination do not affect MSM, who experience a high burden of anal cancer and anogenital warts. Modelling studies also indicate that female-only HPV vaccination, even at high levels of coverage, will not prevent all HPV-related cancers in heterosexual men (Bogaards 2015). The cost-effectiveness of vaccinating boys depends on vaccination coverage in girls, the epidemiology of HPV-related disease, and the costs of the vaccine and the programme (WHO 2017).

The uptake of HPV vaccination varies widely between countries that have introduced it as part of their national immunisation programmes. In 2017, across 82 countries coverage rates ranged from 8% to 98% (Brotherton 2018). To date, few countries in Africa and Asia have introduced HPV vaccine. Whilst there is evidence from some low- and middle-income countries (LMICs) that HPV vaccine can be effectively introduced, countries with challenges have also been reported. For example, Uganda reported coverage of more than 80% for the first dose of a two-dose vaccine schedule, but this was not sustained for the second dose (Brotherton 2018). In high-income countries, such as England, Scotland, and Australia, school-based programmes have reached 70% to 80% of girls for
all doses. In other high-income countries, such as France, USA, Japan and Denmark, coverage has either not reached, or has fallen below 50%. The reasons for low coverage differ between countries, but include organisation of programme implementation, resistance from healthcare providers, adverse media coverage, and concerns about safety (Gallagher 2018).

### How the intervention might work

HPV vaccines containing virus-like particles of the L1 protein are prophylactic, meaning that they prevent infection and the development of intraepithelial lesions caused by HPV genotypes that are present in the vaccine (Stanley 2006). The virus-like particles in the vaccines produce very high levels of antibodies in serum, but the exact mechanisms by which the vaccines prevent HPV infection are not completely understood. The levels of antibodies needed to provide protection against clinical disease caused by HPV (known as the immunological correlate of protection) have not been established because the number of breakthrough infections after vaccination has been too low. The International Agency for Research on Cancer regards persistent HPV infection with HPV types 16 and 18, measured with standardised and validated tests, as an accurate surrogate marker for the precancerous lesions of the cervix and anus (IARC 2014). Post-licensure data from national immunisation programmes show reductions in high-grade lesions of the cervix and anus with three-dose regimens of the bivalent and quadrivalent vaccines (Markowitz 2018). Since precancer is on the causal pathway to invasive cancer, it is assumed that prevention of precancerous lesions will also be shown to prevent cancer when sufficient follow-up time has accrued in post-licensure studies. Less is known about the prognostic value of persistent HPV infection in the development of vaginal, vulval and oropharyngeal cancers (IARC 2014).

All of the randomised controlled trials (RCTs) that established the efficacy of HPV vaccines in the prevention of high-grade precancerous lesions of the cervix used a three-dose vaccination schedule (Arbyn 2018). Because of low HPV exposure and ethical constraints in conducting research that requires genital examination and specimen collection in adolescent populations (under 15 years of age), randomised efficacy trials of vaccines have typically been first conducted in women aged 15 to 25 or 26 years (Arbyn 2018). Once immunogenicity and harms have been evaluated, non-inferiority of immunological outcomes in 9- to 15-year-olds is assessed in non-randomised bridging studies (e.g. Block 2006; Dobson 2013). The International Agency for Research on Cancer regards bridging studies that demonstrate non-inferiority as a sufficient endpoint for individuals under 16 years of age (IARC 2014).

Vaccine schedules are designed to produce a strong and long-lasting antibody response so that, when challenged by exposure to the real pathogen, the immune system prevents infection. A three-dose vaccine schedule is typical for inactivated protein vaccines for infants; the second dose is given one or two months after the first dose and a third dose six months after the first dose. The first two vaccine doses are called ‘prime’ doses that generate immune memory via B-lymphocytes produced in the bone marrow (Stanley 2014). The second dose results in higher levels of antibodies than the first and increases the binding affinity of the antibody to the antigen, in a process that last several months. As a result of this process (affinity maturation), B cells with very high levels of affinity, differentiates in the bone marrow into memory B cells that respond rapidly to produce antibodies on exposure to antigen and long-lived plasma cells that continuously produce antibody at low levels. A third vaccine dose given at least four months after the prime doses ‘boosts’ these responses maximally to provide long-lasting protection (Stanley 2014).

Simplified HPV vaccination schedules with fewer doses should allow more people to receive the vaccine. Preadolescents and adolescents (age 9 to 15 years) produce stronger antibody responses to virus-like protein HPV vaccines than older adolescents and adults (Block 2006; Dobson 2013), even after a single dose (Sankaranarayanan 2016). It appears that multiple repeated doses of these vaccines are not required for affinity maturation and that long-lived plasma cells are more important than memory B cells in the immune response (Schiller 2018). It is thought that structural characteristics of the virus-like particles allow efficient production of the long-lived plasma cells, which continuously produce antigen-specific antibodies, resulting in strong long-lasting immune responses with reduced dose schedules (Schiller 2018).

Evidence of the likely efficacy of a two-dose schedule of virus-like particle HPV vaccines in preventing incident vaccine-type HPV infection comes from studies in which data from RCTs were analysed as cohort studies according to the number of doses of HPV vaccine received (Kreimer 2011; Sankaranarayanan 2016). Kreimer and colleagues conducted a secondary analysis of data from an RCT of the bivalent vaccine amongst 18- to 25-year-old women in Costa Rica (Kreimer 2011). In that trial, 20% of women did not receive all three doses of the vaccine. Women were grouped according to the number of HPV vaccine doses that they received. The proportions of women with incident HPV 16/18 infection that persisted for 12 months or more was similar amongst women who received one, two and three doses (Kreimer 2011). An updated analysis combined data from this Costa Rica vaccine trial and a pivotal trial of the bivalent vaccine, Pavaonen 2007, according to number of doses received after four years of follow-up (Kreimer 2015). In the modified total vaccinated cohort, vaccine efficacy against HPV 16/18 incident infection that persisted for 12 months or more was 83.7% (95% CI 35.7 to 97.5%) with two doses, and 92.6% (95% CI 89.2 to 95.1%) with three doses. Sankaranarayanan and colleagues analysed an RCT of the quadrivalent vaccine in 10- to 18-year-olds in India (which was stopped before enrolment was completed) according to the number of HPV vaccine doses received (Sankaranarayanan 2016). Incidence of HPV 16/18 was 0.8% (95% CI 0.2 to 1.9%, 4/526) amongst participants who received two doses, and 0.4% (95% CI 0.0 to 1.3%, 2/536) amongst those who received three doses (Sankaranarayanan 2016). Additional data from a systematic review of post-licensure studies in national HPV vaccination programmes, show the receipt of two doses of HPV vaccine was associated with a reduction in the incidence of vaccine-type HPV prevalence, anogenital warts and cervical abnormalities in some, but not all, studies (Markowitz 2018).

### Why it is important to do this review

In practice, HPV vaccination rates in many countries remain low.

Simpler HPV immunisation schedules have been identified as a potential strategy to increase the coverage of vaccination (Walling 2016). The World Health Organization (WHO) recommended a two-dose HPV vaccine schedule in 2014, based on a systematic review of studies with immunogenicity as the end-point (D’Addario 2014).
In 2018, a Cochrane Review concluded that the licensed three-dose schedules of the bivalent and quadrivalent HPV vaccines result in limited adverse events and are effective against precancerous cervical lesions in females (Arbyn 2018). Since the 2014 WHO recommendation and original systematic review of two-dose HPV vaccination schedules (D'Addario 2017; WHO 2017), the evidence base from RCTs about alternative vaccination schedules has expanded to include more data about the nonavalent HPV vaccine (Iversen 2016), about HPV vaccination in males, including MSM (Giuliano 2011), and amongst people living with HIV infection (Toft 2014). This review was initially commissioned in 2016 by the WHO Initiative for Vaccine Research to update the evidence for the two-dose recommendation and is an update of D'Addario 2017. We produced a revised protocol for this update (Bergman 2017).

Cochrane Reviews usually include only RCTs with major clinical disease endpoints because RCTs provide the highest level of certainty about critical outcomes of interventions. However, precancer and cancer do not develop until many years after the acquisition of HPV infection, so it is difficult to determine the efficacy of vaccines against these outcomes. Persistent HPV infection is considered by the International Agency for Research on Cancer to be sufficient as a surrogate marker for cervical and anal cancer and non-inferiority of immunogenicity is sufficient to bridge results to under-16-year-olds. It is therefore important to document all infection and immunological outcomes measured in RCTs of HPV vaccines, even if the intended use of the vaccine is to prevent cancer.

This review aims to extend the evidence base on the efficacy and harms of HPV vaccines by including and evaluating RCTs of different HPV vaccines and different dose schedules in adolescent and adult females and males, as well as women and men living with HIV infection.

While RCTs can identify adverse events that take place during the study period, post-marketing surveillance is needed to continue monitoring harms associated with HPV vaccines in the population, and will be incorporated in future updates of this review.

**OBJECTIVES**

To evaluate the efficacy, immunogenicity, and harms of different dose schedules and different types of HPV vaccines in females and males.

**METHODS**

**Criteria for considering studies for this review**

**Types of studies**

We included RCTs with no language restrictions. We included unpublished studies, studies in press, and abstracts without a full-text publication, if they met the inclusion criteria.

**Types of participants**

Females or males aged 9 to 26 years, including MSM. For the comparisons among people living with HIV, we included all age groups.

**Types of interventions**

Prophylactic administration of licensed bivalent (Cervarix, GlaxoSmithKline), quadrivalent (Gardasil, Merck), or nonavalent (Gardasil 9, Merck) HPV vaccines. We excluded studies if they assessed monovalent or plasmid vaccines, or assessed non-prophylactic uses of bivalent, quadrivalent or nonavalent vaccines. In addition, we considered for inclusion any trials reporting on the efficacy, immunogenicity, or adverse events in vaccines currently in phase 2 or 3 development. Studies comparing bivalent versus quadrivalent vaccines were excluded, as these will be included in an update of a separate Cochrane Review (Arbyn 2018).

For males and people living with HIV, we included comparisons of HPV vaccines to placebo containing no adjuvant or only the adjuvant of the HPV vaccine, or another HPV vaccine.

In this review, we use the term ‘control’ to refer to comparator products that contain another vaccine or only vaccine adjuvants, regardless of the terminology used in individual study reports. We use the term ‘placebo’ only to refer to comparator products containing no adjuvant or active vaccine. In Characteristics of included studies we have reported full details of the type of comparison group compound.

The focus of the review was on different dose schedules and comparisons between different types of HPV vaccine. Where possible we stratified data by participant characteristics of age, gender, and HIV status. Specifically, we aimed to investigate the efficacy, immunogenicity, and harms of:

- fewer than three doses of HPV vaccine in females and males;
- different intervals between doses in a two-dose schedule in females and males;
- HPV vaccination compared to control for males (a Cochrane Review for females has been published (Arbyn 2018));
- nonavalent HPV vaccine compared to the other HPV vaccines in females and males;
- HPV vaccination in people living with HIV.

**Types of outcome measures**

**Primary outcomes**

Unless otherwise stated, primary outcomes were assessed at the longest follow-up time reported by the included studies.

- Invasive cervical, vaginal, vulval, anal, or penile cancer
- In females, histologically-confirmed high-grade cervical (CIN2, CIN3, and adenocarcinoma in situ), vaginal, vulval, or anal intraepithelial neoplasia, irrespective of HPV genotype, or any lesions associated with the HPV genotypes included in the vaccine
- In males, histologically-confirmed anal, or penile, perianal or perineal intraepithelial neoplasia of any grade, irrespective of HPV genotype, or any lesions associated with the HPV genotypes included in the vaccine
- Anogenital warts
• Adverse events related to the vaccines: local adverse events (overall local/injection site adverse events, redness, swelling, pain at the injection site), assessed at the follow-up times reported in the trials (usually up to seven days); overall systemic events and general symptoms assessed at the follow-up times reported in the trials (usually up to 15 days)

• Serious adverse events and mortality: any events that are fatal, life-threatening, or result in hospitalisation and mortality. We collected information from each trial about whether these events were considered to be vaccine-related and the methods of adverse events data monitoring and collection, including mode of data collection, timing, attribution methods, intensity of ascertainment, harms-related monitoring and stopping rules, and reporting based on event frequency (i.e. frequency-based filter), based on the CONSORT statement extension for reporting harms (Ioannidis 2004; Lineberry 2016).

Secondary outcomes

Unless otherwise stated, secondary outcomes were assessed at the longest follow-up time reported by the included studies.

• Incident infection with vaccine HPV genotypes (HPV 16 and HPV 18 jointly; HPV 6, HPV 11, HPV 16 and HPV 18 jointly; and HPV 31, HPV 33, HPV 45, HPV 52, and HPV 58 jointly)

• Persistent infection (persisting for at least six months or at least 12 months) with vaccine HPV genotypes

• Immunological outcomes (geometric mean titre (GMT) and seropositivity), assessed at one month following the last dose and at the longest-term follow-up

For the comparisons of dose schedules (i.e. number of doses and longer or shorter interval(s) between doses) we considered immunological outcomes as primary outcomes because these trials were designed to show non-inferiority of immunogenicity. While these trials were not designed to evaluate efficacy or safety of the vaccines, we have included clinical outcomes when reported and comparative estimates of harms associated with the different dose schedules.

Search methods for identification of studies

We attempted to identify all relevant studies regardless of language or publication status (published, unpublished, in press and in progress).

Electronic searches

All searches were conducted on 27 September 2018. We searched the following electronic databases:

• the Cochrane Central Register of Controlled Trials (CENTRAL, Issue 9, 2018) (published in the Cochrane Library)

• Ovid MEDLINE (1946 to September week 2 2018);

• Ovid Embase (1980 to 2018 week 39).

The search terms used are detailed in Appendix 1, Appendix 2, and Appendix 3. We also searched ClinicalTrials.gov and the WHO International Clinical Trials Registry Platform (ICTRP) to identify ongoing trials using ‘genital warts’, ’condyloma’, ’anogenital warts’, ’venereal warts’, ’human papilloma virus vaccine’, and ’HPV vaccine’ as search terms.

Searching other resources

We searched the reference lists of all included studies, as well as the reference lists of any relevant systematic reviews published within the search dates. We searched vaccine manufacturer web sites for relevant clinical trial reports (GlaxoSmithKline; Merck). In addition, we screened a list of HPV vaccine studies (Jørgensen 2018a), that was constructed through enquiries to HPV vaccine manufacturers and regulators, as well as searches of trial registers and journal publication databases. For each included study, where available, we identified and screened study governance documents (protocols, trial registration listings and results, manufacturers’ clinical study reports) for relevant data and outcomes. We also contacted the vaccine manufacturers through the WHO Initiative for Vaccine Research for any additional, potentially relevant studies.

Data collection and analysis

Selection of studies

Two experienced systematic reviewers independently screened citations and abstracts of studies identified from the electronic searches for potential inclusion. A third reviewer resolved any disagreements. We obtained full-text reports for all potentially eligible studies. Two independent reviewers determined the eligibility of studies for inclusion in the review from the full reports according to predefined criteria. A third reviewer resolved any disagreements.

Data extraction and management

For the purpose of the review, we named studies on the basis of the first-named study author and year of publication. Many studies have more than one document associated with them: journal publications (main study reports, reports of long-term follow-up, secondary outcomes and post-hoc analyses), conference abstracts, and study governance documents (protocols, trial registration listings and results, manufacturers’ clinical study reports). For each study we grouped these documents together and designated one report as the primary reference for the study; the study name is derived from the name of the first author and year of publication of this particular report.

In cases where study reports emanate from the same parent study, but are planned or reported, or both, as distinct, discrete studies, we have named and handled these separately.

Two reviewers carried out data extraction independently using pretested data extraction forms. We resolved any differences by discussion between the two reviewers and referral to the study reports.

We cross-checked data for the efficacy outcomes and adverse events between the primary trial publications, trial registries, and clinical study reports. We used the data derived from these sources with the longest follow-up time for the primary analysis.

Assessment of risk of bias in included studies

Two reviewers independently carried out ‘Risk of bias’ assessments using the Cochrane ‘Risk of bias’ tool for all included studies (Higgins 2011b). We judged the risk of bias for each domain as ’low risk’, ’unclear risk’ or ’high risk’. We resolved differences by discussion between the two reviewers and if necessary we referred to a third reviewer for arbitration.
Measures of treatment effect

We calculated risk ratios (RR) with 95% confidence intervals (CI) for dichotomous outcomes. We calculated rate ratios with 95% CIs for dichotomous clinical outcomes reported as incidence rates. For outcomes with rare events (i.e. an event rate of <10%), serious adverse events, and deaths, we calculated Mantel-Haenszel odds ratios (OR) for dichotomous outcomes. We assessed the robustness of the primary analysis for very rare events with alternative statistical methods (see Sensitivity analysis).

For continuous geometric mean titre (GMT) data, we calculated inverse variance (IV) ratios of GMTs with 95% CIs. Initially, we transformed the point estimates as well as the lower and upper bound of the 95% CI of GMT for each group into the logarithmic scale in order to obtain statistically correct standard deviations. Then we calculated the mean difference of the compared group and back-transformed the results (point estimate and 95% CIs) to the original scale through exponentiation. Non-inferiority margins for immunological outcomes were derived from the individual trials (all trials used 0.5 for the GMT ratio). For GMT ratios non-inferiority is demonstrated if the lower 95% CI is greater than 0.5. If the lower confidence interval was below the non-inferiority margin, but the point estimate was within the margin, we considered the result to be inconclusive (Piaggio 2012).

For adverse events and efficacy outcomes we carried out a complete-case analysis (the number analysed) and an intention-to-treat analysis when data were available. For immunogenicity outcomes assessed in non-inferiority trials, we favoured data from per-protocol analyses, in which all participants were HPV-seronegative at baseline. We did not pool studies with participants who were HPV-seropositive at baseline with studies with participants who were HPV-seronegative at baseline.

Unit of analysis issues

If a single trial compared two or more vaccine arms (with or without a control arm), we labelled the arms separately in analyses. We grouped suitable multiple treatment arms (e.g. arms that evaluated different vaccine lots) and excluded irrelevant trial arms. We did not pool data from cluster RCTs with those from individually randomised studies.

Dealing with missing data

If data on specific outcomes or population groups were missing, we attempted to contact study authors or data owners to request this data. We did not impute missing outcome data. Where data were missing or losses to follow-up were substantial, we downgraded the certainty of study evidence due to risk of bias according to GRADE criteria (Guyatt 2011a).

Assessment of heterogeneity

We described potential sources of clinical heterogeneity, and downgraded the certainty of the evidence according to GRADE criteria due to inconsistency where appropriate (Guyatt 2011b). When pooling of studies was feasible (i.e. at least two studies included), we inspected forest plots visually for potential outlying studies and variability in the estimated effects across studies. We assessed statistical heterogeneity using the I² statistic. This statistic quantifies the percentage of inconsistency in the treatment effects across studies beyond simple chance. We regarded heterogeneity as potentially unimportant if the I² was 0% to 40%; that values of 30% to 60% might represent moderate heterogeneity; values between 50% to 90% might represent substantial heterogeneity; and that values between 75% to 100% would represent considerable heterogeneity (Higgins 2011a). Where considerable heterogeneity existed (>75%), we did not pool study data.

Assessment of reporting biases

We had planned to use funnel plots to investigate the possible presence of small-study effects for each outcome. However, we did not produce funnel plots, due to the limited number of studies per outcome (i.e. fewer than 10) (Guyatt 2011c).

Data synthesis

When pooling was considered feasible, we employed a random-effects meta-analysis using the DerSimonian and Laird method (DerSimonian 1986), as it was assumed that effect size might vary across studies and settings. We used data from the last available follow-up for clinical and adverse event outcomes, with the number of participants (rather than the number of events) used in the analysis. For immunological outcomes, we extracted data from one month after the last HPV dose and at the longest-term follow-up.

To assess the harms associated with the HPV vaccine comparisons in this review, we recorded the methods used in each included study to collect adverse event data, and extracted data on common events that we determined a priori as: pain, swelling, redness at the injection site and overall systemic adverse events. For all serious adverse events reported in the included studies, we extracted the number of participants, participants with events and a description of the events. We also extracted information on whether the serious adverse events were considered to be related to the vaccines. We did not conduct statistical hypothesis testing because our protocol did not prespecify hypotheses about differences in the occurrence of any specific serious adverse event.

We prepared ‘Summary of findings’ tables for each comparison for which data were available for the following outcomes that were assessed as critical or important according to GRADE guidelines (Guyatt 2011d):

- for females: high-grade cervical intraepithelial neoplasia, adenocarcinoma in situ, or cervical cancer; high-grade vulval and vaginal disease;
- for males: invasive anal or penile cancer, external genital lesions;
- for all populations: anogenital warts, overall local/injection site adverse events, overall systemic events and general symptoms, serious adverse events, deaths;
- for comparisons of dose schedules (i.e. number of doses and longer or shorter interval between doses): immunological outcomes.

We assessed the certainty of evidence in the review through discussion between review authors using the GRADE approach using GRADEpro online software (GRADEpro GDT). We assessed only the primary outcomes reported in the ‘Summary of findings’ tables and appendices using GRADE. We considered the following factors for downgrading: limitations in the study design (risk of bias); inconsistency of results (heterogeneity); indirectness of evidence (applicability); imprecision (few events and wide

Comparison of different human papillomavirus (HPV) vaccine types and dose schedules for prevention of HPV-related disease in females and males (Review)

Copyright © 2019 The Authors. Cochrane Database of Systematic Reviews published by John Wiley & Sons, Ltd. on behalf of The Cochrane Collaboration.
confidence intervals); and publication bias (Guyatt 2011a). When evidence was downgraded, we detailed the reasons in footnotes of the ‘Summary of findings’ tables and summarised these in the Quality of the evidence section. Depending on whether evidence was downgraded or not, we rated the certainty of the evidence for each outcome as follows:

- high-certainty evidence indicates that we are very confident that the true effect lies close to that of the estimate of the effect (evidence was not downgraded);
- moderate-certainty evidence indicates that we are moderately confident in the effect estimate: the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different (evidence was downgraded one step for any of the factors described above);
- low-certainty evidence indicates that our confidence in the effect estimate is limited: the true effect may be substantially different from the estimate of the effect (evidence was downgraded two steps for any of the factors described above);
- very low-certainty evidence indicates that we have very little confidence in the effect estimate: the true effect is likely to be substantially different from the estimate of effect (evidence was downgraded three steps for any of the factors described above).

We reported relative risks (ORs or RRs) in the Effects of interventions section for all relevant outcomes, but where the evidence was of very low-certainty we reported the number of events in each group only.

Subgroup analysis and investigation of heterogeneity
We performed subgroup meta-analyses where possible, using vaccine type, gender, and age group (9 to 15 years; 16 to 26 years) as stratifying variables.

Sensitivity analysis
We carried out one post-hoc sensitivity analysis for outcomes using a Mantel-Haenszel odds ratio where events were very rare (i.e. an event rate of < 1% across both trial arms). We compared the results of the primary analysis calculated with Mantel-Haenszel methods against those with Peto methods (Bradburn 2007). We also planned to conduct sensitivity analyses for the primary outcomes according to allocation concealment (high risk of bias, low risk of bias, and unclear risk of bias) for outcomes for which data could not be pooled because of considerable heterogeneity (I^2 > 75%).

RESULTS
Description of studies
Overall, 20 RCTs were included for analysis in this review (Figure 1). The characteristics of individual studies and assessment of risk of bias are presented in the Characteristics of included studies section and Figure 2.
Figure 1. Study flow diagram.

3298 records identified through database searching

554 additional records identified through other sources

3291 records after duplicates removed

3291 records screened

2763 records excluded

528 full-text articles assessed for eligibility

438 full-text articles excluded, with reasons
2 studies awaiting classification (5 references)
15 ongoing studies (16 references)

20 studies (69 references) included in qualitative synthesis

19 studies included in quantitative synthesis (meta-analysis)
Figure 2. Risk of bias summary: review authors’ judgements about each risk of bias item for each included study.

| Study Details               | Random sequence generation (selection bias) | Allocation concealment (selection bias) | Blinding of participant and personnel (performance bias) | Blinding of outcome assessment (detection bias) | Incomplete outcome data (attrition bias) | Selective reporting (reporting bias) | Other bias |
|-----------------------------|---------------------------------------------|------------------------------------------|----------------------------------------------------------|------------------------------------------------|----------------------------------------|------------------------------------|-----------|
| Denny 2013                  | ✶✶✴✴ | ✶ | ✶ | ✶ | ✶✴ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ |
| Dobson 2013                 | ✶✶✴✴ | ✶ | ✶ | ✶ | ✶✴ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ |
| Giuliano 2011               | ✶✶✴✴ | ✶ | ✶ | ✶ | ✶✴ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ |
| Hidalgo-Tenorio 2017        | ✶✶✴✴ | ✶ | ✶ | ✶ | ✶✴ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ |
| Iversen 2016                | ✶✶✴✴ | ✶ | ✶ | ✶ | ✶✴ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ |
| Joura 2015                  | ✶✶✴✴ | ✶ | ✶ | ✶ | ✶✴ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ |
| Lehtinen 2016               | ✶✶✴✴ | ✶ | ✶ | ✶ | ✶✴ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ |
| Leung 2015                  | ✶✶✴✴ | ✶ | ✶ | ✶ | ✶✴ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ |
| Levin 2010                  | ✶✶✴✴ | ✶ | ✶ | ✶ | ✶✴ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ |
| Lin 2014                    | ✶✶✴✴ | ✶ | ✶ | ✶ | ✶✴ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ |
| NCT00341889 2016            | ✶✶✴✴ | ✶ | ✶ | ✶ | ✶✴ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ |
| NCT01031069 2017            | ✶✶✴✴ | ✶ | ✶ | ✶ | ✶✴ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ |
| NCT01562574 2018            | ✶✶✴✴ | ✶ | ✶ | ✶ | ✶✴ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ |
| Potaje 2009                 | ✶✶✴✴ | ✶ | ✶ | ✶ | ✶✴ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ |
| Pulhanakit 2016             | ✶✶✴✴ | ✶ | ✶ | ✶ | ✶✴ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ |
| Romanowski 2011             | ✶✶✴✴ | ✶ | ✶ | ✶ | ✶✴ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ |
| Tuft 2014                   | ✶✶✴✴ | ✶ | ✶ | ✶ | ✶✴ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ |
| van Damme 2016              | ✶✶✴✴ | ✶ | ✶ | ✶ | ✶✴ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ |
| Vesikari 2015               | ✶✶✴✴ | ✶ | ✶ | ✶ | ✶✴ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ |
| Vrijkot 2018                | ✶✶✴✴ | ✶ | ✶ | ✶ | ✶✴ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ | ✶ |
Results of the search

The search identified a total of 3852 records; 3298 from electronic databases and 554 from other sources (systematic reviews, vaccine manufacturers, online trial registrations, WHO IHR department, HPV study index (Jørgensen 2018a)). After de-duplication, 3291 records remained. After excluding irrelevant abstracts, we assessed 538 full texts. We excluded 438 full texts and included 20 RCTs (reported in 69 published and unpublished reports) in this review for analysis (Dobson 2013; Giuliano 2011; Hidalgo-Tenorio 2017; Iversen 2016; Joura 2015; Lehtinen 2015; Levin 2010; Lin 2014; NCT00941889 2016; NCT01031069 2017; NCT01862874 2018; Petaja 2009; Puthanakit 2016; Romanowski 2011; Toft 2014; van Damme 2016; Vesikari 2015; Wilkin 2018). We identified 15 ongoing studies (reported in 16 records) and two studies (reported in five references) are awaiting classification.

Included studies

We found 20 RCTs that contained data on vaccine efficacy or harms, or both, and enrolled a total of 31,940 men, women, and children. Ten studies were multi-national and were carried out in two to 18 countries in Africa, Asia, Asia-Pacific, Europe, Latin America, North America, and South America. The other 10 studies were carried out in one country only (USA, including Puerto Rico (3 studies), Finland (2), Canada (1), Denmark (1), Japan (1), Spain (1), South Africa (1)). Owing to differences in the protocols of the included trials, the maximum age for inclusion was either 25 or 26 years.

Description of studies

Four RCTs evaluated the effects of reduced dose schedules (Dobson 2013; Iversen 2016; Leung 2015; Romanowski 2011). All these trials were designed as non-inferiority trials of antibody responses. They reported on immunogenicity as the primary outcome and on adverse events. None of these trials collected data on clinical events. These four RCTs evaluated the effects of two doses of HPV vaccine versus three doses of HPV vaccine in adolescent girls (9 to 15 years). We did not identify any RCTs that evaluated the efficacy or harms of one dose of HPV vaccine.

Four RCTs compared different intervals between doses. Two RCTs compared a longer interval two-dose schedule with a shorter schedule (0 and 6 months versus 0 and 2 months; or 0 and 12 months versus 0 and 6 months) of bivalent HPV vaccine in 9- to 14-year-old females (Puthanakit 2016; Romanowski 2011). One RCT of nonavalent HPV vaccine compared a two-dose schedule with a longer interval (0 and 12 months) and a shorter interval (0 and 6 months) in 9- to 14-year-old females and males (Iversen 2016). One RCT compared a longer interval three-dose schedule (administered at 0, 2, and 6 months) with a shorter schedule (administered at 0, 2, and 6 months) of quadrivalent HPV vaccine in 18- to 25-year-old males (Lin 2014).

Two RCTs compared quadrivalent HPV vaccine versus control in 5189 males aged 16 to 26 years (Giuliano 2011; NCT01862874 2018). A subgroup analysis of Giuliano 2011 also reported on the efficacy and harms of the quadrivalent HPV vaccine compared with control vaccine in MSM. Giuliano 2011 reported on clinical, adverse event, and immunogenicity outcomes, and NCT01862874 2018 reported on clinical outcomes and adverse events. One RCT compared bivalent HPV vaccine versus control hepatitis B virus (HBV) vaccine in 270 boys aged 10 to 18 years and reported on immunogenicity and harms (Petaja 2009). In addition, a cluster-RCT investigating both direct and indirect effects of HPV vaccination of girls and boys (gender-neutral) and girls-only vaccination reported on adverse events in a subgroup of 3703 12- to 15-year-old males vaccinated with the bivalent vaccine or control HBV vaccine (Lehtinen 2018). We identified no studies investigating the clinical efficacy of the nonavalent vaccine in males.

Three RCTs compared three doses of nonavalent vaccine with three doses of quadrivalent vaccine: one in 9- to 15-year-old females (Vesikari 2015), one in 16- to 26-year-old females (Joura 2015), and one in males aged 16 to 26 years (van Damme 2016). Joura 2015 reported clinical outcomes for the 16- to 26-year-old population. All three studies reported on adverse event and immunogenicity outcomes.

Studies including participants living with HIV

We identified seven RCTs that examined HPV vaccines in 1723 people living with HIV (Denny 2013; Hidalgo-Tenorio 2017; Levin 2010; NCT00941889 2016; NCT01031069 2017; Toft 2014; Wilkin 2018):

- Toft 2014 compared bivalent with quadrivalent vaccine in females and males ≥ 18-years old;
- NCT01031069 2017 compared bivalent with quadrivalent vaccine in 15- to 25-year-old females;
- Denny 2013 compared bivalent vaccine with control in women aged 18 to 25 years;
- Hidalgo-Tenorio 2017 compared quadrivalent vaccine with control in MSM ≥ 18-years old;
- Wilkin 2018 compared quadrivalent vaccine with control in females and males ≥ 27-years old;
- NCT00941889 2016 compared quadrivalent vaccine with control in females and males ≥ 18-years old that had been treated for anogenital warts;
- Levin 2010 compared three doses of quadrivalent vaccine with control in 126 children aged 7 to 12 years, and four versus three doses of quadrivalent vaccine in the same participants.

The studies were carried out in Brazil, Denmark, Estonia, India, South Africa, Spain, Thailand, and the USA, including Puerto Rico. Of these, only two reported on clinical outcomes (NCT00941889 2016; Wilkin 2018), as most were designed as non-inferiority trials of antibody responses.

Adverse events

Appendix 4 lists the methods used to collect adverse event data. The mode of data collection was reported in 16 of the 20 studies and was passive in two studies (e.g. patients recording symptoms on diary cards); proactive in three (e.g. investigators observing
participants after vaccine administration, or field workers visiting or calling participants in their homes; both passive and proactive in nine studies; and in two studies, the details were insufficient for us to categorise as passive or proactive. Time frame (duration of follow-up) was reported for all but three studies; for two studies it was unclear, and one study did not report on adverse events (NCT00941889 2016). Methods to determine the relationship between vaccination and adverse events were reported by 10 studies: attribution was done by study investigators in nine studies and by a study co-ordinator in one study. Where the attribution method was not reported, we assumed this role was performed by study investigators. Fourteen studies (74%) provided definitions for the adverse events outcomes. Withdrawals due to adverse events were reported in 14 (70%) studies, but most studies (95%) did not report on how withdrawals would be handled in the analysis. Only one study reported harms-related monitoring and stopping rules (Hidalgo-Tenorio 2017). Seventeen studies reported on all adverse events regardless of frequency (i.e. they did not use a frequency-based filter); NCT01862874 2018 used a 5% threshold for other adverse events; it was unclear whether Dobson 2013 used a filter, and one study did not report on adverse events (NCT00941889 2016).

The length of follow-up for serious adverse events in the included studies ranged from seven months to five years. Table 1 lists the serious adverse events reported in each study. In all studies, the individual serious events were listed for each study arm. In five of the 20 RCTs, 50 or more serious adverse events were reported (Joura 2015, Lehtinen 2018; Puthanakit 2016; Romanowski 2011; Wilkin 2018). Information on whether serious adverse events were considered to be related to the vaccine is reported in the section Effects of interventions.

Studies awaiting classification

We identified two studies that included both males and females randomised to HPV vaccine and control (Li 2012; Reisinger 2007). The male population in these studies would qualify for inclusion in our review, but at the time of preparing this review we were not able to access data for males only. We have requested this information from the study investigators and, should these data become available, they will be included in a future update of this review.

Li 2012 and Reisinger 2007 both compared quadrivalent HPV vaccine to vaccine adjuvant-containing control in 9- to 15-year-old males. The studies reported on the comparison of males with females for immunogenicity outcomes and adverse events for males and females as one group. Li 2012 was carried out in China, and Reisinger 2007 was carried out in 10 countries in North America, Latin America, Europe and Asia. See Characteristics of studies awaiting classification for further details.

Ongoing studies

We identified 15 potentially relevant ongoing studies that have not been completed, but might be relevant for inclusion in future updates of this review. All studies are RCTs and studies may appear in more than one category of the list below:

• eight include healthy males (NCT01735006; NCT02009800; NCT02405520; NCT02562508; NCT02733068; NCT02740777; NCT02834637; NCT03180034);
• four include healthy males and females (NCT01824537; NCT02567955; NCT02710851; NCT02888418);
• one includes HIV-positive MSM (NCT02087384);
• one includes males and females cured of genital warts (NCT03296397);
• one includes females with genital warts (NCT02750202);
• seven are evaluating new vaccines in development in China (NCT01735006; NCT02405520; NCT02562508; NCT02710851; NCT02733068; NCT02740777; NCT02888418);
• four are evaluating the quadrivalent vaccine (NCT02009800; NCT02087384; NCT02750202; NCT03296397);
• one is evaluating the nonavalent vaccine (NCT01824537); and
• three are comparing the bivalent to the nonavalent vaccine (NCT02567955; NCT02834637; NCT03180034).

In addition to the seven studies ongoing in China, three of these studies are ongoing in Canada, and one study each in Costa Rica, France, the Netherlands, South Africa, and Tanzania. See Characteristics of ongoing studies for further details.

Excluded studies

We excluded 438 full texts. Twenty-two of these were potentially relevant studies, and the reasons for their exclusion are included in the Characteristics of excluded studies table. We excluded six studies because they were not RCTs, and two studies because they included females over 26 years of age. Most of the excluded studies contained no comparison of relevance to the review: seven studies compared HPV-vaccinated to HPV-unvaccinated females, five compared different intervals in three-dose schedules in females, one compared three-dose schedules of the bivalent and quadrivalent vaccine in young females, and one evaluated the effect of a booster dose of HPV vaccine.

Risk of bias in included studies

The risk of bias for each included study is detailed in Characteristics of included studies and an overview is presented in Figure 2. Overall risk of bias for each comparison is discussed in each results section below.

Allocation

We assessed most studies as being at low risk of selection bias, as they reported adequate randomisation sequence generation (15/20 = 75%) and allocation concealment procedures (15/20 = 75%). Five studies did not report their methods to conceal allocation adequately (Levin 2010; Lin 2014; NCT01031069 2017; NCT00941889 2016; NCT01862874 2018), and five did not report the method of sequence generation adequately (Levin 2010; NCT01031069 2017; NCT00941889 2016; NCT01862874 2018; Wilkin 2018); we assessed them as being at unclear risk of bias.

Blinding

Blinding of participants and providers was explicitly reported by less than half of the included studies (7/20 = 35%), we assessed those studies that did as being at low risk of performance bias. We assessed eight studies as being at unclear risk of performance bias as they did not report blinding status of participants and personnel clearly (Denny 2013; Hidalgo-Tenorio 2017; Levin 2010; NCT00941889 2016; NCT01031069 2017; NCT01862874 2018; Romanowski 2011; Wilkin 2018), and five studies as being at
high risk of performance bias due to no, or partial blinding, of participants, personnel, or both (Dobson 2013; Lehtinen 2018; Puthanakit 2016; Iversen 2016; Lin 2014).

Less than half of the studies reported adequate blinding of outcome assessors (9/20 = 45%); we considered those that did to be at low risk of detection bias. Eight studies did not report details regarding blinding of outcome assessment and we assessed them as being at unclear risk of bias (Denny 2013; Hidalgo-Tenorio 2017; Levin 2010; Lin 2014; NCT01031069 2017; NCT00941889 2016; NCT01862874 2018; Wilkin 2018), and three studies did not blind outcome assessment and were assessed as being at high risk of detection bias (Iversen 2016; Lehtinen 2018; Puthanakit 2016).

Incomplete outcome data
We assessed most included studies (18/20 = 90%) as having a low risk of attrition bias, as they reported withdrawals and provided adequate reasons for dropouts. We assessed one study as having a high risk of attrition bias because only a subgroup of included participants were analysed (Lehtinen 2018). We assessed another study as having a high risk of attrition bias because data for 62.5% (20/32) of the participants enrolled were missing due to early withdrawals from the study (NCT00941889 2016).

Selective reporting
For the majority of studies (16/20 = 80%) either a study protocol or clinical trial registry entry was available to determine that selective reporting was unlikely; we assessed these studies as having a low risk of reporting bias. We assessed four studies as having a high risk of selective reporting bias; Lehtinen 2018 because most outcomes were not reported separately for boys and girls, indeed, only adverse events were reported separately in boys, but in a selected subset; NCT00941889 2016 because predetermined outcomes, including serious adverse events, were not reported; NCT01031069 2017 because not all outcomes listed in the online trial record were reported in the trial result summary report; and NCT01862874 2018 because HPV disease was not reported as a separate outcome, but were reported as an outcome combined with persistent HPV infection.

Other potential sources of bias
All included studies provided a statement of the funding source for the trial. Thirteen studies were funded by the vaccine manufacturers (GSK, Merck or Sanofi Pasteur) and we rated them as having an unclear risk of other bias. Industry sponsored studies are associated with favourable efficacy results and conclusions (Lundh 2017) which may be mediated by factors other than those assessed by the Cochrane 'Risk of bias' tool. We also rated a further two studies as having an unclear risk of other bias because no published report was identified for either (NCT00941889 2016; NCT01031069 2017), and we extracted data from the clinical trials records, which provided insufficient information to establish whether there was a risk of other bias. We assessed the remaining five studies as being at low risk of other bias (Dobson 2013; Toft 2014; Hidalgo-Tenorio 2017; Levin 2010; Wilkin 2018).

Effects of interventions
See: Summary of findings for the main comparison Two doses of HPV vaccine compared with three doses of HPV vaccine in 9- to 15-year-old females; Summary of findings 2 Two doses of HPV vaccine with longer interval compared with two doses of HPV vaccine with shorter interval in 9- to 14-year-old females and males; Summary of findings 3 Three doses HPV vaccine compared with control in 10- to 26-year-old males; Summary of findings 4 Nonavalent HPV vaccine compared with quadrivalent HPV vaccine in 9- to 26-year-old females and males

1. Two doses of HPV vaccine versus three doses of HPV vaccine in 9- to 15-year-old females or males
The results for this comparison are presented in Summary of findings for the main comparison and Appendix 5. We analysed four studies in females that compared two doses (months 0 and 2, or 0 and 6, or 0 and 12) versus three doses (months 0, 1, and 6; or 0, 2, and 6) of HPV vaccine (Dobson 2013; Iversen 2016; Leung 2015; Romanowski 2011), and reported immunogenicity outcomes (seven months to five years) for all vaccine types and adverse event outcomes throughout the study period (one to five years). No studies included for this comparison collected data about clinical outcomes. No evidence was found from RCTs making this comparison in males.

Immunogenicity results comparing two doses with three doses of HPV vaccine are reported in Appendix 5. Briefly, two doses were non-inferior to or had higher GMTs than three doses for all nine HPV genotypes measured except HPV 45 (where non-inferiority was inconclusive) one month after the last dose (moderate- to high-certainty evidence). At 60-month follow-up after the first dose, non-inferiority of two doses of bivalent vaccine was inconclusive for GMTs of HPV 16 and HPV 18 (low-certainty evidence). Two doses of quadrivalent vaccine resulted in non-inferior GMTs for HPV 6, HPV 11 and HPV 16, while results were inconclusive for HPV 18 (low-certainty evidence). At 36-month follow-up after the first dose, two doses of nonavalent vaccine resulted in non-inferior GMTs for all HPV genotypes measured except HPV 45 and HPV 52 where non-inferiority was inconclusive (high-certainty evidence).

Two studies found that two doses of HPV vaccine resulted in little to no difference in pain at the injection site compared with three doses of HPV vaccine (RR 0.96, 95% CI 0.91 to 1.03; 2 studies; 1189 participants; Analysis 1.1), but reduced swelling (RR 0.76, 95% CI 0.65 to 0.89; 2 studies; 1189 participants; Analysis 1.2) and redness (RR 0.85, 95% CI 0.75 to 0.96; 2 studies; 1189 participants; Analysis 1.3) at the injection site at up to seven days follow-up. The comparative evidence about serious adverse events was considered to be of very low-certainty (risk with two doses 36/1158, risk with three doses 35/1159; 4 studies; 2317 participants; Analysis 1.4). We downgraded certainty for imprecision and indirectness of the composite measure of all serious adverse events, which may or may not be clinically relevant, may or may not be related to the vaccine, and may occur outside a biologically plausible time frame relative to vaccine exposure. Two of the studies reported on withdrawals from the study and reported that no participants had withdrawn because of adverse events. One death was reported in the three-dose group (1/898) and no deaths (0/899) in the two-dose group (OR 0.33, 95% CI 0.01 to 8.19; 3 studies; 1797 participants; low-certainty evidence; Analysis 1.5).
2. Two doses of HPV vaccine with longer interval compared with two doses of HPV vaccine with shorter interval in 9- to 14-year-old females or males

The results for this comparison are presented in Summary of findings 2 and Appendix 6. We included three studies in females that compared two doses with a longer interval between the first and second doses (months 0 and 6 or 12) with a shorter interval between the first and second doses (months 0 and 2 or 6) for immunogenicity outcomes at seven months for all vaccine types and adverse event outcomes throughout the study period (one to five years) (Iversen 2016; Puthanakit 2016; Romanowski 2011). One of these studies compared a longer interval (months 0 and 12) with a shorter interval (months 0 and 6) in males (Iversen 2016). No studies included for this comparison collected data about clinical outcomes. As each study compared different intervals, we did not pool the results in the meta-analysis.

Immunogenicity results are reported in Appendix 6. At one month after the final dose, there was evidence of higher (and non-inferior) GMTs for HPV 16 and HPV 18 with the longer interval schedules compared with the shorter intervals in 9- to 14-year-old females who received bivalent HPV vaccine (moderate-to-high-certainty evidence). There was also evidence of higher GMTs for HPV 16 and HPV 18 at 36 months with the longer interval schedules compared with the shorter intervals in 9- to 14-year-old females who received bivalent HPV vaccine (high-certainty evidence). For seroconversion to HPV 16 and HPV 18, there was evidence of no difference between groups one month after the final dose (high-certainty evidence). For the nonavalent vaccine in girls and boys, there was evidence that a longer interval produced higher and non-inferior GMTs than a shorter interval for all HPV genotypes (high-certainty evidence).

In Romanowski 2011 there was little to no difference in pain (RR 1.01, 95% CI 0.96 to 1.06; 1 study; 477 participants; Analysis 2.1), swelling (RR 0.95, 95% CI 0.76 to 1.20; 1 study; 477 participants; Analysis 2.2), or redness at the injection site (RR 1.02, 95% CI 0.84 to 1.24; 1 study; 477 participants; Analysis 2.3) when comparing a two-month interval between doses to a six-month interval. In Puthanakit 2016 there was also little to no difference in pain (RR 1.02, 95% CI 0.98 to 1.06; 1 study; 963 participants; Analysis 2.1), swelling (RR 1.01, 95% CI 0.87 to 1.18; 1 study; 963 participants; Analysis 2.2), or redness at the injection site (RR 1.06, 95% CI 0.93 to 1.22; 1 study; 963 participants; Analysis 2.3) when comparing a six-month interval between doses to a 12-month interval.

The evidence about serious adverse events was considered to be of very low-certainty, due to impression and indirectness, for comparisons of a two-month (14/240) versus a six-month (16/241) interval (1 study; 481 participants; Analysis 2.4) (Romanowski 2011), and of a six-month (20/550) versus a 12-month (24/415) interval (1 study; 965 participants; Analysis 2.4) (Puthanakit 2016). The evidence about serious adverse events was also considered to be of very low-certainty for the comparison of an interval of six months (15/602) versus 12 months (6/301) between doses of the nonavalent vaccine (1 study; 903 participants; Analysis 2.4) (Iversen 2016). The Iversen 2016 study reported on serious adverse events in males and females, but disaggregated data were not available by sex (Table 1). One of the reported serious adverse events (one case of systemic lupus erythematosus) in the 12-month interval group (Puthanakit 2016), was considered by the study investigators to be related to the vaccine and was the only withdrawal from the studies because of adverse events. No deaths were reported in any of the included trials (Analysis 2.5).

3. Longer interval versus shorter interval between second and third doses of quadrivalent HPV vaccine in 18- to 25-year-old males

The results for this comparison are presented in Appendix 7. We included one study that compared three doses of quadrivalent HPV vaccine with a longer interval between the second and third doses (doses administered at months 0, 2, and 12) against a shorter interval between the second and third doses (doses administered at months 0, 2, and 6) (Lin 2014). For the immunogenicity outcomes (Appendix 8), there was evidence of higher GMTs for HPV 11 with the longer interval schedule compared with the shorter schedule at one month (2 to 6 weeks test window allowed) after the last dose. For GMTs for HPV 6, 16, and 18, there was evidence of little to no difference between groups. The study did not collect data about clinical outcomes.

This study reported local, general, and serious adverse events. No usable data were available for analysis of local and general adverse events so we summarised the results in Analysis 3.1. Briefly, among all study participants 172 local and general reactions were reported. The authors reported no significant difference between groups (P = 0.26). No serious adverse events were reported (120 participants; Analysis 3.2).

4. HPV vaccines versus control in 10- to 26-year-old males

The results for this comparison are presented in Summary of findings 3. Two studies compared quadrivalent HPV vaccine with control (vaccine adjuvant only) (three doses administered at months 0, 2, and 6) in males (Giuliano 2011, NCT01828748 2018), and two studies compared bivalent vaccine with HBV vaccine (Lehtinen 2018; Petaja 2009). Lehtinen 2018, a cluster-randomised trial, was designed to investigate direct and indirect effects of vaccinating boys and girls (gender-neutral) compared with girls-only HPV vaccination. They reported that gender-neutral vaccination was associated with herd effects and cross-protection against a number of non-vaccine HPV types. Clinical outcomes in girls are presented in another Cochrane Review (Arbyn 2018), which covers comparison of bivalent and quadrivalent HPV vaccine with a control HBV vaccine in females; no clinical outcomes in boys were reported.

One study reported clinical outcomes at a median of 2.9 years (Giuliano 2011). There were fewer outcomes of external genital lesions (any genotype) (rate ratio 0.16, 95% CI 0.07 to 0.38; 1 study; 2545 participants; 6254 person-years; moderate-certainty evidence; Analysis 4.1), external genital lesions (HPV 6, 11, 16, 18) (rate ratio 0.10, 95% CI 0.03 to 0.31; 1 study; 2805 participants; 5643 person-years; Analysis 4.2), and anogenital warts (rate ratio 0.11, 95% CI 0.03 to 0.38; 1 study; 2805 participants; 5645 person-years; moderate-certainty evidence; Analysis 4.3) with the quadrivalent HPV vaccine than the control, in both intention-to-treat and per-protocol analyses (per-protocol analyses not shown). There was evidence in favour of quadrivalent HPV vaccine for the outcomes of all penile, perianal, or perineal intraepithelial neoplasia (PIN) lesions (rate ratio 0.17, 95% CI 0.01 to 3.27; 1 study; 2805 participants; 5657 person-years; Analysis 4.4), PIN grade 1 (rate ratio 0.25, 95% CI 0.01 to 6.22; 1 study; 2805 participants; 5659 person-years; Analysis 4.5), or PIN grade 2 or 3 (rate ratio 0.50, 95% CI 0.02 to 14.80; 1 study; 2805 participants; 5658 person-years;
In the quadrivalent vaccine group, there were more overall local/injection site adverse events than with the control (RR 1.12, 95% CI 1.06 to 1.18; 1 study; 3895 participants; high-certainty evidence; Analysis 4.7); the events included pain at injection site (RR 1.13, 95% CI 1.07 to 1.19; 2 studies; 5162 participants; Analysis 4.8), swelling at injection site (RR 1.29, 95% CI 1.04 to 1.60; 2 studies; 5162 participants; Analysis 4.9), and redness at injection site (RR 1.12, 95% CI 0.99 to 1.27; 2 studies; 5162 participants; Analysis 4.10). There was little to no difference in overall systemic events and general symptoms (RR 0.99, 95% CI 0.90 to 1.08; 2 studies; 5008 participants; moderate-certainty evidence; Analysis 4.11) at 15-day follow-up. The bivalent HPV vaccine resulted in more pain (RR 1.99, 95% CI 1.57 to 2.53; 1 study; 268 participants; Analysis 4.8), swelling (RR 2.51, 95% CI 1.17 to 5.42; 1 study; 268 participants; Analysis 4.9), and redness (RR 1.66, 95% CI 0.99 to 2.79; 1 study; 268 participants; Analysis 4.10) at the injection site than the HBV vaccine (Petaja 2009).

Evidence about serious adverse events in the Giuliano 2011 study was of very low-certainty due to imprecision and indirectness (8/2574 participants (0.3%) in the quadrivalent vaccine group and 12/2588 participants (0.5%) in the control group; 2 studies; Analysis 4.12). None of the reported serious adverse events was considered by the study investigators to be vaccine-related. Two participants from the quadrivalent group and seven participants from the control group discontinued participation in the studies because of adverse events. There were fewer deaths in the group that received quadrivalent vaccine (3 deaths in quadrivalent group; 11 deaths in control group), but confidence intervals for the difference were compatible with no effect (OR 0.30, 95% CI 0.09 to 1.01; 2 studies; 5173 participants; low-certainty evidence; Analysis 4.13) at up to three years of follow-up (Giuliano 2011). Lehtinen 2018 reported on serious adverse events for a selected subset of males (data not shown). Fifty-eight of the 2436 subset participants (2.4%) who received the HPV vaccine and 25/1267 subset participants (2.0%) who received the control HBV vaccine experienced serious adverse events (very low-certainty evidence). The investigators reported that four serious adverse events among the males who received the HPV vaccine (abdominal pain, ulcerative colitis, type 1 diabetes mellitus, juvenile idiopathic arthritis) could possibly be vaccine-related and one event among the males who received the control (type 1 diabetes mellitus) could possibly be vaccine-related. In the study on bivalent vaccine (Petaja 2009), three serious adverse events were reported in the bivalent vaccine group (3/181) and one in the control group (1/89) (Analysis 4.12; very low-certainty evidence). The study investigators did not consider these to be related to the vaccine, and no deaths were reported in either group.

For the secondary outcome of persistent HPV infection, there was evidence that quadrivalent HPV vaccine reduced persistent infection caused by HPV 6, 11, 16 or 18 combined, or by each HPV genotype individually, in 16- to 26-year-old males compared with control (Appendix 5).

The Giuliano 2011 study also reported immunogenicity outcomes (data not shown). Briefly, there was evidence that quadrivalent vaccine increased GMTs for HPV 6, 11, 16 and 18 when compared with control at 7, 24 and 36 months. There was a trend towards GMTs levelling off after reaching a peak at month seven.

Comparative data between quadrivalent vaccine and control were not available for the seropositivity outcomes (control group data not reported), but seropositivity for HPV 6, 11, 16 and 18 at seven months was above 97%. Petaja 2009 also reported immunogenicity outcomes seven months after the first dose of bivalent vaccine were higher than the HBV vaccine (Appendix 10).

5. Nonavalent HPV vaccine versus quadrivalent HPV vaccine in 9- to 26-year-old females and males

The results of this comparison are presented in Summary of findings 4. We included three RCTs that compared nonavalent with quadrivalent HPV vaccine (three doses administered at months 0, 2, and 6) in two in females (Joura 2015; Vesikari 2015), and one in males (van Damme 2016). The Joura 2015 study collected data on clinical outcomes in females at up to 4.5 years follow-up. All three trials reported adverse event outcomes throughout the study period and immunogenicity outcomes at seven months for all vaccine types. We did not identify any studies that collected data about clinical outcomes in males.

In females there was little to no difference between nonavalent and quadrivalent HPV vaccines in the incidence of the combined outcome of high-grade cervical epithelial neoplasia, adenocarcinoma in situ, or cervical cancer (OR 1.00, 95% CI 0.85 to 1.16; 1 study; 13,753 participants; high-certainty evidence; Analysis 4.1), or high-grade cervical, vulval, or vaginal disease (OR 0.99, 95% CI 0.85 to 1.15; 1 study; 14,054 participants; high-certainty evidence; Analysis 5.2) at up to 4.5 years follow-up. For high grade cervical disease related to HPV 31, 33, 45, 52, or 58 (i.e. genotypes covered by the nonavalent vaccine but not the quadrivalent vaccine), the effect was in favour of the nonavalent vaccine (OR 0.03, 95% CI 0.00 to 0.21; 1 study; 11,892 participants; Analysis 5.5), but few cases were reported (1/5949 women in the nonavalent vaccine group and 35/5943 women in the quadrivalent vaccine group).

Nonavalent HPV vaccine resulted in slightly more local/injection site adverse events than the quadrivalent vaccine (RR 1.07, 95% CI 1.05 to 1.08; 3 studies; 15,863 participants; high-certainty evidence; Analysis 5.11). There was little to no difference between the vaccines for overall systemic events and general symptoms at 15-day follow-up (RR 1.01, 95% CI 0.98 to 1.04; 3 studies; 15,863 participants; moderate-certainty evidence, Analysis 5.15). For serious adverse events overall, the evidence was considered to be of low-certainty due to imprecision and indirectness (OR 0.60, 95% CI 0.14 to 2.61; 3 studies; 15,863 participants; \( I^2 = 51\% ; \) Analysis 5.16). One study reported similar numbers of events (1/299 with the nonavalent vaccine, 2/300 with the quadrivalent vaccine) in females aged 9 to 15 years over a period of 7 months follow-up (Vesikari 2015). In males, there were no events in 249 participants receiving the nonavalent vaccine and 6/251 with the quadrivalent vaccine over a period of 7 months follow-up (van Damme 2016). In the largest study, in 16- to 26-year-old females, 3.1% (242/7686) of those who received the nonavalent vaccine and 2.6% (184/7078) of those who received the quadrivalent vaccine experienced any serious adverse event after up to 4.5 years of follow-up (Joura 2015). No serious adverse events, when analysed by system organ class, were more common with the nonavalent than with the quadrivalent vaccine. The study authors examined 2269 pregnancy-related events in 2321 women and found no differences between the nonavalent and quadrivalent vaccine arms. The study investigators considered seven serious adverse events to be related to the vaccines.
four in the nonavalent group (allergic reaction; fever, body pain, and headache; hyperventilation; postural orthostatic tachycardia syndrome) and three in the quadrivalent group (headache; paraesthesia and burning sensation; orthostatic intolerance).

Thirteen participants who received nonavalent vaccine and six who received quadrivalent vaccine discontinued participation because of adverse events. There was little to no difference in the number of deaths between nonavalent (6/7370) and quadrivalent (5/7378) HPV vaccine groups (OR 1.20, 95% CI 0.37 to 3.94; 2 studies; 15,248 participants; low-certainty evidence; Analysis 5.17) at up to 4.5 years follow-up. The study investigators considered none of the deaths reported to be related to the vaccine.

Secondary outcomes (persistent infection and immunogenicity) are presented in Appendix 11 and Appendix 12. Briefly, there was evidence of decreased rates of persistent infection with HPV 31, 33, 45, 52, and 58 at six and 12 months with nonavalent vaccine compared with quadrivalent vaccine (Joura 2015). There was little to no difference in immunogenicity between the nonavalent and quadrivalent HPV vaccine and GMTs were non-inferior for HPV 6, 11, 16, and 18 at up to 42 months. The nonavalent HPV vaccine resulted in substantially higher GMTs for HPV 31, 33, 45, 52, and 58 than the quadrivalent HPV vaccine. For seroconversion to HPV 6, 11, 16, and 18 up to 24 months follow-up, 100% of participants seroconverted in both the nonavalent and quadrivalent HPV vaccine groups. The data for GMTs and seroconversion to HPV 31, 33, 45, 52, and 58 were not reported in full (Joura 2015; Vesikari 2015).

6. HPV vaccination in HIV-positive females, males and MSM

Seven RCTs reported on the effects of bivalent and quadravalent HPV vaccines in females, males, or children living with HIV (Denny 2013; Hidalgo-Tenorio 2017; Levin 2010; VGT00941889 2016; VGT01031069 2017; Toft 2014; Wilkin 2018). Two of the studies collected data about clinical outcomes such as anal intraepithelial neoplasia, anogenital warts or persistent infection (VGT00941889 2016; Wilkin 2018). These results are summarised in Table 3; Table 4; and Table 5.

6.1 Quadrivalent HPV vaccine compared with control

6.1.1 Quadrivalent HPV vaccine compared with control in children living with HIV

Levin 2010 included 7- to 12-year-old girls and boys with HIV. The study reported immunogenicity outcomes at seven months (Appendix 13). GMTs for HPV 6, 11, 16 and 18 were 123.8 to 935.8-fold higher at seven months, and 29.6 to 189.4-fold higher at 24 months, than in the control group (described as 'identical placebo', the study did not specify the contents of the placebo) (low-certainty evidence). Seroconversion for the four HPV genotypes was over 97% at seven months (low-certainty evidence). Injection site adverse events were more common with quadrivalent vaccine (21/96) than control (3/30) (1 study; 126 participants; very low-certainty evidence; Analysis 6.4). Three systemic adverse events were reported, two in the quadrivalent group (2/96) and one in the control group (1/30) (1 study; 126 participants; very low-certainty evidence; Analysis 6.5) at 14-day follow-up (three doses administered at months 0, 2, and 6). The study did not report on serious adverse events, but reported that 5/96 (5.2%) children in the quadrivalent vaccine group and 2/30 (6.7%) children in the control group experienced adverse events of grade 3 or 4 severity (OR 0.77, 95% CI 0.14 to 4.18, analysis not shown).

6.1.2 Quadrivalent HPV vaccine compared with control in MSM living with HIV

Hidalgo-Tenorio 2017 included HIV-positive MSM of 18 years of age and above, and compared quadrivalent HPV vaccine with control (saline placebo) (three doses administered at months 0, 2, and 6). This trial reported that 76% of the HPV vaccinated participants were seropositive for at least one of HPV 6, 11, 16, or 18 genotype at seven months compared with 30.2% in the control group (moderate-certainty evidence; Appendix 13). No serious adverse events (1 study; 129 participants; Analysis 6.6) or deaths (1 study; 129 participants; Analysis 6.7) were reported in either group at seven-month follow-up (Table 3).

6.1.3 Quadrivalent HPV vaccine compared with control in adults living with HIV

Two studies included HIV-positive males and females of 18 years of age and above and compared quadrivalent HPV vaccine with control (saline placebo in VGT00941889 2016 and 'placebo vaccine' in Wilkin 2018 - the contents of the placebo were not specified). There was only very low-certainty evidence on high-grade anal intraepithelial neoplasia (46/288 in the quadrivalent group, 45/286 in the control group; 1 study; Analysis 6.1), recurrence of anogenital warts in participants treated for anogenital warts (1/7 in the quadrivalent group, 1/5 in the control group; 1 study; Analysis 6.2), or abnormal anal cytology (58/130 in the quadrivalent group, 72/132 in the control group; 1 study; Analysis 6.3). There was limited evidence for serious adverse events (quadrivalent 33/288 events; control 46/287 events; Analysis 6.6) or deaths (quadrivalent 3/288 deaths; control 6/287 deaths; Analysis 6.7) between the groups. The study investigators considered no serious adverse events to be related to vaccination, and no withdrawals from the studies due to adverse events were reported (Table 3).

6.2 Bivalent HPV vaccine compared with control in females living with HIV

Denny 2013 included HIV-positive 18- to 25-year-old females and reported that, irrespective of baseline HPV serostatus, all participants who received the bivalent HPV vaccine were seropositive for both HPV 16 and HPV 18 after the second vaccine dose (month two), and remained seropositive at month 12 (moderate-certainty evidence). Pain at injection site (RR 1.86, 95% CI 1.38 to 2.51; 1 study; 120 participants; Analysis 7.1) and swelling at injection site (RR 9.19, 95% CI 2.44 to 37.73; 1 study; 120 participants; Analysis 7.2) were more common in the bivalent group than in the control group (vaccine adjutant only) at seven-day follow-up. The study reported 3/61 serious adverse events in the bivalent vaccine group and 2/59 events in the control group (OR 1.47, 95% CI 0.24 to 9.15; 1 study; 120 participants; low-certainty evidence; Analysis 7.3). No deaths were reported (Analysis 7.4). The study investigators considered no serious adverse events to be related to vaccination, and no withdrawals from the study due to adverse events were reported (Table 4).

6.3 Bivalent HPV vaccine compared with quadrivalent HPV vaccine

6.3.1 Bivalent HPV vaccine compared with quadrivalent HPV vaccine in adults living with HIV

Toft 2014 included 92 HIV-positive females and males of 18 years of age and above, and compared bivalent with quadrivalent HPV vaccine (3 doses administered at months 0, 1.5, and 6). There was
Collaboration.

Comparison of different human papillomavirus (HPV) vaccine types and dose schedules for prevention of HPV-related disease in females and males (Review)

Comparison of different human papillomavirus (HPV) vaccine types and dose schedules for prevention of HPV-related disease in females and males, HPV immunogenicity, and adverse events following reduced dose or alternative vaccine schedules in females and males, HPV vaccination compared to control for males, and effects of HPV vaccines in people with HIV infection.

Summary of main results

Immunogenicity, efficacy and adverse events with fewer than three doses of HPV vaccine in females

In adolescent girls (9 to 15 years) a two-dose schedule was non-inferior to a three-dose schedule of any HPV vaccine. There was some evidence that GMTs decrease over time following both two-dose and three-dose schedules, and that a two-dose schedule is non-inferior to a three-dose schedule after five years. There was no difference in seroconversion between two-dose and three-dose schedules at all time points reported; almost all participants seroconverted in both intervention groups. We identified no studies that collected data about efficacy against clinical outcomes. There was very low-certainty evidence of little to no difference in serious adverse events or deaths between dose schedules. No RCTs that evaluated the efficacy or harms of one dose of HPV vaccine were identified.

Immunogenicity, efficacy and adverse events with different intervals between doses of HPV vaccine in females and males

In both females and males, for all HPV vaccines evaluated, a schedule with a longer interval between doses resulted in higher GMTs than a shorter interval. There was very low certainty evidence on the comparative risk of serious adverse events with different intervals between two-doses of HPV vaccine, owing to the very low number of events and indirectness. Results from single studies were consistent with lower or higher rates of serious adverse events with the different intervals tested in the studies.

Efficacy, immunogenicity and adverse events with HPV vaccines in males

Three doses of quadrivalent HPV vaccine reduced the incidence of external genital lesions, anogenital warts, and persistent infection by HPV 6, 11, 16 or 18 compared with control among 16- to 26-year-old males over a median follow-up of 2.9 years (moderate-certainty evidence). The quadrivalent vaccine resulted in more injection-site adverse events, such as pain or redness, than control (high-certainty evidence). There was very low certainty evidence on the comparative risk of serious adverse events and low certainty evidence on the comparative risk of deaths between quadrivalent vaccine and control among 10- to 26-year old males. Limited data were available regarding the efficacy and adverse events with bivalent HPV vaccine in males. We identified no RCTs that evaluated the efficacy of nonavalent vaccine compared with control in males.

Efficacy, immunogenicity and adverse events with the nonavalent HPV vaccine compared with other HPV vaccines in females and males

Among 16- to 26-year-old women, three doses of nonavalent vaccine or of quadrivalent vaccine resulted in a similar incidence of clinical outcomes regardless of HPV genotype at up to 4.5-year follow-up (one RCT, high certainty evidence). The nonavalent vaccine resulted in reduced incidence of persistent HPV infections, CIN1, CIN 2/3, vulval or vaginal intraepithelial neoplasia (grade 1) related to the HPV genotypes unique to the nonavalent vaccine (HPV 31, 33, 45, 52, and 58) compared with the quadrivalent vaccine. Immunogenicity outcomes for nonavalent and quadrivalent HPV vaccines were similar for males and females. There was high-

6.3.2 Bivalent HPV vaccine compared with quadrivalent HPV vaccine in 15- to 25-year-old females living with HIV

One study reported on serious adverse events in 15- to 25-year-old females with HIV who were randomised to receive bivalent or quadrivalent HPV vaccine (NCT01031069 2017). Data for this study were only available through the clinical trials registry, so full details on the methods and other outcome measures were not available. There were nine serious adverse events in 167 female participants with HIV in the bivalent vaccine group and nine in 165 participants in the quadrivalent group (1 study; 332 participants; very low-certainty evidence; Analysis 8.2; Table 5). One participant in the quadrivalent group withdrew due to an adverse event. One serious adverse event (immune thrombocytopenic purpura) was considered by study investigators to be related to the bivalent HPV vaccine.

Sensitivity analysis

We compared the results from the primary analysis with a sensitivity analysis using Peto odds ratios for outcomes with very low event rates (< 1%; Bradburn 2007). This did not change the size of effect for most of the analyses, with the exception of some clinical outcomes in the comparison of nonavalent HPV vaccine versus quadrivalent HPV vaccine in 9- to 26-year-old females (Appendix 14).

Changes were seen in the effect sizes and 95% CIs for the following outcomes:

- high-grade cervical disease related to HPV 31, 33, 45, 52, or 58 (Analysis 5.5) changed from OR 0.03 (0.00 to 0.21) to Peto OR 0.15 (0.08 to 0.29) (Appendix 14);
- cervical intraepithelial neoplasia 2 (CIN2) related to HPV 6, 11, 16, or 18 (Analysis 5.7) changed from OR 0.00 (0.12 to 73.77) to Peto OR 0.74 (0.15 to 373.80) (Appendix 14);
- CIN2 related to HPV 31, 33, 45, 52, or 58 (Analysis 5.8) changed from OR 0.03 (0.00 to 0.23) to Peto OR 0.15 (0.08 to 0.30) (Appendix 14);
- CIN3, adenocarcinoma in situ, and cervical cancer related to HPV 6, 11, 16, or 18 (Analysis 5.9) changed from OR 0.33 (0.01 to 8.19) to Peto OR 0.14 (0.00 to 6.83) (Appendix 14);
- CIN3, adenocarcinoma in situ, and cervical cancer related to HPV 31, 33, 45, 52, or 58 (Analysis 5.10) changed from OR 0.07 (0.00 to 1.16) to Peto OR 0.14 (0.03 to 0.59) (Appendix 14).

Discussion

This review reports on evidence about the efficacy, immunogenicity, and adverse events following reduced dose or alternative vaccine schedules in females and males, HPV vaccination compared to control for males, and effects of HPV vaccines in people with HIV infection.
certainty evidence that the nonavalent vaccine resulted in slightly more local or injection site events but little to no difference in overall systemic events. The evidence comparing serious adverse events was of low-certainty. There was low-certainty evidence of no difference in mortality between these vaccines. There were few vaccine-related serious adverse events reported (seven participants in total) in the included studies.

**Efficacy, immunogenicity and adverse events with HPV vaccines in people living with HIV**

In children living with HIV, the quadrivalent HPV vaccine results in higher GMTs than control at seven months, but there was only very low-certainty evidence about local or systemic adverse events. In adults living with HIV, the evidence about clinical outcomes and harms of quadrivalent HPV vaccine compared with control or other HPV vaccines, was of very low-certainty. One RCT in adults living with HIV reported that the bivalent vaccine had similar immunogenicity outcomes for HPV 16 to the quadrivalent vaccine, but resulted in higher GMTs and greater rate of seroconversion to HPV 18.

**Overall completeness and applicability of evidence**

This review collated evidence about the efficacy - in terms of clinical and immunological endpoints - and harms of different HPV vaccines and different dose schedules in females and males. The information sources searched include electronic databases, websites of the vaccine manufacturers, and a published index of HPV studies (Jørgensen 2018a), so the level of completeness is high. The applicability of the evidence to determine clinical efficacy and harms is, however, limited by the nature of HPV-related disease, as well as the design and outcomes of the studies. The evidence from RCTs about efficacy against severe HPV-related disease, including cancer, is limited for three main reasons. First, it is unethical to collect specimens from the cervix of girls who have not had sexual intercourse. Second, few severe clinical outcome events related to HPV infection occur during the study follow-up periods because they take a number of years to develop following HPV infection. Third, trial participants are offered treatment when HPV-related precancer is found, so progression to cervical cancer would be expected to be very low, even without vaccination.

The focus of this review was on clinical outcomes and harms. Immunogenicity is the primary outcome for many trials of alternative HPV vaccine schedules, however, as noted in the Background, randomised efficacy trials of HPV vaccines were first conducted in women aged 15 to 25 or 26 years (Arbyn 2018). Once efficacy, immunogenicity and safety were established in this age group, non-randomised bridging studies assessed non-inferiority of immunogenicity outcomes in 9- to 15-year-old girls (e.g. Block 2006, Dobson 2013). The International Agency for Research on Cancer regards bridging studies that demonstrate non-inferiority as a sufficient endpoint for individuals under 16 years of age (IARC 2014). Bridging studies have also demonstrated non-inferiority of immunogenicity outcomes of a two-dose schedule in boys aged 9- to 14-years compared to three doses in young women aged 15 to 26 years (Jørgensen 2016). Use of immunogenicity outcomes has limitations because the immunological correlate of protection and the duration of protection remain unknown (Donken 2015). These studies provide lower certainty of evidence, because estimates of clinical outcomes are imprecise and indirect.

The nonavalent HPV vaccine was introduced more recently than the bivalent and quadrivalent HPV vaccines. This review included all studies that compared the nonavalent HPV vaccine with other HPV vaccines; two RCTs were identified in females (Jørgensen 2015; Vesikari 2015), and one in males (Van Damme 2016). A separate Cochrane Review of completed RCTs of three-dose schedules with bivalent and quadrivalent HPV vaccines in women aged 16 to 26 years shows protection against lesions of grade CIN3, but not invasive cervical cancer (Arbyn 2018). Further comparisons between the different HPV vaccines in women will be included in an update of the Arbyn 2018 review. Observational studies in countries that have licensed more than one HPV vaccine will also provide important information on the comparative efficacy and harms of the different HPV vaccines.

With regard to serious adverse events, there is a large degree of uncertainty in the evidence comparing different HPV vaccines and different dose schedules. The 'Summary of findings' tables show low numbers of serious adverse events and deaths in most included studies. Even when the total number of events is high (e.g. Jørgensen 2015), specific events of clinical relevance are still too rare for meaningful comparative analyses. In this review, we used a composite outcome, that is, the overall frequency of serious adverse events, for each comparison, however, analyses based on a composite outcome can produce results that are difficult to interpret for several reasons. This outcome can include events that are not clinically relevant or are not biologically related to the vaccine (Lineberry 2016), occur outside a plausible time frame relative to vaccine exposure (Huang 2011), or are not based on standardised definitions (Bonhoeffer 2002). In addition, trials measure serious adverse events at different time points and there is a large variation in duration of follow-up, which could produce misleading summary estimates (Huang 2011). Finally, there is heterogeneity among trials with regard to the age and gender of participants and clinical measurements of serious adverse events (Appendix 4). Meta-analyses of serious adverse events, such as those presented in this review, should be considered exploratory rather than confirmatory as the analyses are not planned in advance (i.e. when the included studies were designed) (Huang 2011). Despite the uncertainty in the evidence about harms when comparing different HPV vaccines and dose schedules, a previous systematic review reported similar rates of serious adverse events when HPV vaccines were compared to control (Arbyn 2018).

**Quality of the evidence**

The risk of bias of the included studies in this review is generally low. We rated studies that received funding from the vaccine manufacturer as 'unclear' for the 'other risk of bias' domain. This judgement was based on the results of a systematic review which showed more favourable efficacy results and conclusions in studies sponsored by manufacturing companies (Lundh 2017). It has been suggested that industry sponsorship of studies results in overly positive results through a variety of choices in the design and conduct of the trials that leads to bias. Based on the low risk of bias in other methodological domains and adequate reporting in the trials, we did not downgrade the certainty of the evidence using GRADE for this factor. In accordance with Higgins 2017, information on industry sponsorship and other funding sources is captured in the Characteristics of included studies tables.

In studies where participants received a control injection - specifically for the comparisons of HPV vaccines with control in
males and people living with HIV, and different interval schedules - many of the included studies used an adjuvant (either aluminium hydroxide or another aluminium compound) as the control rather than a ‘true’ placebo (NCT00941889 2016 used a saline placebo; Levin 2010 and Wilkin 2018 did not specify the type of placebo). Aluminium adjuvants have been used in vaccines for many years as they are thought to enhance the immune response (HogenEsch 2018), but their suitability as control vaccines in RCTs has been questioned (Jørgensen 2018b). A previous systematic review found no evidence that aluminium adjuvants in diphtheria, tetanus, and poliomyelitis vaccines cause any serious or long-lasting adverse events (Jefferson 2004). The rate of serious adverse events was low for both vaccine and control groups in the studies included in the current review. However, the benefits and harms of aluminium-containing adjuvants are being further assessed in a Cochrane Review (Djurisic 2017), and research is underway to determine how suitable they are as control vaccines for RCTs.

For a number of outcomes presented in the ‘Summary of findings’ tables, especially serious adverse events and deaths, we downgraded the certainty of the evidence for imprecision. In most cases the sample size of the included RCTs was too small to be able to detect an effect between groups for these outcomes - especially for rare outcomes such as death. This is another limitation of RCTs in determining the harms associated with HPV vaccines, and lends further weight to the future use of large observational studies. We also downgraded the evidence on serious adverse events for indirectness because of the limitations to the use of a composite outcome measure of events, as described in the section on applicability.

Potential biases in the review process

We made great efforts to identify relevant published and unpublished data, through a sensitive electronic database search and screening of vaccine manufacturer websites. By linking clinical trial registry entries with published database searches, and by cross-checking the studies included and excluded from our review against a published index of HPV studies (Jørgensen 2018a), we attempted to minimise the risk of missed studies, though relevant data may remain unregistered or unpublished (Jørgensen 2018a).

We used a priori categories of common adverse events - such as pain or swelling at the injection site - or important outcomes such as serious adverse events and deaths when extracting data from included studies. This method of data extraction could have been limited by the reporting in the included studies, as composite outcomes, such as ‘overall injection site/local adverse events’, could not be calculated by reports of all events within the study populations. The range of different adverse events reported in the included studies, as well as the range of methods used to assess these in the studies, makes it unfeasible to extract all adverse events for the purpose of meta-analysis.

We analysed and reported on all serious adverse events in the included studies. Serious adverse events are any events that result in hospitalisation and life-threatening illness. This means that any serious injury or illness is included, even if it is unlikely to be related to the vaccine. We also reported on results and attribution methods used to determine whether serious adverse events were related to the vaccine. We did not analyse these results or report them in the ‘Summary of findings’ tables because attribution methods were either not transparent, or not independent of the study investigators (Appendix 4). These results are reported narratively in the ‘Effects of interventions’ section.

We restricted the sensitivity analysis of very rare events to alternative statistical methods available in Review Manager 5 software. We applied a sensitivity analysis to a number of outcomes where there were studies with zero events in both arms, but they did not contribute information when either method was used. It is possible that other methods could yield different results where there are zero events in both trial arms (Sharma 2017).

Agreements and disagreements with other studies or reviews

The results of this systematic review are in agreement with other published reviews on the efficacy of fewer than three doses of HPV vaccine (D’Addario 2017; Markowitz 2018). The current review aimed to provide further information on clinical outcomes and adverse events. This review provides evidence about other comparisons, such as vaccination of boys and comparisons across types of HPV vaccine, which have not previously been assessed.

AUTHORS’ CONCLUSIONS

Implications for practice

In general, the bivalent, quadrivalent and nonavalent human papillomavirus (HPV) vaccines appear to be efficacious in eliciting immunogenic responses in both males and females for the targeted HPV genotypes and, typically, conversion to seropositivity is almost 100% amongst recipients. A two-dose HPV vaccination schedule is simpler to administer than a three-dose schedule. Immunogenicity data show non-inferior results for a two-dose when compared with a three-dose schedule of bivalent, quadrivalent and nonavalent HPV vaccine. The World Health Organization (WHO) strategic advisory group of experts on vaccination recommends a two-dose schedule with at least six months between the first and second dose, irrespective of sex, if the first dose is given before 15 years of age (WHO 2017). In practice, 65 countries worldwide have adopted two-dose HPV vaccination schedules for girls, as of 31 December 2017. Amongst high-income countries that recommend HPV vaccination for boys, Australia, Switzerland and the USA recommend a two-dose schedule. Given the decision of the International Agency for Research on Cancer that immunogenicity is a surrogate endpoint for individuals under 16 years of age, randomised controlled trials (RCTs) with clinical endpoints in this age group are unlikely.

For males, including men who have sex with men (MSM), the quadrivalent HPV vaccine probably reduces the incidence of external genital lesions and anogenital warts (condylomata acuminata) compared with control. There were slightly more injection-site adverse events with the quadrivalent vaccine compared to control, but insufficient evidence to determine the effects of HPV vaccine on serious adverse events or deaths when compared with control.

The nonavalent vaccine and quadrivalent vaccines offer similar protection levels against cervical, vaginal, and vulval precursor lesions and cancer in young women and similar levels of immunogenicity for the four HPV genotypes included in both vaccines in females and males. For high-grade disease related to HPV 31, 33, 45, 52, or 58 (i.e. those genotypes covered by
the nonavalent vaccine and not the quadrivalent vaccine) in women, the effect favours the nonavalent vaccine. No studies that compared nonavalent and quadrivalent HPV vaccines reported on clinical outcomes in males. The nonavalent vaccine was associated with an increase in local adverse events compared to the quadrivalent vaccine. Comparative evidence about serious adverse events was limited by imprecision and indirectness. Most of the evidence for this comparison comes from the 16 to 26-year-old age group in females, and there are far fewer data for younger females and males.

Evidence about the efficacy and harms of HPV vaccines in people living with HIV is limited because very few trials measured clinical outcomes. In children living with HIV, quadrivalent HPV vaccine probably results in higher GMTs than control at seven months. In adults living with HIV the evidence about clinical outcomes and harms of quadrivalent HPV vaccine, compared with control or other HPV vaccines, was of very low-certainty. The duration of protection of HPV vaccines in people with HIV infection and the effect of declining immunity on protection are unknown.

We identified no studies for any new HPV vaccines in phase 2 or 3 development that plan to report on the comparisons of interest in this review.

Implications for research

Further long-term post-licensure studies are needed to determine the duration of protection of one-dose and two-dose schedules, as well as the efficacy against HPV-related cancer endpoints in women, men, MSM, and people with HIV infection. RCTs of the effects of virus-like particle HPV vaccines on cervical and anal cancer are likely to study surrogate endpoints such as immunogenicity and persistent HPV infection. For vulval and vaginal cancer, clinical disease is still recommended as an endpoint because of insufficient knowledge about persistent infection (IARC 2014). The natural history of HPV-associated oropharyngeal cancer is even less well understood. RCTs of the effects of HPV vaccines will be needed, but might rely on persistent HPV infection as an outcome. The elucidation of the immune correlate of protection for HPV vaccines would be extremely valuable.

Further RCTs to compare different vaccine schedules are needed to determine the most cost-effective strategy to reduce the incidence of persistent HPV infection and related cancers. Evidence about the effectiveness of a two-dose HPV vaccine schedule on clinical HPV-related disease still relies on non-randomised comparisons of RCTs ( Kreimer 2015; Sankaranarayanan 2016), and on data from national immunisation programmes (Markowitz 2018). These studies provide essential ongoing data, but cannot fully overcome confounding effects of differences between groups that receive a certain number of doses. In immunisation programme data in particular, those receiving two doses as part of a three-dose schedule might only have received the first two doses with a one or two month gap and might be beyond the recommended age for vaccination. In this situation, these studies might actually underestimate the effectiveness of a recommended two-dose schedule with at least six months between doses (Markowitz 2018).

An RCT that commenced in August 2018 will provide information about the non-inferiority of one and two doses of bivalent and nonavalent HPV vaccines against incident HPV genotype 16/18 infections that persist for six months or more in young women (NCT03180034). In addition, long-term surveillance and registry-based studies, such as linking vaccination databases with disease- and population-based registries, are needed to establish vaccine effectiveness and harms over time.

This review included a wide range of comparisons of alternative HPV vaccine schedules. In future, studies of the efficacy of different types of HPV vaccine, studies of alternative dose schedules, and studies of the effectiveness of HPV vaccines in people living with HIV infection could be examined in separate systematic reviews. This review has highlighted the limitations of data about harms collected in RCTs, especially imprecision, owing to the low frequency of serious adverse events. Longer-term follow-up is needed to investigate links with specific adverse events, such as new chronic diseases or adverse pregnancy outcomes. Post-marketing surveillance allows continued monitoring and reports events following HPV vaccination in the population beyond the duration of follow-up in RCTs. Surveillance studies of large registry-based data from real-world vaccination programmes can also provide more precise estimates of the incidence of specific adverse events and investigate prespecified hypotheses. In these studies, attribution of whether serious adverse events and deaths are related to the vaccine can be performed independently of study investigators and potential conflicts of interest. Future updates of this review will include observational long-term post-licensure studies to allow more detailed investigation of specific harms associated with HPV vaccines, long-term data on the effectiveness of HPV vaccines, and the value of different dose schedules in increasing vaccine coverage. Future reviews should also consider the synthesis of evidence from vaccination programmes in the context of gender-neutral HPV vaccination, where consideration of indirect effects of HPV vaccination is needed to provide more relevant estimates of vaccine effectiveness for public health stakeholders.

Acknowledgements

The authors would like to acknowledge the contribution of systematic reviewers from Cochrane Response for their assistance in screening abstracts and full-texts for this review.

We would also like to thank Sarah Hodgkinson and Helen Wakeford for their editorial comments and support, Elizabeth Royle for copy-editing, and all those providing referee comments, including: Simon Beddows, Jesse Berlin, Maggie Cruickshank, Nicole Fusco, Henry Kitchener, Yoon Loke and Mary Lunnen.

We thank Jo Morrison for her clinical and editorial advice, Jo Platt for assistance with the searches and and Gail Quinn, Clare Jess for their contribution to the editorial process.

The World Health Organization retains copyright and all other rights in the manuscript of this review as submitted for publication, including any revisions or updates to the manuscript which WHO may make from time to time.
Giuliano 2011 (published and unpublished data)

* Giuliano AR, Palefsky JM, Goldstone S, Moreira ED Jr, Penny ME, Aranda C, et al. Efficacy of quadrivalent HPV vaccine against HPV infection and disease in males. New England Journal of Medicine 2011;364:401-11.

Hillman RJ, Giuliano AR, Palefsky JM, Goldstone S, Moreira ED Jr, Vardas E, et al. Immunogenicity of the quadrivalent human papillomavirus vaccine (type 6/11/16/18) vaccine in males 16 to 26 years old. Clinical and Vaccine Immunology 2012;19:261-7.

Merck Sharp, Dohme. An investigational vaccine in reducing the incidence of anogenital warts in young men. clinicaltrials.gov/ct2/show/results/NCT0090285 (accessed 16 August 2018).

Moreira ED Jr, Palefsky JM, Giuliano AR, Goldstone S, Aranda C, Jessen H, et al. Safety and reactogenicity of a quadrivalent human papillomavirus (types 6, 11, 16, 18) L1 viral-like-particle vaccine in older adolescents and young adults. Human Vaccines 2011;7(7):768-75.

Palefsky JM, Giuliano AR, Goldstone S, Moreira ED, Aranda C, Jessen H, et al. HPV vaccine against anIL virus infection and anal intraepithelial neoplasia. New England Journal of Medicine 2011;365:1576-85.

Hidalgo-Tenorio 2017 (published data only (unpublished sought but not used))

Hidalgo-Tenorio C, Ramirez-Taboada J, Gil-Anguita C, Esquiviñas J, Omar-Mohamed-Balgahata M, SamPedro A, et al. Safety and immunogenicity of the quadrivalent human papillomavirus (qHPV) vaccine in HIV-positive Spanish men who have sex with men (MSM). AIDS Research and Therapy 2017;14:34.

Iversen 2016 (published and unpublished data)

* Iversen OE, Miranda MJ, Uiled A, Soerdal T, Lazarus E, Chokephaibulkit K, et al. Immunogenicity of the 9-valent HPV vaccine using 2-dose regimens in girls and boys vs a 3-dose regimen in women. JAMA 2016;316:2411-21.

Iversen OE, Miranda MJ, Uiled A, Soerdal T, Lazarus E, Chokephaibulkit K, et al. Immunogenicity of the 9-valent HPV vaccine using 2-dose regimens in girls and boys vs a 3-dose regimen in women. Obstetrical and Gynecological Survey 2017;72:412-3.

Merck Sharp, Dohme. Phase III study of a 2-dose regimen of a multivalent human papillomavirus (HPV) vaccine (503), administered to 9 to 14 year-olds and compared to young women, 16 to 26 years old (503-010). clinicaltrials.gov/ct2/show/results/NCT01984697 (accessed 16 August 2018).

Joura 2015 (published and unpublished data)

Bouchard C, Vuocolo S, Merck. Effect of the 9vHPV vaccine on abnormal cytology and genital procedures related to HPV31/33/45/52/58. Journal of Lower Genital Tract Disease 2014;18(Suppl 1):S9.

Chen YH, Gesser R, Luxembourg A. A seamless phase IIb/III adaptive outcome trial: design rationale and implementation challenges. Clinical Trials Journal 2015;12(1):84-90.

Guevara A, Cabello R, Woelber L, Moreira ED Jr, Joura E, Reich O, et al. Antibody persistence and evidence of immune memory at 5 years following administration of the 9-valent HPV vaccine. Vaccine 2017;35:5050-7.

Huh WK, Joura EA, Giuliano AR, Iversen OE, de Andrade RP, Ault KA, et al. Final efficacy, immunogenicity, and safety analyses of a nine-valent human papillomavirus vaccine in women aged 16-26 years: a randomised, double-blind trial. Lancet 2017;390:2143-59.

Joura E, Garland S, Giuliano A, Bautista O, Chen J, Moeller E, et al. End of study efficacy for vulvovaginal disease of a novel
9-valent HPV L1 virus-like particle vaccine in 16-26 year old women. *Journal of Lower Genital Tract Disease* 2015;19(3 Suppl 1):S10.

Joura E, Giuliano A, Iversen OE, Bautista O, Chen J, Moeller E, et al. End of study efficacy and immunogenicity of a novel 9-valent HPV L1 virus-like particle vaccine in 16-26 year old women. *EUROGIN 2015 Abstracts: HPV Infection and Related Cancers 2015; OC6:174.

Joura E, Vuocolo S. Efficacy of a novel 9-valent HPV vaccine against high-grade lesions and cancer in 16-26 year-old women. *International Journal of Gynecological Cancer 2014;24(9):S4:32.

Joura EA. Clinical efficacy and immunogenicity of the nonavalent HPV vaccine. *Acta Cytologica* 2016;60:35-6.

* Joura EA, Giuliano AR, Iversen OE, Bouchard C, Mao C, Mehlisen J, et al. A 9-valent HPV vaccine against infection and intraepithelial neoplasia in women. *New England Journal of Medicine* 2015;372:711-23.

Luxembourg A, Bautista O, Moeller E, Ritter M, Chen J. Design of a large outcome trial for a multivalent human papillomavirus L1 virus-like particle vaccine. *Contemporary Clinical Trials* 2015;42:18-25.

Mayrand MH, Bautista O, Moeller E, Ritter M, Luxembourg A. End of study efficacy, immunogenicity and safety of a novel 9-valent HPV L1 virus-like particle vaccine in 16-26 year old women. *International Journal of Gynecology and Obstetrics* 2015;131 Suppl 5:E270.

Merck Sharp, Dohme. A randomized, international, double-blinded (with in-house blinding), controlled with gardasil, dose-ranging, tolerability, immunogenicity, and efficacy study of a multivalent human papillomavirus (HPV) L1 virus-like particle (VLP) vaccine administered to 16- to 26-year-old women. *clinicaltrials.gov/ct2/show/results/NCT00543543* (accessed 16 August 2018).

Lehtinen 2018 (*published and unpublished data*)

GSK 106636 (HPV-040 PRI). Evaluation of the effectiveness of two vaccination strategies using GlaxoSmithKline Biologicals’ HPV vaccine GSK580299 administered in healthy adolescents. www.gsk-clinicalstudyregister.com/study/1066367 search=study&search_ terms=106636#csr (accessed 25 August 2018).

Lehtinen M, Apter D, Baussano I, Eriksson T, Natunen K, Paavonen J, et al. Characteristics of a cluster-randomized phase IV human papillomavirus vaccination effectiveness trial. *Vaccine* 2015;33(10):1284-90.

Lehtinen M, Eriksson T, Apter D, Hokkanen M, Natunen K, Paavonen J, et al. Safety of the human papillomavirus (HPV)-16/18 AS04-adjuvanted vaccine in adolescents aged 12–15 years: interim analysis of a large community-randomized controlled trial. *Human Vaccines & Immunotherapeutics* 2016;12(12):3177-85.

* Lehtinen M, Soderlund-Strand A, Vanska S, Luostarinen T, Eriksson T, Natunen K, et al. Impact of gender-neutral or girls-only vaccination against human papillomavirus - results of a community-randomized clinical trial (I). *International Journal of Cancer* 2018;142(5):949-58.

NCT00534638. Effectiveness, safety and immunogenicity of GSK Biologicals’ HPV vaccine GSK580299 (Cervarix TM) administered in healthy adolescents. *clinicaltrials.gov/ct2/show/results/NCT00534638* (accessed 25 August 2018).

Leung 2015 (*published and unpublished data*)

GSK 115411 (HPV-071 PRI). Immunogenicity and safety study of GlaxoSmithKline Biologicals’ HPV-16/18 L1 AS04 vaccine and Merck’s Gardasil® vaccine when administered according to alternative 2-dose schedules in 9-14 year old females. www.gsk-clinicalstudyregister.com/files2/gsk-115411-clinical-study-report-redact.pdf (accessed 16 August 2018).

GlaxoSmithKline. Immunogenicity and safety study of GlaxoSmithKline Biologicals’ HPV-16/18 L1 AS04 vaccine and Merck’s Gardasil® vaccine when administered according to alternative 2-dose schedules in 9-14 year old females. *clinicaltrials.gov/ct2/show/results/NCT01462357* (accessed 16 August 2018).

Leung TF, Liu AP, Lim FS, Thollott F, Oh HM, Lee BW, et al. Comparative immunogenicity and safety of human papillomavirus (HPV)-16/18 AS04-adjuvanted vaccine and HPV-6/11/16/18 vaccine administered according to 2- and 3-dose schedules in girls aged 9-14 years: results to month 12 from a randomized trial. *Human Vaccines & Immunotherapeutics* 2015;11:1689-702.

Leung TF, Liu AP, Lim FS, Thollott F, Oh HML, Lee BW, et al. Comparative immunogenicity and safety of human papillomavirus (HPV)-16/18 AS04-adjuvanted vaccine and 4vHPV vaccine administered according to two- or three-dose schedules in girls aged 9-14 years: results to month 36 from a randomized trial. *Vaccine* 2018;36:98-106.

Levin 2010 (*published data only (unpublished sought but not used)*)

Levin MJ, Huang S, Moscicki AB, Song LY, Read JS, Meyer WA, et al. Four-year persistence of type-specific immunity after quadrivalent human papillomavirus vaccination in HIV-infected children: effect of a fourth dose of vaccine. *Vaccine* 2018;35(13):1712-20.

* Levin MJ, Moscicki AB, Song L-Y, Fenton T, Meyer WA, Read JS, et al. Safety and immunogenicity of a quadrivalent human papillomavirus vaccine (types 6, 11, 16, and 18) in HIV-infected children 7 to 12 years old. *Journal of Acquired Immune Deficiency Syndromes* 2010;55(2):197.

Weinberg A, Song L-Y, Saah A, Brown M, Moscicki AB, Meyer WA, et al. Humoral, mucosal, and cell-mediated immunity against vaccine and nonvaccine genotypes after administration of quadrivalent human papillomavirus vaccine to HIV-infected children. *Journal of Infectious Diseases* 2012;206(8):1309-18.

Lin 2014 (*published and unpublished data*)

* Lin CJ, Zimmerman RK, Nowalk MP, Huang HH, Raviotta JM. Randomized controlled trial of two dosing schedules for human
papillomavirus vaccination among college age males. *Vaccine* 2014;32:693-9.

Merck Sharp, Dohme. Randomized trial of alternative HPV vaccination schedules in males in a university setting. clinicaltrials.gov/ct2/show/results/NCT01184079 (accessed 16 August 2018).

Wu RF, Zimmerman RK, Lin CJ. The effect of perceived psychological stress on the immunogenicity of the quadrivalent human papillomavirus vaccine in males. *Human Vaccines & Immunotherapeutics* 2017;13:676-9.

**NCT00941889 2016 (unpublished data only)**

NCT00941889. The effect of HPV vaccination on recurrence rates in HIV patients with condylomata. clinicaltrials.gov/ct2/show/results/NCT00941889/view=results (accessed 27 August 2018).

**NCT01031069 2017 (unpublished data only)**

* GlaxoSmithKline. Safety and immunogenicity of Cervarix™ in human immunodeficiency virus infected females. www.gsk-clinicalstudyregister.com/files/109823-clinical-study-result-summary.pdf (accessed 27 August 2018).

NCT01031069. Evaluation of safety and immunogenicity of a human papillomavirus (HPV) vaccine in human immunodeficiency virus (HIV) infected females. clinicaltrials.gov/ct2/show/NCT01031069 (accessed on 27 August 2018).

**NCT01862874 2018 (published data only)**

NCT01862874. Efficacy and tolerability study of V501 in Japanese males (V501-122). clinicaltrials.gov/ct2/show/NCT01862874 (accessed 27 August 2018).

**Petaja 2009** *(published and unpublished data)*

GSK 580299/011 (HPV-011). A phase I/II, observer-blind, randomized, controlled study to assess the immunogenicity and safety of GlaxoSmithKline Biologicals’ HPV-16/18 L1 VLP AS04 vaccine administered intramuscularly according to a 0, 1, 6 month schedule in healthy male subjects aged 10-18 years. www.gsk-clinicalsudyregister.com/files2/gsk-580299-011-clinical-study-report-redact.pdf (accessed 16 August 2018).

* Petajä T, Keränen H, Karppa T, Kawa A, Lantela S, Siiärit-Mattila M, et al. Immunogenicity and safety of human papillomavirus (HPV)-16/18 AS04-adjuvanted vaccine in healthy boys aged 10-18 years. *Journal of Adolescent Health* 2009;44(1):33-40.

**Puthanakit 2016** *(published and unpublished data)*

GSK 114700 (HPV-070 PRI). Immunogenicity and safety study of GlaxoSmithKline Biologicals’ HPV-16/18 L1 AS04 vaccine when administered according to alternative 2-dose schedules in 9-14 year old females. clinicaltrials.gov/ct2/show/results/NCT01381575 (accessed 16 August 2018).

Huang LM, Puthanakit T, Cheng-Hsun C, Ren-Bin T, Schwarz T, Pellegrino A, et al. Sustained immunogenicity of 2-dose human papillomavirus 16/18 AS04-adjuvanted vaccine schedules in girls aged 9-14 years: a randomized trial. *Journal of Infectious Diseases* 2017;215:1711-9.

* Puthanakit T, Huang LM, Chiu CH, Tang RB, Schwarz TF, Esposito S, et al. Randomized open trial comparing 2-dose regimens of the human papillomavirus 16/18 AS04-adjuvanted vaccine in girls aged 9-14 years versus a 3-dose regimen in women aged 15-25 years. *Journal of Infectious Diseases* 2016;214:525-36.

**Romanowski 2011** *(published and unpublished data)*

GSK 110659 (HPV-048 PRI). Evaluation of the safety and immunogenicity of GSK Biologicals’ HPV vaccine 580299 when administered in healthy females aged 9-25 years using an alternative schedule and an alternative dosing as compared to the standard schedule and dosing. www.gsk-clinicalstudyregister.com/files2/gsk-110659-clinical-study-report-redact.pdf (accessed 16 August 2018).

GlaxoSmithKline. Evaluation of the safety and immunogenicity of GSK Biologicals’ HPV vaccine 580299 when administered in healthy females aged 9-25 years using an alternative schedule and an alternative dosing as compared to the standard schedule and dosing. clinicaltrials.gov/ct2/show/results/NCT00541970 (accessed 16 August 2018).

Romanowski B, Schwarz TF, Ferguson L, Peters K, Dionne M, Behre U, et al. Sustained immunogenicity of the HPV-16/18 AS04-adjuvanted vaccine administered as a two-dose schedule in adolescent girls: five-year clinical data and modelling predictions from a randomized study. *Human Vaccines & Immunotherapeutics* 2016;12:20-9.

Romanowski B, Schwarz TF, Ferguson LM, Peters K, Dionne M, et al. Immune response to the HPV-16/18 AS04-adjuvanted vaccine administered as a 2-dose or 3-dose schedule up to 4 years after vaccination: results from a randomized study. *Human Vaccines & Immunotherapeutics* 2014;10:1155-65.

* Romanowski B, Schwarz TF, Ferguson LM, Peters K, Dionne M, Schulze K, et al. Immunogenicity and safety of the HPV-16/18 AS04-adjuvanted vaccine administered as a 2-dose schedule compared with the licensed 3-dose schedule: results from a randomized study. *Human Vaccines* 2011;7:1374-86.

**Toft 2014** *(published data only (unpublished sought but not used))*

Faust H, Toft L, Sehr P, Müller M, Bonde J, Forslund O, et al. Human papillomavirus neutralizing and cross-reactive antibodies induced in HIV-positive subjects after vaccination with quadrivalent and bivalent HPV vaccines. *Vaccine* 2016;34(13):1559-65.

Toft L, Storgaard M, Muller M, Sehr P, Bonde J, Tolstrup M, et al. Immunogenicity and reactogenicity of Cervarix versus Gardasil in HIV-infected adults: an RCT. *Topics in Antiviral Medicine* 2014;22(e1):174-5.

Comparison of different human papillomavirus (HPV) vaccine types and dose schedules for prevention of HPV-related disease in females and males (Review)}

Copyright © 2019 The Authors. Cochrane Database of Systematic Reviews published by John Wiley & Sons, Ltd. on behalf of The Cochrane Collaboration.
Comparison of different human papillomavirus (HPV) vaccine types and dose schedules for prevention of HPV-related disease in females and males (Review)

References to studies excluded from this review

Cervical, anal, and oral HPV infection. *Journal of the National Cancer Institute* 2016;108(1):djv302.

Bhatia 2016  (*published data only*)

Bhatia R, Kavanagh K, Cubie HA, Serrano I, Wennington H, Hopkins M, et al. Use of HPV testing for cervical screening in vaccinated women – insights from the SHEVs (Scottish HPV Prevalence in Vaccinated Women) study. *International Journal of Cancer* 2016;138(12):2922-31.

Bianchi 2016  (*published data only*)

Bianchi S, Boveri S, Igidbashian S, Amendola A, Urbinati AM, Frati ER, et al. Chlamydia trachomatis infection and HPV/Chlamydia trachomatis coinfection among HPV-vaccinated young women at the beginning of their sexual activity. *Archives of Gynecology and Obstetrics* 2016;294(6):1227-33.

Brown 2012  (*published data only*)

Brown B, Blas M, Cabral A, Carcamo C, Gravitt P, Halsey N. Randomized trial of HPV4 vaccine assessing the response to HPV4 vaccine in two schedules among Peruvian female sex workers. *Vaccine* 2012;30(13):2309–14.

Canfell 2017  (*published data only*)

Canfell K, Caruana M,gebiski V, Darlington-Brown J, Heley S, Brotherton J, et al. Cervical screening with primary HPV testing or cytology in a population of women in which those aged 33 years or younger had previously been offered HPV vaccination: results of the Compass pilot randomised trial. *PLOS Medicine* 2017;14(9):e1002388.

Carozzi 2016  (*published data only*)

Carozzi FM, Ocello C, Burrone E, Faust H, Zappa M, Paci E, et al. Effectiveness of HPV vaccination in women reaching screening age in Italy. *Journal of Clinical Virology* 2016;84:74-81.

Choudhury 2016  (*published data only*)

Choudhury SA, Choudhury NA, Humphrey AD, Berthaud V, Ladson G, Tucker VA, et al. Higher prevalence of human papillomavirus-related cervical precancerous abnormalities in HPV-infected compared to HPV-uninfected women. *Journal of the National Medical Association* 2016;108(1):19–23.

Esposito 2011  (*published data only*)

Esposito S, Burlutiu V, Jarcuska P, Perino A, Man SC, Vladareanu R, et al. Immunogenicity and safety of human papillomavirus-16/18 AS04-adjuvanted vaccine administered according to an alternative dosing schedule compared with the standard dosing schedule in healthy women aged 15 to 25 years: results from a randomized study. *Pediatric Infections Disease Journal* 2011;30(3):e49-55.

Flagg 2018  (*published data only*)

Flagg EW, Torrone EA. Declines in anogenital warts among age groups most likely to be impacted by human papillomavirus vaccination, United States, 2006-2014. *American Journal of Public Health* 2018;108(1):112-9.

Garland 2016  (*published data only*)

Garland SM, Paavonen J, Jaisamrarn U, Naud P, Salmeron J, Chow SN, et al. Prior human papillomavirus-16/18 AS04-
adjuvanted vaccination prevents recurrent high grade cervical intraepithelial neoplasia after definitive surgical therapy: post-hoc analysis from a randomized controlled trial. *International Journal of Cancer* 2016;139(12):2812-26.

**Gilca 2015 (published data only)**

Gilca V, Sauvageau C, Boulianne N, De Serres G, Crajden M, Ouakki M, et al. The effect of a booster dose of quadrivalent or bivalent HPV vaccine when administered to girls previously vaccinated with two doses of quadrivalent HPV vaccine. *Human Vaccines & Immunotherapeutics* 2015;11(3):732-8.

**Hamsikova 2017 (published data only)**

Hamsikova E, Smahelova J, Ludvikova V, Salakova M, Rychla J, Skrenkova J, et al. The prevalence of HPV infections in HPV-vaccinated women from the general population. *Apmis* 2017;125(6):585-95.

**Harari 2016 (published data only)**

Harari A, Chen Z, Rodriguez A, Hildesheim A, Porras C, Herrero R, et al. Cross-protection of the bivalent human papillomavirus (HPV) vaccine against variants of genetically related high-risk HPV infections. *Journal of Infectious Diseases* 2016;213(6):939-47.

**Haskins-Coultier 2017 (published data only)**

Haskins-Coultier T, Southern J, Andrews N, Miller E. Reactogenicity of Cervarix and Gardasil human papillomavirus (HPV) vaccines in a randomized single blind trial in healthy UK adolescent females. *Human Vaccines & Immunotherapeutics* 2017;13(6):1-9.

**Lamontagne 2013 (published data only)**

Lamontagne DS, Thiem VD, Huong VM, Tang Y, Neuzil KM. Immunogenicity of quadrivalent HPV vaccine among girls 11 to 13 years of age vaccinated using alternative dosing schedules: results 29 to 32 months after third dose. *Journal of Infectious Diseases* 2013;208(8):1325-34.

**Lehtinen 2017 (published data only)**

Lehtinen M, Lagheden C, Luostarinen T, Eriksson T, Apter D, Harjula K, et al. Ten-year follow-up of human papillomavirus vaccine efficacy against the most stringent cervical neoplasia end-point-registry-based follow-up of three cohorts from randomized trials. *BMJ Open* 2017;7(8):e015867.

**Luxembourg 2017 (published data only)**

Luxembourg A, Kjaer SK, Nygard M, Ellison MC, Group T, Marshall JB, et al. Design of a long-term follow-up effectiveness, immunogenicity and safety study of women who received the 9-valent human papillomavirus vaccine. *Contemporary Clinical Trials* 2017;52:54-61.

**Money 2016 (published data only)**

Money DM, Moses E, Blitz S, Vandriel SM, Lipsky N, Walmsley SL, et al. HIV viral suppression results in higher antibody responses in HIV-positive women vaccinated with the quadrivalent human papillomavirus vaccine. *Vaccine* 2016;34(40):4799-806.

**Neuzil 2011 (published data only)**

Neuzil KM, Thiem VD, Janmohamed A, Huong VM, Tang Y, Diep NT, et al. Immunogenicity and reactogenicity of alternative schedules of HPV vaccine in Vietnam: a cluster randomized noninferiority trial. *JAMA* 2011;305(14):1424-31.

**Wheeler 2016 (published data only)**

Wheeler CM, Skinner SR, Del Rosario-Raymundo MR, Garland SM, Chatterjee A, Lazzcano-Ponce E, et al. Efficacy, safety, and immunogenicity of the human papillomavirus 16/18 AS04-adjuvanted vaccine in women older than 25 years: 7-year follow-up of the phase 3, double-blind, randomised controlled VIVIANE study. *Lancet Infectious Diseases* 2016;16(10):1154-68.

**Zhu 2017 (published data only)**

Zhu FC, Hu SY, Hong Y, Hu YM, Zhang X, Zhang YJ, et al. Efficacy, immunogenicity, and safety of the HPV-16/18 AS04-adjuvanted vaccine in Chinese women aged 18-25 years: event-triggered analysis of a randomized controlled trial. *Cancer Medicine* 2017;6(1):12-25.

**Zimmerman 2010 (published data only)**

Zimmerman RK, Nowalk MP, Lin CJ, Fox DE, Ko FS, Wettick E, et al. Randomized trial of an alternate human papillomavirus vaccine administration schedule in college-aged women. *Journal of Women's Health* 2010;19(8):1441-7.

**References to studies awaiting assessment**

**Li 2012 (published data only (unpublished sought but not used))**

Huang T, Liu Y, Li Y, Liao Y, Shou Q, Zheng M, et al. Evaluation on the persistence of anti-HPV immune responses to the quadrivalent HPV vaccine in Chinese females and males: Up to 3.5 years of follow-up. *Vaccine* 2018;36(11):1368-1374.

* Li R, Li Y, Radley D, Liu Y, Huang T, Sings HL, et al. Safety and immunogenicity of a vaccine targeting human papillomavirus types 6, 11, 16 and 18: a randomized, double-blind, placebo-controlled trial in Chinese males and females. *Vaccine* 2012;30(28):4284-91.

**Reisinger 2007 (published data only (unpublished sought but not used))**

Ferris D, Samakoses R, Block SL, Lazzcano-Ponce E, Restrepo JA, Reisinger KS, et al. Long-term study of a quadrivalent human papillomavirus vaccine. *Pediatrics* 2014;134(3):e657-65.

Ferris DG, Samakoses R, Block SL, Lazzcano-Ponce E, Restrepo JA, Mehlens J, et al. 4-Valent Human Papillomavirus (4vHPV) Vaccine in Preadolescents and Adolescents After 10 Years. *Pediatrics* 2017;140(6):pii: e20163947.

* Reisinger KS, Block SL, Lazzcano-Ponce E, Samakoses R, Esser MT, Erick J, et al. Safety and persistent immunogenicity of a quadrivalent human papillomavirus types 6, 11, 16, 18L1 virus-like particle vaccine in preadolescents and adolescents: a randomized controlled trial. *Pediatr Infect Dis J* 2007;26(3):201-9.
References to ongoing studies

NCT01735006 (published data only)
NCT01735006. Efficacy and immunogenicity study of recombinant human papillomavirus bivalent (type 16/18) vaccine. clinicaltrials.gov/ct2/show/NCT01735006 (accessed 27 August 2018).

NCT01824537 (published data only)
NCT01824537. Transmission reduction and prevention with HPV vaccination (TRAP-HPV) study (TRAP-HPV). clinicaltrials.gov/ct2/show/NCT01824537 (accessed 27 August 2018).

NCT02009800 (published data only)
NCT02009800. ICI-VPH: impact of HPV immunisation schedules against HPV (I-VPH). clinicaltrials.gov/ct2/show/NCT02009800 (accessed 27 August 2018).

NCT02087384 (published data only)
NCT02087384. HPV (human papilloma virus) vaccination after treatment of anal intraepithelial neoplasia (AIN) (VACCAIN-P). clinicaltrials.gov/ct2/show/NCT02087384 (accessed 27 August 2018).

NCT02405520 (published data only)
NCT02405520. Safety and immunogenicity study of the recombinant human papillomavirus virus type 6/11 bivalent vaccine. clinicaltrials.gov/ct2/show/NCT02405520 (accessed on 27 August 2018).

NCT02562508 (published data only)
NCT02562508. A bridging study of a recombinant human papillomavirus 16/18 bivalent vaccine in preadolescent girls. clinicaltrials.gov/ct2/show/NCT02562508 (accessed 27 August 2018).

NCT02567955 (published data only)
NCT02567955. Immunogenicity and safety of Gardasil-9 and Cervarix. clinicaltrials.gov/ct2/show/NCT02567955 (accessed on 27 August 2018).

NCT02710851 (published data only)
NCT02710851. Immunogenicity study of the recombinant human papillomavirus virus type 6/11 bivalent vaccine. clinicaltrials.gov/ct2/show/NCT02710851 (accessed on 27 August 2018).

NCT02733068 (published data only)
NCT02733068. A phase III study of human papillomavirus (HPV)-16/18 vaccine. clinicaltrials.gov/ct2/show/NCT02733068 (accessed 27 August 2018).

NCT02740777 (published data only)
NCT02740777. Evaluating the 2-dose immunization schedule of human papillomavirus (HPV)-16/18 in adolescent females. clinicaltrials.gov/ct2/show/NCT02740777 (accessed 27 August 2018).

NCT02750202 (published data only)
NCT02750202. Effectiveness study of human papilloma virus (HPV) vaccines to prevent recurrence of genital warts (TheraVACCs). clinicaltrials.gov/ct2/show/NCT02750202 (accessed on 27 August 2018).

NCT02834637 (published data only)
NCT02834637. A dose reduction immunobridging and safety study of two HPV vaccines in Tanzanian girls (DoRIS). clinicaltrials.gov/ct2/show/NCT02834637 (accessed 27 August 2018).

NCT02888418 (published data only)
NCT02888418. Safety and immunogenicity study of human papilloma virus vaccine in women aged 9 to 30 and men aged 9 to 17. clinicaltrials.gov/ct2/show/NCT02888418 (accessed 27 August 2018).

NCT03180034 (published data only)
NCT03180034. Scientific evaluation of one or two doses of the bivalent or nonavalent prophylactic HPV vaccines. https://clinicaltrials.gov/ct2/show/NCT03180034 (accessed on 27 August 2017).

Sampson JN, Hildesheim A, Herrero R, Gonzalez P, Kreimer AR, Gail MH. Design and statistical considerations for studies evaluating the efficacy of a single dose of the human papillomavirus (HPV) vaccine. Contemporary Clinical Trials 2018;68:35-44.

NCT03296397 (published data only)
NCT03296397. Efficacy of quadrivalent HPV vaccine to prevent relapses of genital warts after initial therapeutic response (CONDVAC). clinicaltrials.gov/ct2/show/NCT03296397 (accessed 27 August 2018).

Additional references

Alemany 2014
Alemany L, Saunier M, Tinoco L, Quiros B, Alvarado-Cabrero I, Alejo M, et al on behalf of the HPV VVAP study group. Large contribution of human papillomavirus in vaginal neoplastic lesions: a worldwide study in 597 samples. European Journal of Cancer 2014;50:2846-54.

Arbyn 2015
Arbyn M, Xu L, Simoons C, Martin-Hirsch PP. Prophylactic vaccination against human papillomaviruses to prevent cervical cancer and its precursors. Cochrane Database of Systematic Reviews 2018, Issue 5. [DOI: 10.1002/14651858.CD009069.pub3]

Block 2006
Block SL, Nolan T, Sattler C, Barr E, Giacone KE, Marchant CD, et al. Comparison of the immunogenicity and reactogenicity of a prophylactic quadrivalent human papillomavirus (types 6, 11, 16, and 18) L1 virus-like particle vaccine in male and female adolescents and young adult women. Pediatrics 2006;118(5):2135-45.

Bogaards 2015
Bogaards JA, Wallinga J, Brakenhoff RH, Meijer CJ, Berkhof J. Direct benefit of vaccinating boys along with girls against oncogenic human papillomavirus: bayesian evidence synthesis. BMJ 2015;350:h2016.
Bonhoeffer 2002
Bonhoeffer J, Kohl K, Chen R, Duclos P, Heijbel H, Heininger U, et al: The Brighton Collaboration. The Brighton Collaboration: addressing the need for standardized case definitions of adverse events following immunization (AEFI). Vaccine 2002;21:298-302.

Bosch 2002
Bosch FX, Lorincz A, Munoz N, Meijer CJ, Shah KV. The causal relation between human papillomavirus and cervical cancer. Journal of Clinical Pathology 2002;55:244-65.

Bouvard 2009
Bouvard V, Baan R, Straif K, Grosse Y, Secretan B, El Ghissassi F, et al: WHO International Agency for Research on Cancer Monograph Working Group. A review of human carcinogens-- Part B: biological agents. Lancet Oncology 2009;10(4):321-2.

Bradburn 2007
Bradburn MJ, Deeks JJ, Berlin JA, Russell Localio A. Much ado about nothing: a comparison of the performance of meta-analytical methods with rare events. Statistics in Medicine 2007;26(1):53-77.

Brotherton 2018
Brotherton JM, Bloem PN. Population-based HPV vaccination programmes are safe and effective: 2017 update and the impetus for achieving better global coverage. Best Practice & Research Clinical Obstetrics & Gynaecology 2018;47:42-58.

Bruni 2010
Bruni L, Diaz M, Castellsagué X, Ferrer E, Bosch FX, de Sanjose S. Cervical human papillomavirus prevalence in 5 continents: meta-analysis of 1 million women with normal cytological findings. The Journal of Infectious Diseases 2010;202(12):1789-99.

de Martel 2017
de Martel C, Plummer M, Vignat J, Franceschi S. Worldwide burden of cancer attributable to HPV by site, country and HPV type. International Journal of Cancer 2017;141(4):664-70.

de Sanjose 2010
de Sanjose S, Quint WG, Alemany L, Geraets DT, Klaustermeier JE, Lloveras B, et al on behalf of the Retrospective International Survey and HPV Time Trends Study Group. Human papillomavirus genotype attribution in invasive cervical cancer: a retrospective cross-sectional worldwide study. Lancet Oncology 2010;11:1048-56.

Donken 2015
Donken R, Knol MJ, Bogaards JA, van der Klis FR, Meijer CJ, de Melker HE. Inconclusive evidence for non-inferior immunogenicity of two- compared with three-dose HPV immunization schedules in preadolescent girls: a systematic review and meta-analysis. Journal of Infection 2015;71:61-73.

Drolet 2019
Drolet M, Bénard É, Pérez N, Brisson M, on behalf of the HPV Vaccination Impact Study Group. Population-level impact and herd effects following the introduction of human papillomavirus vaccination programmes: updated systematic review and meta-analysis. Lancet 2019;pii:S0140-6736(19):30298-3.

Gallagher 2018
Gallagher KE, LaMontagne DS, Watson-Jones D. Status of HPV vaccine introduction and barriers to country uptake. Vaccine 2018;36(32 Pt A):4761-7.

Gillison 2015
Gillison ML, Chaturvedi AK, Anderson WF, Fakhry C. Epidemiology of human papillomavirus-positive head and neck squamous cell carcinoma. Journal of Clinical Oncology 2015;33(29):3235-42.

GRADEpro GDT [Computer program]
McMaster University (developed by Evidence Prime). GRADEpro GDT. Version accessed 27 August 2018. McMaster University (developed by Evidence Prime), 2015.

Greer 1995
Greer CE, Wheeler CM, Ladner MB, Beutner K, Coyne MY, Liang H, et al. Human papillomavirus (HPV) type distribution and serological response to HPV type 6 virus-like particles in patients with genital warts. Journal of Clinical Microbiology 1995;33:2058-63.

Guyatt 2011a
Guyatt GH, Oxman AD, Vist G, Kunz R, Brozek J, Alonso-Coello P, et al. GRADE guidelines: 4. Rating the quality of evidence—study limitations (risk of bias). Journal of Clinical Epidemiology 2011;64(4):407-15.

Guyatt 2011b
Guyatt GH, Oxman AD, Kunz R, Woodcock J, Brozek J, Helfland M, et al. GRADE guidelines: 7. Rating the quality of evidence—inconsistency. Journal of Clinical Epidemiology 2011;64(12):1294-302.

Guyatt 2011c
Guyatt GH, Oxman AD, Montori M, Vist G, Kunz R, Brozek J, et al. GRADE guidelines: 5. Rating the quality of evidence—publication bias. Journal of Clinical Epidemiology 2011;64(12):1277-82.

Guyatt 2011d
Guyatt G, Oxman AD, Akl EA, Kunz R, Vist G, Brozek J, et al. GRADE guidelines: 1. Introduction—GRADE evidence profiles and summary of findings tables. Journal of Clinical Epidemiology 2011;64(4):383-94.
Comparison of different human papillomavirus (HPV) vaccine types and dose schedules for prevention of HPV-related disease in females and males (Review)

Copyright © 2019 The Authors. Cochrane Database of Systematic Reviews published by John Wiley & Sons, Ltd. on behalf of The Cochrane Collaboration.
### Characteristics of Studies

#### Characteristics of included studies [ordered by study ID]

| Study | Methods | Participants |
|-------|----------|--------------|
| Denny 2013 | Phase I/II, partially-blind, partially-randomised, placebo-controlled trial | Participants: 120 HIV-positive women (61 in bivalent vaccine group and 59 in control group) in South Africa  
Age range: 18–25 years  
Inclusion criteria: women with an intact cervix who reported no more than 6 lifetime sexual partners and whom the investigator believed would comply with the protocol requirements. Sexually active women had to have a normal colposcopy and normal cervical cytology or no worse than atypical squa- |
| Schiller 2018 | | |
| Schiller J, Lowy D. Explanations for the high potency of HPV prophylactic vaccines. Vaccine 2018;36(32 Pt A):4768-73. |
| Schim van der Loeff 2014 | | |
| Schim van der Loeff MF, Mooij SH, Richel O, de Vries HJ, Prins JM. HPV and anal cancer in HIV-infected individuals: a review. Current HIV/AIDS Reports 2014;11(3):250-62. |
| Sharma 2017 | | |
| Sharma T, Gatzsche P, Kuss O. The Yusuf-Peto method was not a robust method for meta-analyses of rare events data from antidepressant trials. Journal of Clinical Epidemiology 2017;91:129-36. |
| Smith 2011 | | |
| Smith MA, Lew J-B, Walker RJ, Brotherton JM, Nickson C, Canfell K. The predicted impact of HPV vaccination on male infections and male HPV-related cancers in Australia. Vaccine 2011;29:9112-22. |
| Stanley 2006 | | |
| Stanley MA. Human papillomavirus vaccines. Reviews in Medical Virology 2006;16:139-49. |
| Stanley 2014 | Alternative dosage schedules with HPV virus-like particle vaccines. Expert Review of Vaccines 2014;13:1027-38. |
| Sturegard 2013 | | |
| Sturegard E, Johansson H, Ekström J, Hansson B-G, Johnsson A, Gustafsson E, et al. Human papillomavirus typing in reporting of Condyloma. Sexually Transmitted Diseases 2013;40:123-9. |
| Syrjänen 2010 | | |
| Syrjänen S. The role of human papillomavirus infection in head and neck cancers. Annals of Oncology 2010;21:243-5. |
| Vardas 2011 | | |
| Vardas E, Giuliano AR, Goldstone S, Palefsky JM, Moreira ED Jr, Penny ME, et al. External genital human papillomavirus prevalence and associated factors among heterosexual men on 5 continents. Journal of Infectious Diseases 2011;203(1):58-65. |
| Walling 2016 | | |
| Walling EB, Benzioni N, Dornfeld J, Bhandari R, Sisk BA, Garbutt J, et al. Interventions to improve HPV vaccine uptake: a systematic review. Pediatrics 2016;138(1):e20153863. |
| WHO 2017 | | |
| World Health Organization. Human papillomavirus vaccines: WHO position paper, May 2017. Weekly Epidemiological Record 2017;92:241-68. |

* Indicates the major publication for the study
mous cells of undetermined significance at the screening visit. All women had to be willing to undergo HIV counselling and testing and to be informed of their HIV status.

Interventions

Vaccine: bivalent HPV vaccine; 3 doses: day 0, month 1, month 6

Control: aluminium adjuvant placebo (aluminium hydroxide (Al(OH))3); 3 doses: day 0, month 1, month 6

Outcomes

Harms: adverse events

Immunogenicity: GMT, seroconversion

Notes

Other groups: 30 HIV-negative women were enrolled as a control group and received bivalent HPV vaccine

Last report average follow-up time: 12 months

Funding: GlaxoSmithKline Biologicals SA. The study sponsor designed the study in collaboration with the investigators, and co-ordinated collection, analysis, and interpretation of data.

Trial ID: NCT00586339.

Risk of bias

| Bias                                           | Authors' judgement | Support for judgement                                      |
|------------------------------------------------|--------------------|------------------------------------------------------------|
| Random sequence generation (selection bias)   | Low risk           | Centralised, Internet-based randomisation system           |
| Allocation concealment (selection bias)       | Low risk           | Centralised, Internet-based randomisation system           |
| Blinding of participants and personnel (performance bias) | Unclear risk | Participants were blinded to allocation. No clear statement presented regarding blinding of personnel or outcome assessors. |
| Blinding of outcome assessment (detection bias) | Unclear risk | Participants were blinded to allocation. No clear statement presented regarding blinding of personnel or outcome assessors. |
| Incomplete outcome data (attrition bias)      | Low risk           | Most analysis per protocol, but baseline data on full cohort provided, data on withdrawals and reasons for withdrawing also provided. |
| Selective reporting (reporting bias)          | Low risk           | No reasons to suspect that reporting was selective. Clinical trial record checked. |
| Other bias                                    | Unclear risk       | Trial funded by vaccine manufacturer.                     |

Dobson 2013

Methods

Phase III, open-label, non-inferiority, controlled, randomised, multi-centre trial

Participants

Participants: 520 women and young girls (259 to 2-dose quadrivalent HPV vaccine and 261 to 3-dose quadrivalent HPV vaccine) recruited from 3 Canadian provincial centres

Age range: girls aged 9-13 years, young women aged 16-26 years
Inclusion criteria: healthy participants 9-13 years of age (girls) or 16-26 years of age (young women), with 4 or fewer lifetime sexual partners

Interventions
- Vaccine 1: quadrivalent HPV vaccine; 2 doses: day 1, month 6
- Vaccine 2: quadrivalent HPV vaccine; 3 doses: day 1, month 2, month 6

Outcomes
- Harms: adverse events
- Immunogenicity: GMT, seroconversion

Notes
- Other groups: in our analyses we did not include the cohort of 16-26-year-old women that were not randomised within the trial
- Last report average follow-up time: 36 months
- Funding: Ministries of Health in the provinces of British Columbia, Nova Scotia, and Quebec. Merck Laboratories Inc conducted the antibody assays at no cost to the study.
- Merck had no role in the design or conduct of the study; collection, management, analysis, or interpretation of the data; or preparation, review, or approval of the manuscript.
- Trial ID: NCT00501137

Risk of bias

| Bias                                   | Authors' judgement | Support for judgement                                                                 |
|----------------------------------------|--------------------|---------------------------------------------------------------------------------------|
| Random sequence generation (selection bias) | Low risk           | Girls were randomised (1:1) in balanced, stratified blocks of 6 to receive either 2 doses (at 0 and 6 months) or 3 doses (at 0, 2, and 6 months). The co-ordinating centre used SAS, version 9.2 (SAS Institute Inc) to generate randomisation lists for each site. |
| Allocation concealment (selection bias) | Low risk           | Co-ordinating centre generated randomisation sequence and allocated girls.             |
| Blinding of participants and personnel (performance bias) All outcomes | High risk          | Impossible to blind girls as to whether they were randomised to 2 or 3 doses; the young women were not randomised, all receiving 3 doses. |
| Blinding of outcome assessment (detection bias) All outcomes | Low risk           | Laboratory staff, blinded to group assignment, conducted the HPV antibody assays.     |
| Incomplete outcome data (attrition bias) All outcomes | Low risk           | Data were reported for both ITT and per protocol populations, with full information on exclusions and withdrawals. |
| Selective reporting (reporting bias)    | Low risk           | The primary interest was in the per-protocol population; however, the results presented were the ITT population because these results could be generalised more readily. |
| Other bias                             | Low risk           | No other bias apparent                                                                |
### Giuliano 2011

**Methods**

Phase III, double-blind, parallel, placebo-controlled, randomised and multi-site trial

**Participants**

Participants: 4065 boys and men (2032 to the vaccine group and 2033 to the control group) recruited from 18 countries in five regions (Africa, Asia-Pacific, Europe, Latin America, North America)

Age range: 16-26 years

Inclusion criteria: heterosexual males 16-23 years old with between 1-5 lifetime female sexual partners, plus males who have sex with male partners 16-26 years old with 1-5 lifetime male or female partners

**Interventions**

Vaccine: quadrivalent HPV vaccine; 3 doses: day 1, month 2, month 6

Control: aluminium adjuvant placebo (amorphous aluminium hydroxy-phosphate sulphate (AAHS)); 3 doses: day 1, month 2, month 6

**Outcomes**

Clinical: external genital lesions; penile, perianal, or perineal intraepithelial neoplasia; or penile, perianal, or perineal cancer

Harms: adverse events, deaths

Immunogenicity: GMT, seroconversion

**Notes**

Other groups: N/A

Last report average follow-up time: 36 months

Funding: Merck, in collaboration with external investigators and an external data and safety monitoring board. The sponsor co-designed the trial, collated the data, monitored the conduct of the trial, performed statistical analyses, and co-ordinated the writing of the manuscript with all the authors.

Trial ID: NCT00090285

### Risk of bias

| Bias                                           | Authors' judgement | Support for judgement |
|------------------------------------------------|--------------------|-----------------------|
| Random sequence generation (selection bias)   | Low risk           | A computer-generated allocation schedule was produced by the sponsor. Following informed consent and determination that all entry criteria were met, eligible subjects were randomised to a vaccination group. (Hillman 2012, companion paper) |
| Allocation concealment (selection bias)       | Low risk           | Following informed consent and determination that all entry criteria were met, eligible subjects were randomised to a vaccination group. All investigators and site personnel, subjects, monitors, and laboratory personnel remained blinded to treatment allocation throughout the study. Staff of the sponsor were blinded from the study onset through the database lock for this analysis. (Hillman 2012, companion paper) |
| Blinding of participants and personnel (performance bias) | Low risk           | Quote: “visually indistinguishable AAHS-containing placebo”; All investigators and site personnel, subjects, monitors, and laboratory personnel remained blinded to treatment allocation throughout the study. Staff of the sponsor were blinded from the study onset through the database lock for this analysis. (Hillman 2012) |
| Blinding of outcome assessment (detection bias) | Low risk           | All biopsy specimens were processed independently to prevent contamination of HPV DNA and were assessed in a blinded fashion, first for the purpose of clinical management by pathologists at the central laboratory (Diagnostic Cytology Laboratories) and then for end-point adjudication by a 4-member panel of pathologists. |
### Giuliano 2011 (Continued)

| Bias                                      | Authors' judgement | Support for judgement                                      |
|-------------------------------------------|--------------------|------------------------------------------------------------|
| Incomplete outcome data (attrition bias)  | Low risk           | Data reported adequately.                                  |
| All outcomes                              |                    |                                                            |
| Selective reporting (reporting bias)      | Low risk           | No reason to suspect that reporting was selective - clinical trial registry checked. |
| Other bias                                | Unclear risk       | Trial funded by vaccine manufacturer.                      |

### Hidalgo-Tenorio 2017

**Methods**

Randomised, double blind, placebo-controlled trial

**Participants**

Participants: 129 HIV-positive men who have sex with men (66 received quadrivalent HPV vaccine and 63 received control) recruited from the Infectious Diseases Service in Spain

Age range: ≥18 years of age

Inclusion criteria: participants not infected simultaneously by the 4 genotypes of HPV that the quadrivalent vaccine addresses; with a normal high-resolution anoscopy at screening for inclusion, or with only condylomas or low squamous intraepithelial lesion, or both, in anal biopsy.

**Interventions**

Vaccine: quadrivalent HPV vaccine; 3 doses: day 1, month 2, month 6

Control: saline placebo ("water used in the preparation of injectable with <1 mmol of Na"); 3 doses: day 1, month 2, month 6

**Outcomes**

Harms: adverse events, deaths

**Notes**

Other groups: N/A

Last report average follow-up time: 7 months

Funding: Public Health and Social Progress Foundation of the Government of Andalucía [La Fundación Pública Andaluza Progreso y Salud de la Consejería de Igualdad Salud y Política Social]

Trial ID: ISRCTN14732216

**Risk of bias**

| Bias                                      | Authors' judgement | Support for judgement                                      |
|-------------------------------------------|--------------------|------------------------------------------------------------|
| Random sequence generation (selection bias) | Low risk           | Computer generated list of random numbers                  |
| Allocation concealment (selection bias)    | Low risk           | Quote: “The person in charge of generating and keeping the list was not part of the research team and did not participate in evaluation or enrolment of patients, therefore guaranteeing patient blinding.” |
| Blinding of participants and personnel (performance bias) All outcomes | Unclear risk       | Participants were blinded to allocation. No clear statement provided regarding blinding of personnel or outcome assessors. |
| Blinding of outcome assessment (detection bias) All outcomes | Unclear risk       | Participants were blinded to allocation. No clear statement provided regarding blinding of personnel or outcome assessors. |
Hidalgo-Tenorio 2017 (Continued)

Incomplete outcome data (attrition bias)

All outcomes
Low risk
129 of 162 screened subjects were included. Reasons for ineligibility, withdrawal, and protocol violation fully reported.

Selective reporting (reporting bias)

Low risk
No reason to suspect that reporting was selective. Trial registered retrospectively.

Other bias
Low risk
No other bias apparent.

Iversen 2016

Methods

Phasae III, open-label, controlled, randomised and multi-centre trial

Participants

Participants: 1518 girls, boys, and young women (301 girls aged 9–14 years and 301 boys aged 9-14 years received 2 doses 6 months apart; 301 girls and boys aged 9–14 years received 2 doses 12 months apart; 301 girls aged 9-14 years and 314 young women aged 16-26 years received 3 doses at 0, 2, 6 months) recruited from 15 countries (Canada, Chile, Colombia, Czech Republic, Denmark, Israel, Malaysia, Norway, South Korea, South Africa, Spain, Taiwan, Thailand, Turkey, and the USA)

Age range: girls and boys aged 9-14 years and girls and young women aged 16-26 years

Inclusion criteria: girls and boys 9-14 years had to be generally healthy and not sexually active prior to enrolment. Girls and young women 16-26 years had to be generally healthy with 4 or fewer lifetime sexual partners, without a history of abnormal Papanicolaou test results or other cervical abnormalities, and to agree to use effective contraception through to study month 7.

Interventions

Vaccine 1: nonavalent HPV vaccine; 2 doses: day 1, month 6
Vaccine 2: nonavalent HPV vaccine; 2 doses: day 1, month 12
Vaccine 3: nonavalent HPV vaccine; 3 doses: day 1, month 2, month 6

Outcomes

Harms: adverse events, deaths
Immunogenicity: GMT, seroconversion

Notes

Other groups:

• boys aged 9-14 years receiving 2 doses nonavalent HPV vaccine;
• adolescent girls and young women 16-26 years receiving 3 doses of nonavalent HPV vaccine

Last report average follow-up time: 13 months (1 month after the last dose)

Funding: Merck & Co, manufacturer of the quadrivalent and nonavalent HPV vaccines. Merck, as the study sponsor, was directly involved in the design and conduct of the study in conjunction with external investigators; collection, management, analysis, and interpretation of the data; and preparation and review of the manuscript. The presentation also underwent formal review by Merck. However, Merck could not prevent submission of the manuscript.

Trial ID: NCT01984697

Risk of bias

Bias
Authors' judgement
Support for judgement

Random sequence generation (selection bias)
Low risk
Randomisation occurred centrally using interactive voice response system/integrated web response system (IVRS/IWRS). Subjects were assigned randomly
### Iversen 2016 (Continued)

| Allocation concealment (selection bias) | Low risk | Randomisation occurred centrally using interactive voice response system/integrated web response system (IVRS/IWRS). Subjects were assigned randomly to 1 of the 3 vaccination arms based on their age stratum according to a computer-generated allocation schedule. |
|----------------------------------------|----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Blinding of participants and personnel (performance bias) | High risk | Blinding was not possible due to the nature of the trial; however, all participants, investigators, and study personnel were blinded to the type of vaccine administered. |
| Blinding of outcome assessment (detection bias) | High risk | No information provided on blinding of outcome assessment. |
| Incomplete outcome data (attrition bias) | Low risk | Accurate follow-up data with no significant loss to follow-up. |
| Selective reporting (reporting bias) | Low risk | No indication of selective reporting; trial protocol and clinical trial registry cross-referenced. |
| Other bias | Unclear risk | Funding: Merck |

### Joura 2015

| Methods | Phase II/III, double-blind, randomised, multi-centre trial |
|---------|----------------------------------------------------------|
| Participants | Participants: 14215 women (6792 in the nonavalent HPV vaccine group and 6795 in the quadrivalent HPV vaccine group) recruited from 18 countries (Austria, Brazil, Canada, Chile, Colombia, Denmark, Germany, Hong Kong, Japan, Korea, Mexico, New Zealand, Norway, Peru, Sweden, Taiwan, Thailand, and the USA (including Puerto Rico)) Age range: 16-26 years Inclusion criteria: no history of an abnormal result on a Papanicolaou (Pap) test, no more than 4 lifetime sexual partners, and no previous abnormal finding on cervical biopsy |
| Interventions | Vaccine 1: nonavalent HPV vaccine; 3 doses: day 1, month 2, month 6 Vaccine 2: quadrivalent HPV vaccine; 3 doses: day 1, month 2, month 6 |
| Outcomes | Clinical: high grade cervical, vulval, and vaginal disease; cervical cancer; persistent HPV infection Harms: adverse events, deaths Immunogenicity: GMT, seroconversion |
| Notes | Other groups: N/A Last report average follow-up time: 54 months Funding: Merck Trial ID: NCT00543543 |
### Risk of bias

| Bias                                       | Authors' judgement | Support for judgement                                                                                                                                 |
|--------------------------------------------|--------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|
| Random sequence generation (selection bias) | Low risk           | Quote: "An Interactive Voice Response System (IVRS) was used to allocate study subjects and balance randomisation between sites. Subjects were assigned an allocation number from an allocation schedule via the IVRS. Study personnel utilized IVRS at each vaccination visit for assignment of the clinical material from the appropriate vaccination group to be administered to the subject.” (From protocol, supplementary material online) |
| Allocation concealment (selection bias)    | Low risk           | Quote: "An Interactive Voice Response System (IVRS) was used to allocate study subjects and balance randomisation between sites. Subjects were assigned an allocation number from an allocation schedule via the IVRS. Study personnel utilized IVRS at each vaccination visit for assignment of the clinical material from the appropriate vaccination group to be administered to the subject.” (From protocol, supplementary material online) |
| Blinding of participants and personnel (performance bias) All outcomes | Low risk           | Quote: "The subjects, investigators (and his/her staff), laboratory staff, members of the Scientific Advisory Committee, and HPV Vaccine Program Pathology Panel will remain blinded to subject vaccination group allocations for the duration of the study.” (From protocol, supplementary material online) |
| Blinding of outcome assessment (detection bias) All outcomes | Low risk           | Quote: "The subjects, investigators (and his/her staff), laboratory staff, members of the Scientific Advisory Committee, and HPV Vaccine Program Pathology Panel will remain blinded to subject vaccination group allocations for the duration of the study. The SPONSOR will remain blinded to subject vaccination allocations until the required number of cases of the primary efficacy endpoint have been observed and the database is unblinded for the primary efficacy analysis, with the exception of unblinded personnel who will provide data summaries for dose selection and DSMB meetings, and those who will determine when the required number of cases of the primary efficacy endpoint have been observed. These unblinded personnel will not be associated with the conduct of the study or the design of any of the statistical analyses for the study (other than those requested by the DSMB).” (From protocol, supplementary material online) |
| Incomplete outcome data (attrition bias) All outcomes | Low risk           | Data reported adequately in published report, with extra data published in Supplementary materials online.                                                                                                |
| Selective reporting (reporting bias)       | Low risk           | Full protocol published as supplementary material alongside published paper, including analysis plan.                                                                                           |
| Other bias                                 | Unclear risk       | Trial funded by vaccine manufacturer.                                                                                                                                   |

### Lehtinen 2018

Methods
- Partially blind cluster-randomised trial

Participants
- Participants: 32,175 early adolescents (20,514 girls and 11,661 boys) living in 33 community clusters in Finland; 3703 male participants were included in narrative results
- Age range: 12-15 years
Lehtinen 2018 (Continued)

Inclusion criteria: born 1992–1995; parental consent; healthy, as established by medical history. If female, not pregnant and not of child-bearing potential or using adequate contraception for 30 days prior to vaccination and to continue for 2 months after completion of the vaccination series

Interventions
Vaccine 1: 90% of the girls and boys assigned to receive bivalent HPV vaccine (Cervarix) and 10% assigned to receive hepatitis B vaccine (HBV; Engerix) at 0,1 and 6 months (11 clusters)

Vaccine 2: 90% of the girls assigned to receive bivalent HPV vaccine, 10% of girls assigned to receive HBV vaccine and all boys received HBV-vaccine (11 clusters)

Control: all participants assigned to receive active control HBV vaccine (11 clusters)

Outcomes
Harms: adverse events (active surveillance subgroup 12-month follow-up)

Notes
Other groups: the data provided on harms in the male participants was based on the 2436 in group 1 who received bivalent vaccine and a sub-set of 1267 of those who received HBV vaccine in group 2.

Last report average follow-up time: 4 years

Funding: GlaxoSmithKline

Trial ID: NCT00534638

Risk of bias

| Bias                                      | Authors' judgement | Support for judgement                                                                                                                                                                                                 |
|-------------------------------------------|--------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Random sequence generation (selection bias) | Low risk           | Cluster-randomised: “communities were randomly assigned in equal numbers (1:1:1) to the three intervention arms using a random number generator”                                                                                                                             |
| Allocation concealment (selection bias)   | Low risk           | Although the trial used central randomisation: “study participants were to be administered the vaccine dose according to a central randomisation system on Internet”                                                                 |
| Blinding of participants and personnel (performance bias) All outcomes | High risk          | Although the study was blinded for participants in the first arm (HPV or HBV vaccine), the participants in the third arm were aware of their allocation (all received HBV vaccine).                                                                 |
| Blinding of outcome assessment (detection bias) All outcomes | High risk          | Quote: "For investigators, the study was open"                                                                                                                                                                          |
| Incomplete outcome data (attrition bias) All outcomes | High risk          | For active adverse event surveillance, data were collected only for a subset of male participants and it was unclear how these participants were selected. Passive adverse event surveillance was conducted for all participants, but not reported for males separately. |
| Selective reporting (reporting bias)       | High risk          | No outcomes were reported completely separately for boys and girls. Adverse events were reported in boys separately, but in a selected subset.                                                                                |
| Other bias                                | Unclear risk       | Trial funded by vaccine manufacturer.                                                                                                                                                                                  |

Leung 2015

Methods
Phase III, observer-blind, parallel, randomised trial
### Participants

Participants: 1075 girls (359 to 2 doses of bivalent HPV; 358 to 2 doses of quadrivalent HPV; 358 to 3 doses of quadrivalent HPV; recruited at 21 sites in France, Hong Kong, Singapore and Sweden

Age range: 9-14 years

Inclusion criteria: healthy girls aged 9–14 years; girls of childbearing potential could be enrolled if they were abstinent or practised adequate contraception for 30 days prior to vaccination, had a negative pregnancy test on the day of each vaccination, and agreed to continue contraception for up to 2 months after completion of the vaccination series.

### Interventions

- **Vaccine 1**: quadrivalent HPV vaccine; 2 doses: day 1, month 6
- **Vaccine 2**: quadrivalent HPV vaccine; 3 doses: day 1, month 2, month 6

Girls in the 2-dose group received aluminium adjuvant placebo (Al(OH)$_3$) at month 2 to maintain the observer blindness.

### Outcomes

- **Harms**: adverse events, deaths
- **Immunogenicity**: GMT, seroconversion

### Notes

- Other groups: 358 girls aged 9-14 years who received 2 doses of bivalent HPV vaccine.
- Last report average follow-up time: 36 months
- Funding: GlaxoSmithKline Biologicals SA funded this study and was involved in all stages of study conduct, including analysis of the data and the development and publication of the manuscript.
- Trial ID: NCT01462357

### Risk of bias

| Bias                                      | Authors' judgement | Support for judgement                                                                 |
|-------------------------------------------|--------------------|---------------------------------------------------------------------------------------|
| Random sequence generation (selection bias) | Low risk           | The randomisation code was generated using MATEX, a program developed for use in SAS (Cary, NC, USA), by GSK Vaccines, Belgium. |
| Allocation concealment (selection bias)   | Low risk           | Quote: "Treatment allocation at the investigator site was performed using a centralized internet-based randomisation system" |
| Blinding of participants and personnel (performance bias) | Low risk           | The study was conducted in an observer-blind manner (i.e. vaccines were prepared and administered by qualified medical personnel not otherwise involved in the conduct of this study). Personnel involved in subject evaluation and subjects themselves were blinded to group assignments. Girls in the 2-dose groups received control Al(OH)$_3$ at month 2 to maintain observer blinding. |
| Blinding of outcome assessment (detection bias) | Low risk           | Personnel involved in subject evaluation, and subjects themselves, were blinded to group assignments. |
| Incomplete outcome data (attrition bias)  | Low risk           | Data appeared to be reported adequately, including reasons for withdrawals.             |
| Selective reporting (reporting bias)      | Low risk           | No reason to suspect that reporting was selective. Clinical trial registry checked.   |
| Other bias                                | Unclear risk       | Trial funded by vaccine manufacturer.                                                 |
**Levin 2010**

**Methods**
Randomised, double-blind, placebo-controlled trial

**Participants**
Participants: 126 children with HIV infection (96 received quadrivalent HPV vaccine and 30 received control) from the USA and Puerto Rico
Age range: children 7-12 years old
Inclusion criteria: CD4% ≥15; at least 3 months of HAART was required for subjects with a CD4% < 25.

**Interventions**
Vaccine: quadrivalent HPV vaccine; 3 doses: day 1, month 2, month 6
Control: 'identical placebo' (contents of placebo were not specified (e.g. whether it was aluminium adjuvant or saline)); 3 doses: day 1, month 2, month 6

**Outcomes**
Harms: adverse events
Immunological: GMT, seroconversion

**Notes**
Other groups: N/A
Last report average follow-up time: 4-5 years
Funding: overall support for the International Maternal Pediatric Adolescent AIDS Clinical Trials Group (IMPAACT) was provided by the National Institute of Allergy and Infectious Diseases (NIAID), the Eunice Kennedy Shriver National Institute of Child Health and Human Development (NICHD), and the National Institute of Mental Health (NIMH)
Trial ID: NCT01206556

**Risk of bias**

| Bias                                      | Authors' judgement | Support for judgement                                                                 |
|-------------------------------------------|--------------------|---------------------------------------------------------------------------------------|
| Random sequence generation (selection bias) | Unclear risk       | Quote: "randomly assigned"                                                             |
| Allocation concealment (selection bias)   | Unclear risk       | No statement provided about allocation concealment.                                    |
| Blinding of participants and personnel (performance bias) All outcomes | Unclear risk | No detailed statement provided about how blinding was maintained or who was blinded. |
| Blinding of outcome assessment (detection bias) All outcomes | Unclear risk | No detailed statement provided about how blinding was maintained or who was blinded. |
| Incomplete outcome data (attrition bias) All outcomes | Low risk | Data were provided for the total vaccinated cohort (100% of enrolled participants), together with full information about reasons for exclusions and withdrawals from follow-up. |
| Selective reporting (reporting bias)      | Low risk           | No reason to suspect that reporting was selective. Clinical trial record checked.      |
| Other bias                                | Low risk           | No other bias apparent.                                                                |
Lin 2014

| Methods                          | Open-label, parallel, randomised trial |
|----------------------------------|----------------------------------------|
| Participants                     | Participants: 220 males (111 to the alternate schedule and 109 to the standard schedule) recruited from the USA |
|                                  | Age range: 18-25 years old             |
|                                  | Inclusion criteria: males 18-25 years with 4 or fewer lifetime sexual partners |
| Interventions                    | Vaccine 1: standard schedule quadrivalent HPV vaccine; 3 doses at 0, 2, and 6 months |
|                                  | Vaccine 2: alternate schedule quadrivalent HPV vaccine; 3 doses at 0, 2 and 12 months |
| Outcomes                         | Harms: compliance with third dose, adverse events |
|                                  | Immunogenicity: GMT                    |
| Notes                            | Other groups: N/A                      |
|                                  | Last report average follow-up time: month 7 or 13 (depending on group) |
|                                  | Funding: the authors and this work were supported in part by a research grant from the Investigator-Initiated Studies Program of Merck & Co, Inc, manufacturer of Gardasil® quadrivalent human papillomavirus vaccine. |
|                                  | Trial ID: NCT01184079                  |

**Risk of bias**

| Bias                                      | Authors' judgement | Support for judgement                                                                 |
|-------------------------------------------|--------------------|----------------------------------------------------------------------------------------|
| Random sequence generation (selection bias) | Low risk           | Quote: "Participants were randomised as they were scheduled for the initial visit using a simple random number sequence to determine the order of assignment into the Standard schedule or the Alternate schedule" |
| Allocation concealment (selection bias)   | Unclear risk       | Not described                                                                           |
| Blinding of participants and personnel (performance bias) | High risk          | Open label; "Participants were aware of their group assignment"                        |
| Blinding of outcome assessment (detection bias) | Unclear risk       | Not described                                                                           |
| Incomplete outcome data (attrition bias) | Low risk           | Quote: "Out of 220 participants enrolled, 204 completed the study"                     |
|                                            |                    | Reasons for withdrawal and protocol violation fully reported. Results for both ITT and per protocol populations reported. |
| Selective reporting (reporting bias)      | Low risk           | No reason to suspect that reporting was selective - clinical trial registry checked     |
| Other bias                                | Unclear risk       | Trial funded by vaccine manufacturer                                                   |
NCT00941889 2016

Methods
Double blind, controlled, randomised, single-centre trial

Participants
Participants: 32 HIV-positive males and females with anal warts (15 to the vaccine group and 17 to the control group) recruited from the USA

Age range: 18 to 65 years old

Inclusion criteria: HIV positive, ≥ 18 years of age, CD4 > 200 and viral RNA < 400 on HAART or CD4 > 350 if not on HAART, presence of anal warts that required surgical excision or ablation

Interventions
Vaccine: quadrivalent HPV vaccine; 3 doses at 0, 2, and 6 months

Control: saline placebo; 3 doses at 0, 2 and 6 months

Outcomes
Clinical: persistence and recurrence of anal warts

Notes
Other groups: N/A

Last report average follow-up time: month 18

Funding: Washington University School of Medicine

Trial ID: NCT00941889

Risk of bias

| Bias                                      | Authors' judgement | Support for judgement                                                                 |
|-------------------------------------------|--------------------|---------------------------------------------------------------------------------------|
| Random sequence generation (selection bias) | Unclear risk       | The online clinical trials record states "Randomized", but details about how randomisation was achieved were not reported. |
| Allocation concealment (selection bias)   | Unclear risk       | Details of allocation concealment were not reported.                                    |
| Blinding of participants and personnel (performance bias) All outcomes | Unclear risk       | The online clinical trials record states "Masking: Double (Participant, Investigator)", but details about how blinding was achieved were not reported. |
| Blinding of outcome assessment (detection bias) All outcomes | Unclear risk       | The online clinical trials record states "Masking: Double (Participant, Investigator)", but details about how blinding was achieved were not reported. |
| Incomplete outcome data (attrition bias) All outcomes | High risk          | Data for 62.5% (20/32) of the participants enrolled were missing due to withdrawal from the study, the online trial record states "No outcomes data were collected or analysed due to lack of participant follow-up" |
| Selective reporting (reporting bias)       | High risk          | The study did not report on adverse events and the online trial record states "No outcomes data were collected or analysed due to lack of participant follow-up" |
| Other bias                                | Unclear risk       | No published report was identified for this study, data were extracted from the clinical trials record which had insufficient information to establish whether there was a risk of other bias. |
### NCT01031069 2017

**Methods**  
Phase IV, observer-blind, randomised, controlled, multi-centric study

**Participants**  
Participants: 649 HIV seropositive and seronegative females aged 15-25 years (331 to the bivalent vaccine group and 330 to the quadrivalent vaccine group) recruited from Brazil, Estonia, India, and Thailand  
Age range: 15-25 years  
Inclusion criteria: female 15-25 years old, HIV voluntary counselling and testing

**Interventions**  
Vaccine 1: bivalent HPV vaccine; 3 doses at day 0, week 6, and month 6  
Vaccine 2: quadrivalent HPV vaccine; 3 doses at day 0, week 6, and month 6

**Outcomes**  
Harms: adverse events  
Immunogenicity

**Notes**  
Other groups: N/A  
Last report average follow-up time: month 7  
Funding: GlaxoSmithKline  
Trial ID: NCT01031069

### Risk of bias

| Bias                                      | Authors' judgement | Support for judgement                                                                 |
|-------------------------------------------|--------------------|---------------------------------------------------------------------------------------|
| Random sequence generation (selection bias) | Unclear risk       | The online clinical trials record and clinical trial result summary state "Randomized", but details about how randomisation was achieved were not reported. |
| Allocation concealment (selection bias)   | Unclear risk       | Details of allocation concealment were not reported                                   |
| Blinding of participants and personnel (performance bias) | Unclear risk       | The online clinical trials record states "Triple (Participant, Investigator, Outcomes Assessor)", but details about how blinding was achieved were not reported. |
| Blinding of outcome assessment (detection bias) | Unclear risk       | The online clinical trials record states "Triple (Participant, Investigator, Outcomes Assessor)", but details about how blinding was achieved were not reported. |
| Incomplete outcome data (attrition bias)  | Low risk           | Data were provided for the total vaccinated cohort (100% of enrolled participants), together with full information about reasons for exclusions and withdrawals from follow-up. |
| Selective reporting (reporting bias)      | High risk          | Not all outcomes listed in the online trial registration were reported in the trial result summary report. |
| Other bias                                | Unclear risk       | No published report was identified for this study; data were extracted from the clinical trials results summary on the manufacturer’s web site (https://www.gsk-clinicalstudyregister.com/) which had insufficient information to establish whether there was a risk of other bias. |
### Methods
Phase 3, parallel, randomised, controlled trial

### Participants
Participants: 1124 boys and men (562 received vaccine, 562 received placebo) recruited from Japan
Age range: 16-26 years
Inclusion criteria: Japanese males with no clinical evidence of sexually transmitted disease and no clinically present external genital warts

### Interventions
Vaccine: quadrivalent HPV vaccine; 3 doses at day 1, month 2, month 6
Control: aluminium adjuvant placebo (placebo formulated with aluminium hydroxyphosphate sulfate adjuvant); 3 doses at day 1, month 2, month 6

### Outcomes
Incidence of persistent HPV-6/11/16/18 infection or disease
Adverse events

### Notes
Other groups: N/A
Last report average follow-up time: month 36
Funding: Merck Sharp & Dohme Corp
Trial ID: NCT01862874

### Risk of bias

| Bias | Authors' judgement | Support for judgement |
|------|--------------------|-----------------------|
| Random sequence generation (selection bias) | Unclear risk | The online clinical trials record and clinical trial result summary state "Randomized", details about how randomisation was achieved were not reported. |
| Allocation concealment (selection bias) | Unclear risk | Details of allocation concealment were not reported. |
| Blinding of participants and personnel (performance bias) | Unclear risk | The clinical trial record states "masking: triple (participant, investigator, outcomes assessor" but no other details were provided. |
| Blinding of outcome assessment (detection bias) | Unclear risk | The clinical trial record states "masking: triple (participant, investigator, outcomes assessor" but no other details were provided. |
| Incomplete outcome data (attrition bias) | Low risk | Reasons for withdrawals were reported and balanced between groups. |
| Selective reporting (reporting bias) | High risk | HPV disease (HPV Type 6, 11, 16, or 18-related condyloma acuminata, penile, perianal, or perineal intraepithelial neoplasia or cancer) was not reported separately; persistent HPV infection and HPV disease were reported as a combined outcome. |
| Other bias | Unclear risk | No published report was identified for this trial. Trial funded by vaccine manufacturer. |
Methods
Phase I/II, observer-blind, parallel-group, randomised study

Participants
Participants: 270 boys (181 received bivalent HPV vaccine and 89 received hepatitis B vaccine) recruited from 7 study sites in Finland
Age range: 10-18 years old
Inclusion criteria: boys free of obvious health problems as established by medical history and clinical examination before entering into the study

Interventions
Vaccine: bivalent HPV vaccine; 3 doses: day 1, month 1, month 6
Control: hepatitis B active control vaccine; 3 doses: day 1, month 1, month 6

Outcomes
Harms: adverse events, deaths
Immunogenicity: GMT, seroconversion

Notes
Other groups: N/A
Last report average follow-up time: 12 months
Funding: GlaxoSmithKline
Trial ID: NCT00309166

Risk of bias

| Bias                                | Authors' judgement | Support for judgement |
|-------------------------------------|--------------------|-----------------------|
| Random sequence generation (selection bias) | Low risk           | Randomisation list generated at GlaxoSmithKline Biologicals (Rixensart, Belgium) using a standard SAS program (SAS Institute, Cary, NC). |
| Allocation concealment (selection bias) | Low risk           | Participants were assigned a vaccine treatment number; blinding was maintained to the individual treatment allocated. |
| Blinding of participants and personnel (performance bias) All outcomes | Low risk           | Participants were assigned a vaccine treatment number; blinding was maintained to the individual treatment allocated. All study personnel were blinded to the vaccines used, except the study nurse administering the vaccines. |
| Blinding of outcome assessment (detection bias) All outcomes | Low risk           | Participants were assigned a vaccine treatment number; blinding was maintained to the individual treatment allocated. All study personnel were blinded to the vaccines used, except the study nurse administering the vaccines. |
| Incomplete outcome data (attrition bias) All outcomes | Low risk           | Data for all participants enrolled were reported for adverse events. Reasons for exclusion from immunogenicity analysis was provided. |
| Selective reporting (reporting bias) | Low risk           | All relevant outcomes were reported in clinical trials record and clinical study report. |
| Other bias                          | Unclear risk       | No report of industry funding in publication, though the study report is available on GSK web site. |
### Methods
Phase III, open-label, controlled, randomised, multi-centre trial

### Participants
Participants: 1447 participants (482 women to the 3-dose schedule (months 0, 1, 6); 550 girls to the 2-dose schedule (months 0 and 6); 415 girls to the 2-dose schedule (0 and 12 months)) recruited from Canada, Germany, Italy, Taiwan, and Thailand

Age range: girls 9-14 years old and women 15-25 years old

Inclusion criteria: women of childbearing age required to be abstinent or use adequate contraceptive precautions for 30 days before first vaccination and agree to continue such precautions for 2 months after the last vaccine dose

### Interventions
Vaccine 1: bivalent HPV vaccine; 2 doses: month 0 and month 6
Vaccine 2: bivalent HPV vaccine; 2 doses: month 0 and month 12

### Outcomes
Harms: adverse events, deaths
Immunogenicity: GMT, seroconversion

### Notes
Other groups: 482 women aged 15-25 years received 3 doses bivalent HPV vaccine, data not extracted
Last report average follow-up time: 13 months, study ongoing
Funding: GlaxoSmithKline Biologicals SA. GlaxoSmithKline Biologicals designed the study in collaboration with investigators and co-ordinated gathering, analysis, and interpretation of data and writing of the report.

Trial ID: NCT01381575

### Risk of bias

| Bias                                           | Authors' judgement | Support for judgement |
|------------------------------------------------|--------------------|-----------------------|
| Random sequence generation (selection bias)    | Low risk           | The randomisation list was generated by GSK Vaccines using a standard SAS program. A randomisation blocking scheme (1:1 ratio) ensured that balance between the two 2-dose schedules was maintained. Treatment allocation at each site used a central randomisation system on the Internet. |
| Allocation concealment (selection bias)        | Low risk           | Treatment allocation at each site used a central randomisation system on the Internet. |
| Blinding of participants and personnel (performance bias) | High risk | Investigators and participants were not blinded to group assignment. Girls aged 9–14 years were randomised (1:1) to receive 2-dose schedule (months 0, and 6 or months 0, and 12) and women aged 15–25 years were allocated to receive 3-dose schedule (months 0, 1, and 6). |
| Blinding of outcome assessment (detection bias) | High risk          | Investigators and participants were not blinded to group assignment. |
| Incomplete outcome data (attrition bias)       | Low risk           | Data reported adequately in published report, with extra data published in Supplementary materials online. |
| Selective reporting (reporting bias)           | Low risk           | No reason to suspect that reporting was selective. Clinical trial registry checked. |
| Other bias                                     | Unclear risk       | Trial funded by vaccine manufacturer. |
### Methods

Phase I/II, partially blind, controlled, age-stratified, randomised and multi-centre trial

### Participants

#### Participants: 960 girls and women (240 in 2-dose schedule 20 μg dose (months 0 and 6); 241 in 2-dose schedule 40 μg dose (months 0 and 6); 240 in 2-dose schedule 40 μg dose (months 0 and 2); 239 in 3-dose schedule 20 μg dose (months 0, 1, and 6)) recruited from Canada and Germany

- **Age range:** girls and young women aged 9-25 years at the time of first vaccination
- **Inclusion criteria:** participants with childbearing potential had to use adequate contraception for 30 days prior to vaccination, have a negative pregnancy test, and continue contraceptive precautions for 2 months after completion of the vaccination series

### Interventions

- **Vaccine 1:** bivalent HPV vaccine; 20 μg dose; 3 doses: day 1, month 1, month 6
- **Vaccine 2:** bivalent HPV vaccine; 20 μg dose; 2 doses: day 1, month 6
- **Vaccine 3:** bivalent HPV vaccine; 40 μg dose; 2 doses: day 1, month 6
- **Vaccine 4:** bivalent HPV vaccine; 40 μg dose; 2 doses: day 1, month 2

In the 2-dose schedule groups, an aluminium adjuvant placebo was administered at month 2 (Groups 20 μg dose (months 0 and 6) and 40 μg dose (months 0 and 6)) or at month 6 (Group 40 μg dose months 0 and 2) to maintain blinding.

### Outcomes

- **Harms:** adverse events, deaths
- **Immunogenicity:** GMT, seroconversion

### Notes

- **Other groups:** N/A
- **Last report average follow-up time:** up to month 60
- **Funding:** GlaxoSmithKline Biologicals

### Trial ID

- **NCT00541970**

### Risk of bias

| Bias                                          | Authors' judgement | Support for judgement                                                                 |
|-----------------------------------------------|--------------------|---------------------------------------------------------------------------------------|
| Random sequence generation (selection bias)   | Low risk           | The randomisation list was computer-generated at GlaxoSmithKline Biologicals.         |
| Allocation concealment (selection bias)       | Low risk           | Treatment allocation at the investigator site was performed using a central randomisation call-in system on the internet; the randomisation algorithm used a minimisation procedure accounting for centre and age (9–14, 15–19 and 20–25 years). |
| Blinding of participants and personnel (performance bias) | Unclear risk | The trial was partially blinded within the 2-dose schedule groups (observers were blinded to group assignment) and open in the 3-dose schedule group. In the 2-dose schedule groups, a placebo was administered at month 2 (Groups 20 μg dose (months 0 and 6) and 40 μg dose (months 0 and 6)) or at month 6 (Group 40 μg dose (months 0 and 2) to maintain blinding. |
| Blinding of outcome assessment (detection bias) | Low risk           | The trial was partially blinded within the 2-dose schedule groups (observers were blinded to group assignment). |
Romanowskii 2011 (Continued)

| Incomplete outcome data (attrition bias) | Low risk | Data appeared to be reported adequately, and included reasons for withdrawals. |
|----------------------------------------|----------|------------------------------------------------------------------------------|
| All outcomes                           |          |                                                                              |

| Selective reporting (reporting bias)   | Low risk | No reason to suspect that reporting was selective. Clinical trial registry checked. |
|----------------------------------------|----------|------------------------------------------------------------------------------|
|                                        |          |                                                                              |

| Other bias                             | Unclear risk | Trial funded by vaccine manufacturer. |
|----------------------------------------|--------------|-------------------------------------|
|                                        |              |                                     |

Toft 2014

| Methods                                | Randomised, double-blind, head-to-head trial |
|----------------------------------------|---------------------------------------------|
| Participants                           | Participants: 92 male and female HIV-positive participants (46 to 3-dose bivalent vaccine and 46 to 3-dose quadrivalent vaccine) recruited from outpatient clinic in Denmark. |
|                                        | Age range: at least 18 years old           |
|                                        | Inclusion criteria: consenting HIV-seropositive volunteers at least 18 years old |
| Interventions                          | Vaccine 1: bivalent HPV vaccine; 3 doses: day 1, month 1.5, month 6 |
|                                        | Vaccine 2: quadrivalent HPV vaccine; 3 doses: day 1, month 1.5, month 6 |
| Outcomes                               | Harms: adverse events                     |
|                                        | Immunogenicity: GMT, seroconversion        |
| Notes                                  | Other groups: N/A                          |
|                                        | Last report average follow-up time: 6 months |
|                                        | Funding: Aarhus University, Henrik Henriksen’s Foundation, The Hede Nielsen Family Foundation, Aase and Ejnar Danielsen’s Foundation, Jørgen Holm and Wife’s Foundation, Lykfeldt and Wife’s Foundation, and the Danish Medical Association |
|                                        | Trial ID: NCT01386146                      |

Risk of bias

| Bias                                      | Authors’ judgement | Support for judgement                                                                 |
|-------------------------------------------|--------------------|----------------------------------------------------------------------------------------|
| Random sequence generation (selection bias) | Low risk           | Random allocation sequences were computer generated by the hospital pharmacy. Participants were assigned their study identification number according to the chronological order in which they were enrolled. Participants and investigators were masked to the assigned vaccine throughout the study. |
| Allocation concealment (selection bias)   | Low risk           | Random allocation sequences were computer generated by the hospital pharmacy. Participants were assigned their study identification number according to the chronological order in which they were enrolled. Participants and investigators were masked to the assigned vaccine throughout the study. |
| Blinding of participants and personnel (performance bias) | Low risk | Participants and investigators were masked to the assigned vaccine throughout the study. |
van Damme 2016

Methods Phase III, double-blind, controlled, randomised and multicenter trial

Participants Participants: 500 males (249 to the nonavalent HPV vaccine arm, 251 to the quadrivalent HPV vaccine arm) recruited from Belgium, Germany, and the Netherlands

Age range: 16-26 years

Inclusion criteria: good physical health, no more than 5 lifetime female and no male sexual partners

Interventions Vaccine 1: nonavalent HPV vaccine; 3 doses: day 1, month 2, and month 6

Vaccine 2: quadrivalent HPV vaccine; 3 doses: day 1, month 2, and month 6

Outcomes Harms: adverse events, deaths

Immunogenicity: GMT, seroconversion

Notes Other groups: N/A

Last report average follow-up time: 7 months

Funding: Sanofi Pasteur MSD provided financial support for the conduct of the research and preparation of the article and were involved in the study design, in the collection, analysis and interpretation of data and in the writing of the trial report.

Trial ID: NCT02114385

Risk of bias

| Bias                              | Authors' judgement | Support for judgement |
|-----------------------------------|--------------------|-----------------------|
| Random sequence generation (selection bias) | Low risk           | Quote: "An interactive Web Response System (IWRS) was used to allocate participants to 9vHPV or qHPV vaccine in a blinded manner. The system assigned an allocation number from a randomised, age-stratified (16-17 years and 18-26 years) allocation schedule." |
| Allocation concealment (selection bias) | Low risk           | Quote: "An interactive Web Response System (IWRS) was used to allocate participants to 9vHPV or qHPV vaccine in a blinded manner. The system assigned an allocation number from a randomised, age-stratified (16-17 years and 18-26 years) allocation schedule." |
### van Damme 2016 (Continued)

| Bias                        | Authors' judgement | Support for judgement |
|-----------------------------|--------------------|-----------------------|
| Blinding of participants and personnel (performance bias) | Low risk | Participants and personnel were blinded: "Masking: Quadruple (Participant, Care Provider, Investigator, Outcomes Assessor)" "We conducted a double-blind, randomised controlled with qHPV vaccine, immunogenicity and safety of the 9vHPV vaccine in young men aged 16-26 years of age." |
| Blinding of outcome assessment (detection bias) | Low risk | Outcome assessors were blinded: "Masking: Quadruple (Participant, Care Provider, Investigator, Outcomes Assessor)" |
| Incomplete outcome data (attrition bias) | Low risk | Fig 1 shows 97.8% completed. |
| Selective reporting (reporting bias) | Low risk | No reason to suspect that reporting was selective - clinical trial record checked and all immunogenicity outcomes reported. |
| Other bias | Unclear risk | Trial funded by vaccine manufacturer. |

### Vesikari 2015

**Methods**
Phase III, double-blind, controlled, randomised and multi-centre trial

**Participants**
Participants: 600 girls (300 in the nonavalent HPV vaccine arm, 300 in the quadrivalent HPV vaccine arm), recruited from Belgium, Denmark, Finland, Italy, Spain, and Sweden
Age range: 9-15 years old
Inclusion criteria: girls aged ≥ 9 to < 16 years at enrolment, in good physical health, who were virgins and who were not planning to become sexually active before month 7 of the study.

**Interventions**
Vaccine 1: nonavalent HPV vaccine; 3 doses: day 1, month 2, month 6
Vaccine 2: quadrivalent HPV vaccine; 3 doses: day 1, month 2, month 6

**Outcomes**
Harms: adverse events, deaths
Immunogenicity: GMT, seroconversion

**Notes**
Other groups: N/A
Last report average follow-up time: 7 months
Funding: Sanofi Pasteur MSD
Trial ID: NCT01304498

### Risk of bias

| Bias                        | Authors' judgement | Support for judgement |
|-----------------------------|--------------------|-----------------------|
| Random sequence generation (selection bias) | Low risk | A central randomisation system, which used an interactive web response system, assigned participants to a vaccine group (blinded) and an allocation number according to the randomised allocation schedules. |
Methods

Participants
Participants: 575 HIV-positive males and females (288 to the vaccine group and 287 to the control group) recruited from the USA, Brazil, and Puerto Rico

Age range: at least 27 years old

Inclusion criteria: HIV-1 infection, laboratory values and anal cytology result obtained within 45 days prior to entry

Interventions
Vaccine: quadrivalent HPV vaccine; 3 doses at 0, 8, and 24 weeks
Control: 'placebo vaccine' (contents of placebo vaccine were not specified (e.g. whether it was aluminium adjuvant-containing or saline)); 3 doses at 0, 8, and 24 weeks

Outcomes
Clinical: anal intraepithelial neoplasia, persistent infection
Harms: adverse events

Notes
Other groups: N/A
Last report average follow-up time: 4 years
Funding: National Institute of Allergy and Infectious Diseases
Trial ID: NCT01461096

Risk of bias

Bias Authors' judgement Support for judgement
Wilkin 2018 (Continued)

Random sequence generation (selection bias) | Unclear risk | Quote: "Permutated-block randomisation was balanced by site and stratified by sex and presence of bHSIL at study screening.", details on how randomisation sequence was generated was not fully reported

Allocation concealment (selection bias) | Low risk | Central allocation: "The treatment assignment was provided electronically to local study pharmacists who prepared identical prefilled vaccine syringes."

Blinding of participants and personnel (performance bias) | Unclear risk | Quote: ""Investigators, participants, and study staff were masked to treatment allocation.", details about how blinding was achieved were not reported

Blinding of outcome assessment (detection bias) | Unclear risk | Quote: ""Investigators, participants, and study staff were masked to treatment allocation.", details about how blinding was achieved were not reported

Incomplete outcome data (attrition bias) | Low risk | Data were provided for 99% (569/575) participants; full information about reasons for exclusions and withdrawals were provided.

Selective reporting (reporting bias) | Low risk | All outcomes listed in online trial registration were reported.

Other bias | Low risk | No other bias apparent.

Abbreviations

AAHS: amorphous aluminium hydroxy-phosphate sulphate
CD4%: percentage of white blood cells that are CD4 cells
GMT: geometric mean titre
HAART: highly active antiretroviral therapy
HPV: human papillomavirus
ITT: intention-to-treat
qHPV: quadrivalent human papillomavirus vaccine
9vHPV: nonavalent human papillomavirus vaccine

Characteristics of excluded studies [ordered by study ID]

| Study          | Reason for exclusion                                                                 |
|----------------|--------------------------------------------------------------------------------------|
| Beachler 2016  | No relevant comparison, does not meet protocol: bivalent HPV vs hepatitis A vaccine (control) in women (NCT00128661) |
| Bhatia 2016    | No relevant comparison, does not meet protocol: observational study of vaccinated vs unvaccinated females |
| Bianchi 2016   | No relevant comparison, does not meet protocol: observational study of vaccinated vs unvaccinated females |
| Brown 2012     | No relevant comparison, does not meet protocol: 3 doses vs 3 doses comparing intervals in females (NCT00925288) |
| Canfell 2017   | Not a relevant population: women 25-64 years (ACTRN12613001207707) |
| Carozzi 2016   | No relevant comparison, does not meet protocol: vaccinated vs unvaccinated females (NCT02296255) |
| Study          | Reason for exclusion                                                                                                                                 |
|---------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|
| Choudhury 2016| No relevant comparison, does not meet protocol: observational study of vaccinated vs unvaccinated in HIV+ females, none of the HIV+ population was vaccinated |
| Esposito 2011 | No relevant comparison, does not meet protocol: 3 doses vs 3 doses comparing intervals in females (NCT00552279)                                      |
| Flagg 2018    | No relevant comparison, does not meet protocol: observational study of anogenital warts prevalence before and after national HPV vaccination introduction for females, males were not vaccinated |
| Garland 2016  | No relevant comparison, does not meet protocol: vaccinated versus unvaccinated females (NCT00122681 PATRICIA)                                           |
| Gilca 2015    | No relevant comparison, does not meet protocol: booster dose given to girls who had already received 2 doses of vaccine (NCT01456715)                  |
| Hamsikova 2017| No relevant comparison, does not meet protocol: observational study of bivalent versus quadrivalent HPV vaccines                                     |
| Harari 2016   | No relevant comparison, does not meet protocol: HPV vaccine vs hepatitis A vaccine (control) in females (NCT00128661)                                  |
| Haskins-Coulter 2017 | No relevant comparison, does not meet protocol: 3-dose bivalent vaccine vs 3-dose quadrivalent vaccine in young females (NCT00956553) |
| Lamontagne 2013| No relevant comparison, does not meet protocol: 3 doses vs 3 doses comparing intervals in females (NCT00524745)                                      |
| Lehtinen 2017 | No relevant comparison, does not meet protocol: long-term follow-up of vaccinated versus unvaccinated females combining arms from 3 RCTs (NCT01393470 (unvaccinated arm); NCT00122681 (PATRICIA vaccinated arm); NCT00169494 (HPV-012 vaccinated arm)) |
| Luxembourg 2017| No relevant comparison, does not meet protocol: vaccinated versus unvaccinated females (protocol) (V503-021, NCT02653118)                              |
| Money 2016    | No relevant comparison, does not meet protocol: single arm HIV+ cohort (ISRCTN33674451)                                                              |
| Neuzil 2011   | No relevant comparison, does not meet protocol: 3 doses vs 3 doses comparing intervals in adolescent girls (NCT00524745)                             |
| Wheeler 2016  | Not a relevant population: women 26 years and older, 7-year follow-up of VIVIANE study (NCT00294047)                                                  |
| Zhu 2017      | No relevant comparison, does not meet protocol: HPV vaccine versus aluminium hydroxide control in females (NCT00779766)                               |
| Zimmerman 2010| No relevant comparison, does not meet protocol: 3 doses vs 3 doses comparing intervals in females (NCT00572832)                                      |

**Abbreviations**

HIV+: HIV positive  
HPV: human papillomavirus  
RCT: randomised controlled trial
### Characteristics of studies awaiting assessment [ordered by study ID]

**Li 2012**

| Methods                     | Randomised, double-blind, placebo-controlled trial |
|-----------------------------|----------------------------------------------------|
| Participants                | Participants: 100 healthy Chinese males and 500 healthy Chinese females (302 received the quadrivalent vaccine and 298 received the control vaccine) from Wuzhou, Guangxi, China |
|                             | Age range: males aged 9–15 years and females aged 9–45 years |
|                             | Inclusion criteria: no history of severe allergic reaction or allergic reaction to any vaccine component and a lifetime number of no more than 4 sex partners. |
|                             | Exclusion criteria: pregnant post-pubertal females; history of an abnormal Papanicolaou test or biopsy showing cervical intraepithelial neoplasia (CIN) or worse |
| Interventions               | Vaccine: quadrivalent HPV vaccine (Gardasil/Silgard, Merck, Whitehouse Station, NJ) (3 doses: day 1, month 2, month 6) |
|                             | Control: adjuvant-containing placebo (3 doses: day 1, month 2, month 6) |
| Outcomes                    | Immunogenicity: GMTs, seroconversion |
|                             | Safety: adverse events, serious adverse events, death |
| Notes                       | Other groups: N/A |
|                             | Last report average follow-up time: 7 months |
|                             | Funding: Merck Sharp & Dohme Corp |
|                             | Trial ID: NCT01427777 |

**Reisinger 2007**

| Methods                     | Randomised, double-blind, placebo-controlled, multicenter study |
|-----------------------------|---------------------------------------------------------------|
| Participants                | Participants: 1781 boys and girls (1181 received the quadrivalent vaccine and 597 received the non-aluminium placebo) from 47 study sites located in 10 countries in North America, Latin America, Europe and Asia |
|                             | Age: 9-15 years old |
|                             | Inclusion criteria: healthy, sexually naive boys and girls |
| Interventions               | Vaccine: quadrivalent HPV-6/11/16/18 L1 VLP vaccine (GARDASIL/SILGARD, Merck and Co, Inc, Whitehouse Station, NJ) |
|                             | Control: placebo vaccine (identical components to those in the vaccine, with the exception of HPV L1 VLPs and aluminium adjuvant) |
| Outcomes                    | Immunogenicity: GMT, seroconversion |
|                             | Safety: adverse events, serious adverse events, death |
| Notes                       | Other groups: N/A |
|                             | Last report average follow-up time: 18 months |
|                             | Funding: Merck and Co, Inc |
### Characteristics of ongoing studies [ordered by study ID]

#### NCT01735006

| Trial name or title | Efficacy and immunogenicity study of recombinant human papillomavirus bivalent (genotype 16/18) vaccine |
|---------------------|---------------------------------------------------------------------------------------------------|
| Methods             | RCT                                                                                              |
| Participants        | Females 18-45 years Country: China                                                               |
| Interventions       | - HPV vaccine containing 40 µg HPV 16 virus-like particle antigen and 20 µg HPV 18 virus-like particle antigen adsorbed in alum-adjuvant  
                      | - Hepatitis E virus (HEV) vaccine contains 30 µg HEV antigen adsorbed in alum-adjuvant           |
| Outcomes            | Clinical outcomes, adverse events, immunogenicity                                                |
| Starting date       | November 2012                                                                                    |
| Contact information | Jun Zhang, Xiamen University; Youlin Qiao, Cancer Institute and Hospital, Chinese Academy of Medical Sciences; Ting Wu, Xiamen University |
| Notes               | Sponsors: Xiamen University; Xiamen Innovax Biotech Co, Ltd; Beijing Wantai Biological Pharmacy Enterprise Co, Ltd; Ministry of Science and Technology of the People’s Republic of China  
                      | Trial status in August 2018: active, not recruiting                                               |

#### NCT01824537

| Trial name or title | Transmission reduction and prevention with HPV vaccination (TRAP-HPV) study (TRAP-HPV) |
|---------------------|------------------------------------------------------------------------------------------------|
| Methods             | RCT                                                                                          |
| Participants        | 18-45 year-old couples, males and females Country: Canada                                    |
| Interventions       | - Nonavalent HPV vaccine (Gardasil 9, Merck)  
                      | - Hepatitis A virus vaccine (Havrix, Merck)                                                   |
| Outcomes            | HPV DNA positivity                                                                         |
| Starting date       | September 2013                                                                               |
| Contact information | Allita Rodrigues (allita.rodrigues@mcgill.ca); Anna Tzagourni (canepiadm.med@mcgill.ca)      |
| Notes               | Sponsors: McGill University                                                                   |
### NCT01824537 (Continued)

Trial status in August 2018: recruiting

### NCT02009800

| Trial name or title | ICI-VPH: Impact of HPV immunisation schedules against HPV (ICI-VPH) |
|---------------------|---------------------------------------------------------------------|
| Methods             | RCT                                                                 |
| Participants        | Females 14-16 years old                                             |
|                     | Country: Canada                                                      |
| Interventions       | • 2 doses quadrivalent HPV vaccine (Gardasil, Merck)                |
|                     | • 3 doses quadrivalent HPV vaccine (Gardasil, Merck)                |
| Outcomes            | Incidence of persistent HPV-16/18 infections; GMT of antibodies and seropositivity for HPV genotypes 6, 11, 16 and 18 |
| Starting date       | November 2013                                                       |
| Contact information | Chantal Sauvageau, CHU de Quebec-Universite Laval                   |
| Notes               | Sponsors: CHU de Quebec-Universite Laval; Centre hospitalier de l'Universite de Montréal; Quebec Public Health National Institute; Quebec Ministry of Health and Social Services |
|                     | Trial status in August 2018: active, not recruiting                 |

### NCT02087384

| Trial name or title | HPV (human papilloma virus) vaccination after treatment of anal intraepithelial neoplasia (AIN) (VACCAIN-P) |
|---------------------|----------------------------------------------------------------------------------------------------------|
| Methods             | RCT                                                                                                       |
| Participants        | HIV positive MSM ≥ 18 years old                                                                           |
|                     | Country: the Netherlands                                                                                   |
| Interventions       | • Quadrivalent HPV vaccine: intramuscular Gardasil vaccination at 0, 2 and 6 months                        |
|                     | • Control: intramuscular saline 0.9% vaccination at 0, 2 and 6 months                                      |
| Outcomes            | Recurrence of intra-anal or peri-anal high-grade AIN; toxicity/safety; Intra-anal or peri-anal low-grade AIN; anogenital warts; causative HPV genotype in recurrent AIN lesions; HPV genotype-specific antibody response |
| Starting date       | March 2014                                                                                                 |
| Contact information | Jan M Prins, Academisch Medisch Centrum, Universiteit van Amsterdam; Henry JC de Vries, Academisch Medisch Centrum, Universiteit van Amsterdam |
| Notes               | Sponsors: Prof Jan Prins                                                                                   |
|                     | Trial status in August 2018: active, not recruiting                                                       |
### NCT02405520

**Trial name or title**
Safety and immunogenicity study of the recombinant human papillomavirus virus type 6/11 bivalent vaccine

**Methods**
RCT

**Participants**
Males and females 18-55 years
Country: China

**Interventions**
- Low dosage HPV 6/11 bivalent vaccine at 0, 1, 6 month for 3 doses
- Medium dosage HPV 6/11 bivalent vaccine at 0, 1, 6 month for 3 doses
- High dosage HPV 6/11 bivalent vaccine at 0, 1, 6 month for 3 doses
- Aluminium adjuvant at 0, 1, 6 month for 3 doses

**Outcomes**
Adverse events; anti-HPV 6/11 antibody

**Starting date**
March 2015

**Contact information**
Jun Zhang, Xiamen University; Zhao-Jun Mo, Guangxi Center for Disease Prevention and Control; Ting Wu, Xiamen University

**Notes**
Sponsors: Jun Zhang; Xiamen Innova x Biotech Co, Ltd; Beijing Wantai Biological Pharmacy Enterprise Co, Ltd
Trial status in August 2018: active, not recruiting

### NCT02562508

**Trial name or title**
Immunogenicity and safety study of a bivalent human papillomavirus (type 16, 18) recombinant vaccine (E.coli) in healthy female subjects aged 9-17 years

**Methods**
RCT

**Participants**
Females 9-26 years
Country: China

**Interventions**
- 3 doses of HPV 16/18 bivalent vaccine
- 2 doses of HPV 16/18 bivalent vaccine

**Outcomes**
Adverse events and immunogenicity

**Starting date**
5 December 2015

**Contact information**
Ting Wu, Xiamen University; Yuemei Hu, Jiangsu Provincial Centre for Disease Control and Prevention

**Notes**
Sponsors: Jun Zhang; Xiamen Innova x Biotech Co, Ltd; Beijing Wantai Biological Pharmacy Enterprise Co, Ltd
Trial status in August 2018: completed in August 2016, we contacted study investigators but they had provided no data at the time of submitting this review for publication
### NCT02567955

**Trial name or title**
Immunogenicity and safety of Gardasil-9 and Cervarix

**Methods**
RCT

**Participants**
Boys and girls 9-10 years old
Country: Canada

**Interventions**
- Nonavalent HPV vaccine (Gardasil-9) (0.5 mL), 2 doses according to 0-6 month schedule
- 1 dose bivalent HPV vaccine (Cervarix) (0.5 mL) and 1 dose nonavalent HPV vaccine (Gardasil-9) (0.5 mL) according to 0-6 month schedule

**Outcomes**
Antibodies to 9 HPV genotypes included in the Gardasil-9 vaccine; tolerability profile

**Starting date**
September 2015

**Contact information**
Vladimir Gilca (vladimir.gilca@inspq.qc.ca); Chantal Sauvageau (CHANTAL.sauvageau@inspq.qc.ca)

**Notes**
Sponsors: Laval University
Trial status in August 2018: recruiting

### NCT02710851

**Trial name or title**
Immunogenicity study of the recombinant human papillomavirus virus type 6/11 bivalent vaccine

**Methods**
RCT

**Participants**
Males and females 18-55 years old
Country: China

**Interventions**
- Low dosage (1:1) bivalent HPV vaccine: virus-like particles genotype 6 and 11 at 1:1 ratio
- Low dosage (1:2) bivalent HPV vaccine: virus-like particles genotype 6 and 11 at 1:2 ratio
- High dosage (1:1) bivalent HPV vaccine: virus-like particles genotype 6 and 11 at 1:1 ratio
- Control: hepatitis E vaccine (Hecolin)

**Outcomes**
Anti-HPV 6 and anti-HPV 11 seroconversion rates; serious adverse events

**Starting date**
March 2016

**Contact information**
Jun Zhang, Xiamen University; Yuemei Hu, Jiangsu Center for Disease Prevention and Control

**Notes**
Sponsors: Jun Zhang; Xiamen Innovax Biotech Co., Ltd; Beijing Wantai Biological Pharmacy Enterprise Co, Ltd
Trial status in August 2018: active, not recruiting
### NCT02733068

| Trial name or title                                                                 | A phase III double blinded, randomized controlled study to evaluate efficacy of protection against HPV-16 and 18 related diseases, immunogenicity and safety of HPV-16/18 vaccine in healthy females aged 18-30 years |
|------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Methods                                                                            | RCT                                                                                                                                  |
| Participants                                                                      | Females aged 18-30 years                                                                                                              |
| Country: China                                                                     |                                                                                                                                     |
| Interventions                                                                      | • HPV-16/18 vaccine  
• placebo                                                                 |
| Outcomes                                                                           | Clinical outcomes, adverse events, immunogenicity                                                                                     |
| Starting date                                                                      | November 2014                                                                                                                         |
| Contact information                                                                 | Zhaojun Mo, Guangxi Center for Disease Prevention and Control                                                                             |
| Notes                                                                              | Sponsors: Shanghai Zerun Biotechnology Co, Ltd; Guangxi Center for Disease Control and Prevention  
Trial status in August 2018: active, not recruiting                                                                 |

### NCT02740777

| Trial name or title                                                                 | Immunogenicity study of a 2-dose immunization schedule of recombinant human papillomavirus virus-like particle vaccine (type 16 and 18 l1 proteins, yeast) in adolescent females aged 9 to 14 years |
|------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Methods                                                                            | RCT                                                                                                                                  |
| Participants                                                                      | Females aged 9-14 years                                                                                                              |
| Country: China                                                                     |                                                                                                                                     |
| Interventions                                                                      | HPV-16/18 vaccine (2 doses)  
HPV-16/18 vaccine (3 doses)                                                                 |
| Outcomes                                                                           | Adverse events and immunogenicity                                                                                                     |
| Starting date                                                                      | February 2016                                                                                                                         |
| Contact information                                                                 | Zhaojun Mo, Guangxi Center for Disease Prevention and Control                                                                             |
| Notes                                                                              | Sponsors: Shanghai Zerun Biotechnology Co, Ltd; Guangxi Center for Disease Control and Prevention  
Trial status in August 2018: recruiting                                                                 |
### NCT02750202

**Trial name or title**
Effectiveness study of human papilloma virus (HPV) vaccines to prevent recurrence of genital warts (TheraVACCs)

**Methods**
RCT

**Participants**
Females ≤ 16 years with vulval vaginal genital warts

**Interventions**
- Quadrivalent HPV vaccine (Gardasil) doses administered intramuscular as 3 separate 0.5 mL doses at month 0, month 2 and month 6
- Control: hepatitis B vaccine doses administered intramuscular as 3 separate 0.5 mL doses at month 0, month 2 and month 6

**Outcomes**
Change in size of genital wart lesion; surgical treatment of warts; surgical treatment of cervical disease; immunogenicity; HIV status

**Starting date**
July 2016

**Contact information**
Greta G Dreyer (Greta.Dreyer@up.ac.za); Cathy Visser (visser.cathy@gmail.com)

**Notes**
Sponsors: University of Pretoria; University of Stellenbosch

Trial status in August 2018: not yet recruiting

### NCT02834637

**Trial name or title**
A dose reduction immunobridging and safety study of two HPV vaccines in Tanzanian girls

**Methods**
RCT

**Participants**
Females 9 -14 years

**Interventions**
- Bivalent HPV vaccine
- Nonavalent HPV vaccine

**Outcomes**
Adverse events and immunogenicity

**Starting date**
23 February 2017

**Contact information**
Deborah Watson-Jones, London School of Hygiene and Tropical Medicine

**Notes**
Sponsors: London School of Hygiene and Tropical Medicine; University of York; Catalan Institute of Oncology; National Cancer Institute (NCI); Karolinska Institutet; Technische Universität Berlin; Tanzanian National Institute for Medical Research; University of Glasgow

Trial status in August 2018: active, not recruiting
### NCT02888418

**Trial name or title**
Random, double blind, placebo controlled phase I clinical trials to estimate the safety and preliminary immunogenicity of tetravalent recombinant human papilloma virus vaccine (6,11,16,18 type) (Hansenula polymorpha) in women of 9-30 years old and men of 9-17 years old

**Methods**
RCT

**Participants**
Males 9-17 years old, females 9-30 years old
Country: China

**Interventions**
- Tetravalent recombinant human papillomavirus vaccine (6,11,16,18 type) (Hansenula polymorpha)
- Control vaccine

**Outcomes**
Adverse events and immunogenicity

**Starting date**
October 2016

**Contact information**
Beijing Chaoyang District Centre for Disease Control and Prevention

**Notes**
Sponsors: Beijing Chaoyang District Centre for Disease Control and Prevention
Trial status in August 2018: unknown, in August 2016 it was 'Not yet recruiting'

### NCT03180034

**Trial name or title**
A scientific evaluation of one or two doses of vaccine against human papillomavirus: the ESCUDO study

**Methods**
RCT

**Participants**
Females 12-16 years old
Country: Costa Rica

**Interventions**
- Cervarix, 1 dose
- Gardasil 9, 1 dose
- Cervarix, 2 doses
- Gardasil 9, 2 doses

**Outcomes**
Clinical outcomes, adverse events, immunogenicity

**Starting date**
26 June 2018

**Contact information**
Aimee R Kreimer (kreimera@mail.nih.gov), National Cancer Institute

**Notes**
Sponsors: National Cancer Institute; Bill and Melinda Gates Foundation
Trial status in August 2018: recruiting
### NCT03296397

#### Trial name or title
Efficacy of quadrivalent HPV vaccine to prevent relapses of genital warts after initial therapeutic response (CONDYVAC)

#### Methods
RCT

#### Participants
Males and females ≥ 18 years old, cured of genital warts
Country: France

#### Interventions
- Quadrivalent HPV vaccine (Gardasil)
- Saline placebo

#### Outcomes
Relapse free survival; Improvement of quality of life; adverse events

#### Starting date
November 2017

#### Contact information
Sebastien Fouere (sebastien.fouere@aphp.fr); Olivier Chosidow (olivier.chosidow@aphp.fr)

#### Notes
Sponsors: Assistance Publique - Hôpitaux de Paris
Trial status in August 2018: recruiting

### Abbreviations
AIN: anal intraepithelial neoplasia
HPV: human papillomavirus
MSM: men who have sex with men
RCT: randomised controlled trial

### DATA AND ANALYSES

#### Comparison 1. Two versus three doses of HPV vaccines in 9- to 15-year-old females

| Outcome or subgroup title | No. of studies | No. of participants | Statistical method | Effect size |
|---------------------------|----------------|---------------------|--------------------|-------------|
| 1 Pain at injection site  | 2              | 1189                | Risk Ratio (M-H, Random, 95% CI) | 0.96 [0.91, 1.03] |
| 1.1 Bivalent vaccine      | 1              | 476                 | Risk Ratio (M-H, Random, 95% CI) | 0.99 [0.94, 1.03] |
| 1.2 Quadrivalent vaccine  | 1              | 713                 | Risk Ratio (M-H, Random, 95% CI) | 0.93 [0.87, 1.00] |
| 2 Swelling at injection site | 2              | 1189                | Risk Ratio (M-H, Random, 95% CI) | 0.76 [0.65, 0.89] |
| 2.1 Bivalent vaccine      | 1              | 476                 | Risk Ratio (M-H, Random, 95% CI) | 0.70 [0.57, 0.87] |
| 2.2 Quadrivalent vaccine  | 1              | 713                 | Risk Ratio (M-H, Random, 95% CI) | 0.83 [0.66, 1.04] |
| 3 Redness at injection site | 2              | 1189                | Risk Ratio (M-H, Random, 95% CI) | 0.85 [0.75, 0.96] |
| 3.1 Bivalent vaccine      | 1              | 476                 | Risk Ratio (M-H, Random, 95% CI) | 0.85 [0.72, 0.99] |
| 3.2 Quadrivalent vaccine  | 1              | 713                 | Risk Ratio (M-H, Random, 95% CI) | 0.85 [0.71, 1.02] |
| Outcome or subgroup title | No. of studies | No. of participants | Statistical method | Effect size |
|---------------------------|----------------|---------------------|--------------------|-------------|
| 4 Serious adverse events (overall) | 4 | 2317 | Odds Ratio (M-H, Random, 95% CI) | 1.03 [0.64, 1.66] |
| 4.1 Bivalent vaccine | 1 | 479 | Odds Ratio (M-H, Random, 95% CI) | 1.28 [0.64, 2.59] |
| 4.2 Quadrivalent vaccine | 2 | 1236 | Odds Ratio (M-H, Random, 95% CI) | 0.78 [0.35, 1.74] |
| 4.3 Nonavalent vaccine | 1 | 602 | Odds Ratio (M-H, Random, 95% CI) | 1.0 [0.32, 3.14] |
| 5 Deaths | 3 | 1797 | Odds Ratio (M-H, Random, 95% CI) | 0.33 [0.01, 8.19] |
| 5.1 Bivalent vaccine | 1 | 479 | Odds Ratio (M-H, Random, 95% CI) | 0.0 [0.0, 0.0] |
| 5.2 Quadrivalent vaccine | 1 | 716 | Odds Ratio (M-H, Random, 95% CI) | 0.0 [0.0, 0.0] |
| 5.3 Nonavalent vaccine | 1 | 602 | Odds Ratio (M-H, Random, 95% CI) | 0.33 [0.01, 8.19] |

### Analysis 1.1. Comparison 1 Two versus three doses of HPV vaccines in 9- to 15-year-old females, Outcome 1 Pain at injection site.

| Study or subgroup | 2 doses | 3 doses | Risk Ratio | Weight | Risk Ratio |
|-------------------|---------|---------|------------|--------|------------|
| **1.1.1 Bivalent vaccine** | | | | | |
| Romanowski 2011 | 222/238 | 225/238 | 59.84% | 0.99 [0.94, 1.03] |
| **Subtotal (95% CI)** | 238 | 238 | 59.84% | 0.99 [0.94, 1.03] |
| Total events: 222 (2 doses), 225 (3 doses) | | | | | |
| Heterogeneity: Not applicable | | | | | |
| Test for overall effect: Z=0.57 (P=0.57) | | | | | |

| **1.1.2 Quadrivalent vaccine** | | | | | |
| Leung 2015 | 276/357 | 295/356 | 40.16% | 0.93 [0.87, 1] |
| **Subtotal (95% CI)** | 357 | 356 | 40.16% | 0.93 [0.87, 1] |
| Total events: 276 (2 doses), 295 (3 doses) | | | | | |
| Heterogeneity: Not applicable | | | | | |
| Test for overall effect: Z=1.85 (P=0.06) | | | | | |

Total (95% CI) 595 594 100% 0.96 [0.91, 1.03]  

Total events: 498 (2 doses), 520 (3 doses)  
Heterogeneity: Tau²=0; Chi²=2.24, df=1 (P=0.13); I²=55.26%  
Test for overall effect: Z=1.11 (P=0.27)  
Test for subgroup differences: Chi²=1.61, df=1 (P=0.2), I²=37.77%  

Favours 2 doses 1 Favours 3 doses
### Analysis 1.2. Comparison 1 Two versus three doses of HPV vaccines in 9- to 15-year-old females, Outcome 2 Swelling at injection site.

| Study or subgroup | 2 doses n/N | 3 doses n/N | Risk Ratio M-H, Random, 95% CI | Weight | Risk Ratio M-H, Random, 95% CI |
|------------------|------------|------------|--------------------------------|--------|--------------------------------|
| **1.2.1 Bivalent vaccine** | | | | | |
| Romanowski 2011 | 83/238 | 118/238 | 51.77% | 0.7[0.57,0.87] | |
| Subtotal (95% CI) | 238 | 238 | 51.77% | 0.7[0.57,0.87] | |
| Total events: 83 (2 doses), 118 (3 doses) | | | | | |
| Heterogeneity: Not applicable | | | | | |
| Test for overall effect: Z=3.2(P=0) | | | | | |
| **1.2.2 Quadrivalent vaccine** | | | | | |
| Leung 2015 | 98/357 | 118/356 | 48.23% | 0.83[0.66,1.04] | |
| Subtotal (95% CI) | 357 | 356 | 48.23% | 0.83[0.66,1.04] | |
| Total events: 98 (2 doses), 118 (3 doses) | | | | | |
| Heterogeneity: Not applicable | | | | | |
| Test for overall effect: Z=1.65(P=0.1) | | | | | |
| Total (95% CI) | 595 | 594 | 100% | 0.76[0.65,0.89] | |
| Total events: 181 (2 doses), 236 (3 doses) | | | | | |
| Heterogeneity: Tau²=0; Chi²=1.07, df=1(P=0.3); I²=6.16% | | | | | |
| Test for overall effect: Z=3.34(P=0) | | | | | |
| Test for subgroup differences: Chi²=1.06, df=1 (P=0.3), I²=5.57% | | | | | |

### Analysis 1.3. Comparison 1 Two versus three doses of HPV vaccines in 9- to 15-year-old females, Outcome 3 Redness at injection site.

| Study or subgroup | 2 doses n/N | 3 doses n/N | Risk Ratio M-H, Random, 95% CI | Weight | Risk Ratio M-H, Random, 95% CI |
|------------------|------------|------------|--------------------------------|--------|--------------------------------|
| **1.3.1 Bivalent vaccine** | | | | | |
| Romanowski 2011 | 123/238 | 145/238 | 55.38% | 0.85[0.72,0.99] | |
| Subtotal (95% CI) | 238 | 238 | 55.38% | 0.85[0.72,0.99] | |
| Total events: 123 (2 doses), 145 (3 doses) | | | | | |
| Heterogeneity: Not applicable | | | | | |
| Test for overall effect: Z=2.02(P=0.04) | | | | | |
| **1.3.2 Quadrivalent vaccine** | | | | | |
| Leung 2015 | 134/357 | 157/356 | 44.62% | 0.85[0.71,1.02] | |
| Subtotal (95% CI) | 357 | 356 | 44.62% | 0.85[0.71,1.02] | |
| Total events: 134 (2 doses), 157 (3 doses) | | | | | |
| Heterogeneity: Tau²=0; Chi²=0, df=0(P<0.0001); I²=100% | | | | | |
| Test for overall effect: Z=1.78(P=0.08) | | | | | |
| Total (95% CI) | 595 | 594 | 100% | 0.85[0.75,0.96] | |
| Total events: 257 (2 doses), 302 (3 doses) | | | | | |
| Heterogeneity: Tau²=0; Chi²=0, df=1(P=0.98); I²=0% | | | | | |
| Test for overall effect: Z=2.69(P=0.01) | | | | | |
| Test for subgroup differences: Chi²=0, df=1 (P=0.98), I²=0% | | | | | |
### Analysis 1.4. Comparison 1 Two versus three doses of HPV vaccines in 9- to 15-year-old females, Outcome 4 Serious adverse events (overall).

| Study or subgroup | 2 doses | 3 doses | Odds Ratio | Weight | Odds Ratio |
|-------------------|---------|---------|------------|--------|------------|
|                   | n/N     | n/N     | M-H, Random, 95% CI |        | M-H, Random, 95% CI |
| **1.4.1 Bivalent vaccine** |         |         | M-H, Random, 95% CI |        | M-H, Random, 95% CI |
| Romanowski 2011   | 19/240  | 15/239  | 46.72% 1.28 | 46.72% 1.28 |
| **Subtotal (95% CI)** | 240     | 239     |          |        |            |
| Total events: 19 (2 doses), 15 (3 doses) |         |         |          |        |            |
| Heterogeneity: Not applicable |         |         |          |        |            |
| Test for overall effect: Z=0.7(P=0.49) |         |         |          |        |            |
| **1.4.2 Quadrivalent vaccine** |         |         | M-H, Random, 95% CI |        | M-H, Random, 95% CI |
| Dobson 2013       | 0/259   | 0/261   | Not estimable |        |            |
| Leung 2015        | 11/358  | 14/358  | 35.65% 0.78 | 35.65% 0.78 |
| **Subtotal (95% CI)** | 617     | 619     |          |        |            |
| Total events: 11 (2 doses), 14 (3 doses) |         |         |          |        |            |
| Heterogeneity: Tau²=0; Chi²=0, df=0(P=0.0001); I²=100% |         |         |          |        |            |
| Test for overall effect: Z=0.61(P=0.54) |         |         |          |        |            |
| **1.4.3 Nonavalent vaccine** |         |         | M-H, Random, 95% CI |        | M-H, Random, 95% CI |
| Iversen 2016      | 6/301   | 6/301   | 17.62% 1 | 17.62% 1 |
| **Subtotal (95% CI)** | 301     | 301     |          |        |            |
| Total events: 6 (2 doses), 6 (3 doses) |         |         |          |        |            |
| Heterogeneity: Not applicable |         |         |          |        |            |
| Test for overall effect: Not applicable |         |         |          |        |            |
| Total (95% CI)    | 1158    | 1159    | 100% 1.03 | 100% 1.03 |
| Total events: 36 (2 doses), 35 (3 doses) |         |         |          |        |            |
| Heterogeneity: Tau²=0; Chi²=0.85, df=2(P=0.66); I²=0% |         |         |          |        |            |
| Test for overall effect: Z=0.11(P=0.91) |         |         |          |        |            |
| Test for subgroup differences: Chi²=0.85, df=1 (P=0.66), I²=0% |         |         |          |        |            |

### Analysis 1.5. Comparison 1 Two versus three doses of HPV vaccines in 9- to 15-year-old females, Outcome 5 Deaths.

| Study or subgroup | 2 doses | 3 doses | Odds Ratio | Weight | Odds Ratio |
|-------------------|---------|---------|------------|--------|------------|
|                   | n/N     | n/N     | M-H, Random, 95% CI |        | M-H, Random, 95% CI |
| **1.5.1 Bivalent vaccine** |         |         | M-H, Random, 95% CI |        | M-H, Random, 95% CI |
| Romanowski 2011   | 0/240   | 0/239   | Not estimable |        | Not estimable |
| **Subtotal (95% CI)** | 240     | 239     |          |        |            |
| Total events: 0 (2 doses), 0 (3 doses) |         |         |          |        |            |
| Heterogeneity: Not applicable |         |         |          |        |            |
| Test for overall effect: Not applicable |         |         |          |        |            |
| **1.5.2 Quadrivalent vaccine** |         |         | M-H, Random, 95% CI |        | M-H, Random, 95% CI |
| Leung 2015        | 0/358   | 0/358   | Not estimable |        | Not estimable |
| **Subtotal (95% CI)** | 358     | 358     |          |        |            |
| Total events: 0 (2 doses), 0 (3 doses) |         |         |          |        |            |
| Heterogeneity: Not applicable |         |         |          |        |            |
### 1.5.3 Nonavalent vaccine

| Study or subgroup | 2 doses | 3 doses | Odds Ratio M-H, Random, 95% CI | Weight | Odds Ratio M-H, Random, 95% CI |
|-------------------|---------|---------|-----------------------------|--------|-----------------------------|
|                    | n/N     | n/N     |                             |        |                             |
| Iversen 2016       | 0/301   | 1/301   |                             | 100%   | 0.33 [0.01, 8.19]           |
| **Subtotal (95% CI)** | 301     | 301     |                             | 100%   | 0.33 [0.01, 8.19]           |
| **Total (95% CI)** | 899     | 898     |                             | 100%   | 0.33 [0.01, 8.19]           |

Test for overall effect: Not applicable

Total events: 0 (2 doses), 1 (3 doses)

Heterogeneity: Not applicable

Test for overall effect: Z=0.67 (P=0.5)

### Comparison 2. Two doses of HPV vaccine with longer interval versus two doses of HPV vaccine with shorter interval in 9- to 14-year-olds

#### Outcome or subgroup title

| No. of studies | No. of participants | Statistical method | Effect size |
|----------------|---------------------|-------------------|-------------|
| 1 Pain at injection site | 2 | Risk Ratio (M-H, Random, 95% CI) | Subtotals only |
| 1.1 Bivalent vaccine (0 and 2 months vs 0 and 6 months) | 1 | 477 | Risk Ratio (M-H, Random, 95% CI) | 1.01 [0.96, 1.06] |
| 1.2 Bivalent vaccine (0 and 6 months vs 0 and 12 months) | 1 | 963 | Risk Ratio (M-H, Random, 95% CI) | 1.02 [0.98, 1.06] |
| 2 Swelling at injection site | 2 | Risk Ratio (M-H, Random, 95% CI) | Subtotals only |
| 2.1 Bivalent vaccine (0 and 2 months vs 0 and 6 months) | 1 | 477 | Risk Ratio (M-H, Random, 95% CI) | 0.95 [0.76, 1.20] |
| 2.2 Bivalent vaccine (0 and 6 months vs 0 and 12 months) | 1 | 963 | Risk Ratio (M-H, Random, 95% CI) | 1.01 [0.87, 1.18] |
| 3 Redness at injection site | 2 | Risk Ratio (M-H, Random, 95% CI) | Subtotals only |
| 3.1 Bivalent vaccine (0 and 2 months vs 0 and 6 months) | 1 | 477 | Risk Ratio (M-H, Random, 95% CI) | 1.02 [0.84, 1.24] |
| 3.2 Bivalent vaccine (0 and 6 months vs 0 and 12 months) | 1 | 963 | Risk Ratio (M-H, Random, 95% CI) | 1.06 [0.93, 1.22] |
| 4 Serious adverse events (overall) | 3 | Odds Ratio (M-H, Random, 95% CI) | Subtotals only |
| Outcome or subgroup title | No. of studies | No. of participants | Statistical method | Effect size          |
|---------------------------|----------------|---------------------|--------------------|----------------------|
| 4.1 Bivalent vaccine (0, 2 months vs 0, 6 months) | 1 | 481 | Odds Ratio (M-H, Random, 95% CI) | 1.15 [0.55, 2.41] |
| 4.2 Bivalent vaccine (0 and 6 months vs 0 and 12 months) | 1 | 965 | Odds Ratio (M-H, Random, 95% CI) | 1.63 [0.89, 2.99] |
| 4.3 Nonavalent vaccine (0 and 6 months vs 0 and 12 months) - females and males | 1 | 903 | Odds Ratio (M-H, Random, 95% CI) | 0.80 [0.31, 2.07] |
| 5 Deaths | 3 | | Odds Ratio (M-H, Random, 95% CI) | Subtotals only |
| 5.1 Bivalent vaccine (0 and 2 months vs 0 and 6 months) | 1 | 481 | Odds Ratio (M-H, Random, 95% CI) | 0.0 [0.0, 0.0] |
| 5.2 Bivalent vaccine (0 and 6 months vs 0 and 12 months) | 1 | 965 | Odds Ratio (M-H, Random, 95% CI) | 0.0 [0.0, 0.0] |
| 5.3 Nonavalent vaccine (0 and 6 months vs 0 and 12 months) | 1 | 452 | Odds Ratio (M-H, Random, 95% CI) | 0.0 [0.0, 0.0] |

### Analysis 2.1. Comparison 2 Two doses of HPV vaccine with longer interval versus two doses of HPV vaccine with shorter interval in 9- to 14-year-olds, Outcome 1 Pain at injection site.

| Study or subgroup | Longer interval | Shorter interval | Risk Ratio | Weight | Risk Ratio |
|-------------------|-----------------|-----------------|------------|--------|------------|
|                   | n/N             | n/N             | M-H, Random, 95% CI |        | M-H, Random, 95% CI |
| 2.1.1 Bivalent vaccine (0 and 2 months vs 0 and 6 months) | | | | | |
| Romanowski 2011   | 225/239         | 222/238         | 1.01 [0.96, 1.06] | 100%   | 1.01 [0.96, 1.06] |
| Subtotal (95% CI) | 239             | 238             |           | 100%   |           |
| Total events: 225 (Longer interval), 222 (Shorter interval) | | | | | |
| Heterogeneity: Not applicable | | | | | |
| Test for overall effect: Z=0.39(P=0.7) | | | | | |
| 2.1.2 Bivalent vaccine (0 and 6 months vs 0 and 12 months) | | | | | |
| Puthanakit 2016   | 381/413         | 499/550         | 1.02 [0.98, 1.06] | 100%   | 1.02 [0.98, 1.06] |
| Subtotal (95% CI) | 413             | 550             |           | 100%   |           |
| Total events: 381 (Longer interval), 499 (Shorter interval) | | | | | |
| Heterogeneity: Not applicable | | | | | |
| Test for overall effect: Z=0.84(P=0.4) | | | | | |

Favours longer interval 1 Favours shorter interval
## Analysis 2.2. Comparison 2 Two doses of HPV vaccine with longer interval versus two doses of HPV vaccine with shorter interval in 9- to 14-year-olds, Outcome 2 Swelling at injection site.

| Study or subgroup | Longer interval | Shorter interval | Risk Ratio | Weight | Risk Ratio |
|-------------------|-----------------|-----------------|------------|--------|------------|
|                   | n/N             | n/N             | M-H, Random, 95% CI |        | M-H, Random, 95% CI |
| **2.2.1 Bivalent vaccine (0 and 2 months vs 0 and 6 months)** | | | | | |
| Romanowski 2011   | 88/239          | 92/238          | 0.95[0.76,1.2] | 100%   | 0.95[0.76,1.2] |
| **Subtotal (95% CI)** | 239             | 238             | 100% | 0.95[0.76,1.2] |
| Total events: 88 (Longer interval), 92 (Shorter interval) | | | | |
| Heterogeneity: Not applicable | | | | |
| Test for overall effect: Z=0.41 (P=0.68) | | | | |
| **2.2.2 Bivalent vaccine (0 and 6 months vs 0 and 12 months)** | | | | | |
| Puthanakit 2016   | 171/413         | 225/550         | 1.01[0.87,1.18] | 100%   | 1.01[0.87,1.18] |
| **Subtotal (95% CI)** | 413             | 550             | 100% | 1.01[0.87,1.18] |
| Total events: 171 (Longer interval), 225 (Shorter interval) | | | | |
| Heterogeneity: Not applicable | | | | |
| Test for overall effect: Z=0.15 (P=0.88) | | | | |
| Test for subgroup differences: Chi²=0.19, df=1 (P=0.67), I²=0% | | | | |

### Favours longer interval 1  
### Favours shorter interval 1

## Analysis 2.3. Comparison 2 Two doses of HPV vaccine with longer interval versus two doses of HPV vaccine with shorter interval in 9- to 14-year-olds, Outcome 3 Redness at injection site.

| Study or subgroup | Longer interval | Shorter interval | Risk Ratio | Weight | Risk Ratio |
|-------------------|-----------------|-----------------|------------|--------|------------|
|                   | n/N             | n/N             | M-H, Random, 95% CI |        | M-H, Random, 95% CI |
| **2.3.1 Bivalent vaccine (0 and 2 months vs 0 and 6 months)** | | | | | |
| Romanowski 2011   | 112/239         | 109/238         | 1.02[0.84,1.24] | 100%   | 1.02[0.84,1.24] |
| **Subtotal (95% CI)** | 239             | 238             | 100% | 1.02[0.84,1.24] |
| Total events: 112 (Longer interval), 109 (Shorter interval) | | | | |
| Heterogeneity: Not applicable | | | | |
| Test for overall effect: Z=0.23 (P=0.80) | | | | |
| **2.3.2 Bivalent vaccine (0 and 6 months vs 0 and 12 months)** | | | | | |
| Puthanakit 2016   | 197/413         | 247/550         | 1.06[0.93,1.12] | 100%   | 1.06[0.93,1.12] |
| **Subtotal (95% CI)** | 413             | 550             | 100% | 1.06[0.93,1.12] |
| Total events: 197 (Longer interval), 247 (Shorter interval) | | | | |
| Heterogeneity: Not applicable | | | | |
| Test for overall effect: Z=0.86 (P=0.39) | | | | |
| Test for subgroup differences: Chi²=0.1, df=1 (P=0.76), I²=0% | | | | |

### Favours longer interval 0.5 0.7 1 1.5 2  
### Favours shorter interval 1
### Analysis 2.4. Comparison 2 Two doses of HPV vaccine with longer interval versus two doses of HPV vaccine with shorter interval in 9- to 14-year-olds, Outcome 4 Serious adverse events (overall).

| Study or subgroup | Longer interval | Shorter interval | Odds Ratio | Weight | Odds Ratio |
|------------------|-----------------|-----------------|------------|--------|------------|
|                  | n/N             | n/N             | M-H, Random, 95% CI |        | M-H, Random, 95% CI |
| **2.4.1 Bivalent vaccine (0, 2 months vs 0, 6 months)** | | | | | |
| Romanowski 2011 | 16/241          | 14/240          |             | 100%   | 1.15[0.55,2.41] |
| Subtotal (95% CI) | 241             | 240             |             | 100%   | 1.15[0.55,2.41] |
| Total events: 16 (Longer interval), 14 (Shorter interval) | | | | | |
| Heterogeneity: Not applicable | | | | | |
| Test for overall effect: Z=0.37(P=0.72) | | | | | |
| **2.4.2 Bivalent vaccine (0 and 6 months vs 0 and 12 months)** | | | | | |
| Puthanakit 2016 | 24/415          | 20/550          |             | 100%   | 1.63[0.89,2.99] |
| Subtotal (95% CI) | 415             | 550             |             | 100%   | 1.63[0.89,2.99] |
| Total events: 24 (Longer interval), 20 (Shorter interval) | | | | | |
| Heterogeneity: Not applicable | | | | | |
| Test for overall effect: Z=1.57(P=0.12) | | | | | |
| **2.4.3 Nonavalent vaccine (0 and 6 months vs 0 and 12 months) - females and males** | | | | | |
| Iversen 2016 | 6/301           | 15/602          |             | 100%   | 0.8[0.31,2.07] |
| Subtotal (95% CI) | 301             | 602             |             | 100%   | 0.8[0.31,2.07] |
| Total events: 6 (Longer interval), 15 (Shorter interval) | | | | | |
| Heterogeneity: Not applicable | | | | | |
| Test for subgroup differences: Ch^2=1.62, df=1 (P=0.44), I^2=0% | | | | | |

### Analysis 2.5. Comparison 2 Two doses of HPV vaccine with longer interval versus two doses of HPV vaccine with shorter interval in 9- to 14-year-olds, Outcome 5 Deaths.

| Study or subgroup | Longer interval | Shorter interval | Odds Ratio | Weight | Odds Ratio |
|------------------|-----------------|-----------------|------------|--------|------------|
|                  | n/N             | n/N             | M-H, Random, 95% CI |        | M-H, Random, 95% CI |
| **2.5.1 Bivalent vaccine (0 and 2 months vs 0 and 6 months)** | | | | | |
| Romanowski 2011 | 0/241           | 0/240           |             |        | Not estimable |
| Subtotal (95% CI) | 241             | 240             |             |        | Not estimable |
| Total events: 0 (Longer interval), 0 (Shorter interval) | | | | | |
| Heterogeneity: Not applicable | | | | | |
| Test for overall effect: Not applicable | | | | | |
| **2.5.2 Bivalent vaccine (0 and 6 months vs 0 and 12 months)** | | | | | |
| Puthanakit 2016 | 0/415           | 0/550           |             |        | Not estimable |
| Subtotal (95% CI) | 415             | 550             |             |        | Not estimable |
| Total events: 0 (Longer interval), 0 (Shorter interval) | | | | | |
| Heterogeneity: Not applicable | | | | | |
| Test for overall effect: Not applicable | | | | | |
| **2.5.3 Nonavalent vaccine (0 and 6 months vs 0 and 12 months)** | | | | | |
| Iversen 2016 | 0/151           | 0/301           |             |        | Not estimable |
| Subtotal (95% CI) | 151             | 301             |             |        | Not estimable |
| Total events: 0 (Longer interval), 0 (Shorter interval) | | | | | |
| Heterogeneity: Not applicable | | | | | |
| Test for overall effect: Not applicable | | | | | |
Comparison 3. Three doses of HPV vaccine with longer interval versus three doses of HPV vaccine with shorter interval in 18- to 25-year-old males

| Outcome or subgroup title | No. of studies | No. of participants | Statistical method | Effect size |
|---------------------------|----------------|---------------------|--------------------|-------------|
| 1 Adverse events          |                |                     | Other data         | No numeric data |
| 2 Serious adverse events (overall) | 1 | 220 | Odds Ratio (M-H, Random, 95% CI) | 0.0 [0.0, 0.0] |

Analysis 3.1. Comparison 3. Three doses of HPV vaccine with longer interval versus three doses of HPV vaccine with shorter interval in 18- to 25-year-old males, Outcome 1 Adverse events.

| Study          | Adverse events |
|----------------|----------------|
| Lin 2014       | Adverse events data not reported separately for each arm. *Participants reported side effects following 646 separate vaccinations; 172 local and general reactions were reported, with no difference in proportion of side effects reported between Standard (24.4%) and Alternate (28.9%) schedule groups (P = 0.26). The majority of side effects were pain and redness at the injection site (86%; n = 148), with the remainder composed of fever (3.5%; n = 6), and miscellaneous symptoms (16.5%; n = 18). There were no reports of any serious side effects.* |

Analysis 3.2. Comparison 3. Three doses of HPV vaccine with longer interval versus three doses of HPV vaccine with shorter interval in 18- to 25-year-old males, Outcome 2 Serious adverse events (overall).

| Study or subgroup | Longer interval | Shorter interval | Odds Ratio | Weight | Odds Ratio |
|-------------------|----------------|-----------------|------------|--------|------------|
| Lin 2014          | 0/111          | 0/109           | M-H, Random, 95% CI | M-H, Random, 95% CI |
| Total (95% CI)    | 111            | 109             | Not estimable  | Not estimable |

Total events: 0 (Longer interval), 0 (Shorter interval)
Heterogeneity: Not applicable
Test for overall effect: Not applicable

Favours longer interval | 0.01 | 0.1 | 1 | 10 | 100 | Favours shorter interval
### Comparison 4. HPV vaccine versus control in males

| Outcome or subgroup title | No. of studies | No. of participants | Statistical method | Effect size |
|---------------------------|----------------|---------------------|--------------------|-------------|
| 1 External genital lesions (any type) | 1 | | Rate Ratio (Random, 95% CI) | Subtotals only |
| 1.1 Quadrivalent vaccine (16- to 26-year olds) | 1 | | Rate Ratio (Random, 95% CI) | 0.16 [0.07, 0.38] |
| 2 External genital lesions (HPV 6, 11, 16, or 18) | 1 | | Rate Ratio (Random, 95% CI) | Subtotals only |
| 2.1 Quadrivalent vaccine (16- to 26-year olds) | 1 | | Rate Ratio (Random, 95% CI) | 0.10 [0.03, 0.31] |
| 3 Anogenital warts | 1 | | Rate Ratio (Random, 95% CI) | Subtotals only |
| 3.1 Quadrivalent vaccine (16- to 26-year olds) | 1 | | Rate Ratio (Random, 95% CI) | 0.11 [0.03, 0.38] |
| 4 All penile, perianal, or perineal intraepithelial neoplasia lesions | 1 | | Rate Ratio (Random, 95% CI) | Subtotals only |
| 4.1 Quadrivalent vaccine (16- to 26-year olds) | 1 | | Rate Ratio (Random, 95% CI) | 0.17 [0.01, 3.27] |
| 5 Penile, perianal, or perineal intraepithelial neoplasia grade 1 | 1 | | Rate Ratio (Random, 95% CI) | Subtotals only |
| 5.1 Quadrivalent vaccine (16- to 26-year olds) | 1 | | Rate Ratio (Random, 95% CI) | 0.25 [0.01, 6.22] |
| 6 Penile, perianal, or perineal intraepithelial neoplasia grade 2 or 3 | 1 | | Rate Ratio (Random, 95% CI) | Subtotals only |
| 6.1 Quadrivalent vaccine (16- to 26-year olds) | 1 | | Rate Ratio (Random, 95% CI) | 0.50 [0.02, 14.80] |
| 7 Overall local/injection site adverse events | 1 | | Risk Ratio (M-H, Random, 95% CI) | Subtotals only |
| 7.1 Quadrivalent vaccine (16- to 26-year olds) | 1 | 3895 | Risk Ratio (M-H, Random, 95% CI) | 1.12 [1.06, 1.18] |
| 8 Pain at injection site | 3 | | Risk Ratio (M-H, Random, 95% CI) | Subtotals only |
| 8.1 Bivalent vaccine (10- to 18-year-olds) | 1 | 268 | Risk Ratio (M-H, Random, 95% CI) | 1.99 [1.57, 2.53] |
| 8.2 Quadrivalent vaccine (16- to 26-year olds) | 2 | 5162 | Risk Ratio (M-H, Random, 95% CI) | 1.13 [1.07, 1.19] |
| 9 Swelling at injection site | 3 | | Risk Ratio (M-H, Random, 95% CI) | Subtotals only |
| Outcome or subgroup title                                      | No. of studies | No. of participants | Statistical method                        | Effect size               |
|---------------------------------------------------------------|----------------|---------------------|-------------------------------------------|---------------------------|
| 9.1 Bivalent vaccine (10- to 18-year-olds)                    | 1              | 268                 | Risk Ratio (M-H, Random, 95% CI)          | 2.51 [1.17, 5.42]         |
| 9.2 Quadrivalent vaccine (16- to 26-year olds)               | 2              | 5162                | Risk Ratio (M-H, Random, 95% CI)          | 1.29 [1.04, 1.60]         |
| 10 Redness at injection site                                 | 3              |                     | Risk Ratio (M-H, Random, 95% CI)          | Subtotals only            |
| 10.1 Bivalent vaccine (10- to 18-year-olds)                  | 1              | 268                 | Risk Ratio (M-H, Random, 95% CI)          | 1.66 [0.99, 2.79]         |
| 10.2 Quadrivalent vaccine (16- to 26-year olds)              | 2              | 5162                | Risk Ratio (M-H, Random, 95% CI)          | 1.12 [0.99, 1.27]         |
| 11 Overall systemic events and general symptoms               | 2              |                     | Risk Ratio (M-H, Random, 95% CI)          | Subtotals only            |
| 11.1 Quadrivalent vaccine (16- to 26-year olds)              | 2              | 5008                | Risk Ratio (M-H, Random, 95% CI)          | 0.99 [0.90, 1.08]         |
| 12 Serious adverse events (overall)                          | 3              |                     | Odds Ratio (M-H, Random, 95% CI)          | Subtotals only            |
| 12.1 Bivalent vaccine (10- to 18-year-olds)                  | 1              | 270                 | Odds Ratio (M-H, Random, 95% CI)          | 1.48 [0.15, 14.46]        |
| 12.2 Quadrivalent vaccine (16- to 26-year olds)              | 2              | 5162                | Odds Ratio (M-H, Random, 95% CI)          | 0.69 [0.29, 1.66]         |
| 13 Deaths                                                    | 3              |                     | Odds Ratio (M-H, Random, 95% CI)          | Subtotals only            |
| 13.1 Bivalent vaccine (10- to 18-year-olds)                  | 1              | 270                 | Odds Ratio (M-H, Random, 95% CI)          | 0.0 [0.0, 0.0]            |
| 13.2 Quadrivalent vaccine (16- to 26-year olds)              | 2              | 5173                | Odds Ratio (M-H, Random, 95% CI)          | 0.30 [0.09, 1.01]         |

### Analysis 4.1. Comparison 4 HPV vaccine versus control in males, Outcome 1 External genital lesions (any type).

| Study or subgroup | Quadrivalent vaccine | Control | log(Rate Ratio) (SE) | Rate Ratio | Weight | Rate Ratio (95% CI) |
|-------------------|----------------------|---------|---------------------|------------|--------|-------------------|
| 4.1.1 Quadrivalent vaccine (16- to 26-year olds)  | 0       | 0       | -1.8 (0.441)        |            | 100%   | 0.16 [0.07, 0.38] |

Heterogeneity: Tau²=0; Chi²=0; df=0(P=0.0001); I²=100%
Test for overall effect: Z=4.13(P=0.0001)
### Analysis 4.2. Comparison 4 HPV vaccine versus control in males, Outcome 2 External genital lesions (HPV 6, 11, 16, or 18).

| Study or subgroup | Quadrivalent vaccine | Control | log(Rate Ratio) | Rate Ratio | Weight | Rate Ratio |
|-------------------|----------------------|---------|-----------------|------------|--------|------------|
|                    | N                    | N (SE)  | IV, Random, 95% CI | IV, Random, 95% CI |        |            |
| 4.2.1 Quadrivalent vaccine (16- to 26-year olds) | Giuliano 2011 | 0 | 0 | -2.3 (0.594) | 100% | 0.1[0.03,0.31] |
|                   | Subtotal (95% CI)    |         |                 |           | 100% | 0.1[0.03,0.31] |

Heterogeneity: Not applicable
Test for overall effect: Z=3.94(P<0.0001)

Favours quadrivalent 0.01 0.1 1 10 100  Favor favours control

### Analysis 4.3. Comparison 4 HPV vaccine versus control in males, Outcome 3 Anogenital warts.

| Study or subgroup | Quadrivalent vaccine | Control | log(Rate Ratio) | Rate Ratio | Weight | Rate Ratio |
|-------------------|----------------------|---------|-----------------|------------|--------|------------|
|                    | N                    | N (SE)  | IV, Random, 95% CI | IV, Random, 95% CI |        |            |
| 4.3.1 Quadrivalent vaccine (16- to 26-year olds) | Giuliano 2011 | 0 | 0 | -2.2 (0.646) | 100% | 0.11[0.03,0.38] |
|                   | Subtotal (95% CI)    |         |                 |           | 100% | 0.11[0.03,0.38] |

Heterogeneity: Not applicable
Test for overall effect: Z=3.46(P<0)

Favours quadrivalent 0.01 0.1 1 10 100  Favor favours control

### Analysis 4.4. Comparison 4 HPV vaccine versus control in males, Outcome 4 All penile, perianal, or perineal intraepithelial neoplasia lesions.

| Study or subgroup | Quadrivalent vaccine | Control | log(Rate Ratio) | Rate Ratio | Weight | Rate Ratio |
|-------------------|----------------------|---------|-----------------|------------|--------|------------|
|                    | N                    | N (SE)  | IV, Random, 95% CI | IV, Random, 95% CI |        |            |
| 4.4.1 Quadrivalent vaccine (16- to 26-year olds) | Giuliano 2011 | 0 | 0 | -1.8 (1.52) | 100% | 0.17[0.01,3.27] |
|                   | Subtotal (95% CI)    |         |                 |           | 100% | 0.17[0.01,3.27] |

Heterogeneity: Not applicable
Test for overall effect: Z=1.18(P=0.24)

Favours quadrivalent 0.001 0.1 1 10 1000  Favor favours control

### Analysis 4.5. Comparison 4 HPV vaccine versus control in males, Outcome 5 Penile, perianal, or perineal intraepithelial neoplasia grade 1.

| Study or subgroup | Quadrivalent vaccine | Control | log(Rate Ratio) | Rate Ratio | Weight | Rate Ratio |
|-------------------|----------------------|---------|-----------------|------------|--------|------------|
|                    | N                    | N (SE)  | IV, Random, 95% CI | IV, Random, 95% CI |        |            |
| 4.5.1 Quadrivalent vaccine (16- to 26-year olds) | Giuliano 2011 | 0 | 0 | -1.4 (1.641) | 100% | 0.25[0.01,6.22] |
|                   | Subtotal (95% CI)    |         |                 |           | 100% | 0.25[0.01,6.22] |

Favours quadrivalent 0.001 0.1 1 10 1000  Favor favours control
### Analysis 4.6. Comparison 4 HPV vaccine versus control in males, Outcome 6 Penile, perianal, or perineal intraepithelial neoplasia grade 2 or 3.

| Study or subgroup | Quadrivalent vaccine | Control | log(Rate Ratio) | Rate Ratio | Weight | Rate Ratio |
|-------------------|----------------------|---------|----------------|------------|--------|------------|
|                   | N        | N    | (SE)           | IV, Random, 95% CI | IV, Random, 95% CI |
| 4.6.1 Quadrivalent vaccine (16- to 26-year olds) | | | | | |
| Giuliano 2011     | 0       | 0    | -0.7 (1.73)    | 100%       | 0.5[0.02,14.8] |
| Subtotal (95% CI) |         |      |                | 100%       | 0.5[0.02,14.8] |
| Heterogeneity: Not applicable | | | | |
| Test for overall effect: Z=0.4(P=0.69) | | | | |

Favours quadrivalent 0.001 0.1 1 10 1000 Favours control

### Analysis 4.7. Comparison 4 HPV vaccine versus control in males, Outcome 7 Overall local/injection site adverse events.

| Study or subgroup | Quadrivalent vaccine | Control | Risk Ratio | Weight | Risk Ratio |
|-------------------|----------------------|---------|------------|--------|------------|
|                   | n/N     | n/N    | M-H, Random, 95% CI | M-H, Random, 95% CI |
| 4.7.1 Quadrivalent vaccine (16- to 26-year olds) | | | | |
| Giuliano 2011     | 1169/1945 | 1047/1950 | 100% | 1.12[1.06,1.18] |
| Subtotal (95% CI) | 1945 | 1950 | 100% | 1.12[1.06,1.18] |
| Heterogeneity: Not applicable | | | | |
| Test for overall effect: Z=4.03(P<0.0001) | | | | |

Favours quadrivalent 0.001 0.1 1 10 1000 Favours control

### Analysis 4.8. Comparison 4 HPV vaccine versus control in males, Outcome 8 Pain at injection site.

| Study or subgroup | HPV vaccine | Control | Risk Ratio | Weight | Risk Ratio |
|-------------------|-------------|---------|------------|--------|------------|
|                   | n/N        | n/N    | M-H, Random, 95% CI | M-H, Random, 95% CI |
| 4.8.1 Bivalent vaccine (10- to 18-year-olds) | | | | |
| Petaja 2009       | 159/180 | 39/88 | 100% | 1.99[1.57,2.53] |
| Subtotal (95% CI) | 180 | 88 | 100% | 1.99[1.57,2.53] |
| Total events: 159 (HPV vaccine), 39 (Control) | | | | |
| Heterogeneity: Tau²=0; Chi²=0, df=0(P=0.0001); I²=100% | | | | |
| Test for overall effect: Z=5.63(P<0.0001) | | | | |

Favours HPV vaccine 0.1 0.2 0.5 1 2 5 10 Favours control

Favours control

Comparison of different human papillomavirus (HPV) vaccine types and dose schedules for prevention of HPV-related disease in females and males (Review)

Copyright © 2019 The Authors. Cochrane Database of Systematic Reviews published by John Wiley & Sons, Ltd. on behalf of The Cochrane Collaboration.
### Analysis 4.9. Comparison 4 HPV vaccine versus control in males, Outcome 9 Swelling at injection site.

| Study or subgroup | HPV vaccine n/N | Control n/N | Risk Ratio M-H, Random, 95% CI | Weight | Risk Ratio M-H, Random, 95% CI |
|-------------------|----------------|-------------|--------------------------------|--------|-------------------------------|
| **4.9.1 Bivalent vaccine (10- to 18-year-olds)** | | | | | |
| Petaja 2009       | 36/180         | 7/88        |                                | 100%   | 2.51[1.17,5.42]              |
| Subtotal (95% CI) | 180            | 88          |                                | 100%   | 2.51[1.17,5.42]              |
| Total events: 36 (HPV vaccine), 7 (Control) | | | | | |
| Heterogeneity: Not applicable | | | | | |
| Test for overall effect: Z=2.35(P=0.02) | | | | | |
| Test for subgroup differences: Chi^2=16.88, df=1 (P<0.0001), I^2=78.71% | | | | | |
| **4.9.2 Quadrivalent vaccine (16- to 26-year olds)** | | | | | |
| Giuliano 2011     | 219/2020       | 187/2029    |                                | 58.35% | 1.18[0.98,1.42]              |
| NCT01862874 2018  | 118/554        | 81/559      |                                | 41.65% | 1.47[1.14,1.9]               |
| Subtotal (95% CI) | 2574           | 2588        |                                | 100%   | 1.29[1.04,1.6]               |
| Total events: 337 (HPV vaccine), 268 (Control) | | | | | |
| Heterogeneity: Tau^2=0.03; Chi^2=19.5, df=10 (P=0.02), I^2=50.38% | | | | | |
| Test for overall effect: Z=2.32(P=0.02) | | | | | |
| Test for subgroup differences: Chi^2=20.45, df=1 (P=0.0001), I^2=95.11% | | | | | |

### Analysis 4.10. Comparison 4 HPV vaccine versus control in males, Outcome 10 Redness at injection site.

| Study or subgroup | HPV vaccine n/N | Control n/N | Risk Ratio M-H, Random, 95% CI | Weight | Risk Ratio M-H, Random, 95% CI |
|-------------------|----------------|-------------|--------------------------------|--------|-------------------------------|
| **4.10.1 Bivalent vaccine (10- to 18-year-olds)** | | | | | |
| Petaja 2009       | 51/180         | 15/88       |                                | 100%   | 1.66[0.99,2.79]              |
| Subtotal (95% CI) | 180            | 88          |                                | 100%   | 1.66[0.99,2.79]              |
| Total events: 51 (HPV vaccine), 15 (Control) | | | | | |
| Heterogeneity: Not applicable | | | | | |
| Test for overall effect: Z=1.93(P=0.05) | | | | | |
| **4.10.2 Quadrivalent vaccine (16- to 26-year olds)** | | | | | |
| Giuliano 2011     | 304/2020       | 275/2029    |                                | 66.94% | 1.11[0.95,1.29]              |
| NCT01862874 2018  | 136/554        | 121/559     |                                | 33.06% | 1.13[0.91,1.41]              |
| Subtotal (95% CI) | 2574           | 2588        |                                | 100%   | 1.12[0.99,1.27]              |
| Total events: 440 (HPV vaccine), 396 (Control) | | | | | |
| Heterogeneity: Tau^2=0.02; Chi^2=6.42, df=1 (P=0.087), I^2=0% | | | | | |
| Test for overall effect: Z=1.77(P=0.08) | | | | | |

Comparison of different human papillomavirus (HPV) vaccine types and dose schedules for prevention of HPV-related disease in females and males (Review)

Copyright © 2019 The Authors. Cochrane Database of Systematic Reviews published by John Wiley & Sons, Ltd. on behalf of The Cochrane Collaboration.
### Analysis 4.11. Comparison 4 HPV vaccine versus control in males, Outcome 11 Overall systemic events and general symptoms.

| Study or subgroup | HPV vaccine | Control | Risk Ratio | Weight | Risk Ratio |
|-------------------|-------------|---------|------------|--------|------------|
|                   | n/N         | n/N     | M-H, Random, 95% CI | M-H, Random, 95% CI |
| 4.11.1 Quadrivalent vaccine (16- to 26-year olds) |            |         |           |        |            |
| Giuliano 2011     | 616/1945    | 622/1950| 90.31%     | 0.99[0.91,1.09] |
| NCT01862874 2018  | 80/554      | 86/559  | 9.69%      | 0.94[0.71,1.24] |
| Subtotal (95% CI) | 2499        | 2509    | 100%       | 0.99[0.9,1.08] |
|                   |             |         |           |        |            |
|                   | Favours quadrivalent | 0.5 | 0.7 | 1 | 1.5 | 2 | Favours control |

#### Test for subgroup differences: Chi²=2.14, df=1 (P=0.14), I²=53.35%

#### Analysis 4.12. Comparison 4 HPV vaccine versus control in males, Outcome 12 Serious adverse events (overall).

| Study or subgroup | HPV vaccine | Control | Odds Ratio | Weight | Odds Ratio |
|-------------------|-------------|---------|------------|--------|------------|
|                   | n/N         | n/N     | M-H, Random, 95% CI | M-H, Random, 95% CI |
| 4.12.1 Bivalent vaccine (10- to 18-year-olds) |            |         |           |        |            |
| Petaja 2009       | 3/181       | 1/89    | 100%       | 1.48[0.15,14.46] |
| Subtotal (95% CI) | 181         | 89      | 100%       | 1.48[0.15,14.46] |
|                   |             |         |           |        |            |
|                   | Favours HPV vaccine | 0.01 | 0.1 | 1 | 10 | 100 | Favours control |

#### Test for subgroup differences: Chi²=0.38, df=1 (P=0.54), I²=0%

#### Analysis 4.13. Comparison 4 HPV vaccine versus control in males, Outcome 13 Deaths.

| Study or subgroup | HPV vaccine | Control | Odds Ratio | Weight | Odds Ratio |
|-------------------|-------------|---------|------------|--------|------------|
|                   | n/N         | n/N     | M-H, Random, 95% CI | M-H, Random, 95% CI |
| 4.13.1 Bivalent vaccine (10- to 18-year-olds) |            |         |           |        |            |
|                   |             |         |           |        |            |

#### Test for subgroup differences: Chi²=0.12, df=1 (P=0.72), I²=0%
| Study or subgroup | HPV vaccine | Control | Odds Ratio | Weight | Odds Ratio |
|------------------|-------------|---------|------------|--------|------------|
|                  | n/N         | n/N     | M-H, Random, 95% CI |        | M-H, Random, 95% CI |
| Petaja 2009      | 0/181       | 0/89    | Not estimable |        | Not estimable |
| Subtotal (95% CI)| 181         | 89      | Not estimable |        | Not estimable |
| Total events: 0 (HPV vaccine), 0 (Control) |
| Heterogeneity: Not applicable |
| Test for overall effect: Not applicable |

4.13.2 Quadrivalent vaccine (16- to 26-year olds)

| Study          | HPV vaccine | Control | Odds Ratio | Weight | Odds Ratio |
|----------------|-------------|---------|------------|--------|------------|
| Giuliani 2011  | 3/2020      | 10/2029 | 0.33 [0.08, 1.09] | 86.01% | 0.33 [0.08, 1.09] |
| NCT01862874 2018 | 0/562      | 1/562   | 13.99%     | 0.33 [0.01, 8.19] | |
| Subtotal (95% CI) | 2582       | 2591    | 100%       | 0.33 [0.01, 8.19] | |
| Total events: 3 (HPV vaccine), 11 (Control) |
| Heterogeneity: Tau²=0; Chi²=0, df=1(P=0.95); I²=0% |
| Test for overall effect: Z =1.94(P=0.05) |
| Test for subgroup differences: Not applicable |

Comparison 5. Nonavalent HPV vaccine versus quadrivalent HPV vaccine in 9- to 26-year-olds

| Outcome or subgroup title | No. of studies | No. of participants | Statistical method | Effect size |
|---------------------------|----------------|---------------------|--------------------|-------------|
| 1 High-grade cervical epithelial neoplasia, adenocarcinoma in situ, and cervical cancer | 1 | 13753 | Odds Ratio (M-H, Random, 95% CI) | 1.00 [0.85, 1.16] |
| 2 High-grade cervical, vulval, and vaginal disease | 1 | 14054 | Odds Ratio (M-H, Random, 95% CI) | 0.99 [0.85, 1.15] |
| 3 High-grade cervical disease related to HPV 6, 11, 16, or 18 | 1 | 11656 | Odds Ratio (M-H, Random, 95% CI) | 1.00 [0.06, 16.01] |
| 4 High-grade vulval and vaginal disease related to HPV 6, 11, 16, or 18 | 1 | 11769 | Odds Ratio (M-H, Random, 95% CI) | 0.14 [0.01, 2.77] |
| 5 High-grade cervical disease related to HPV 31, 33, 45, 52, or 58 | 1 | 11892 | Odds Ratio (M-H, Random, 95% CI) | 0.03 [0.00, 0.21] |
| 6 High-grade vulval and vaginal disease related to HPV 31, 33, 45, 52, or 58 | 1 | 12021 | Odds Ratio (M-H, Random, 95% CI) | 0.14 [0.01, 2.77] |
| 7 Cervical intraepithelial neoplasia 2 related to HPV 6, 11, 16, or 18 | 1 | 11656 | Odds Ratio (M-H, Random, 95% CI) | 3.00 [0.12, 73.77] |
| 8 Cervical intraepithelial neoplasia 2 related to HPV 31, 33, 45, 52, or 58 | 1 | 11892 | Odds Ratio (M-H, Random, 95% CI) | 0.03 [0.00, 0.23] |
| 9 Cervical intraepithelial neoplasia 3, adenocarcinoma in situ, and cervical cancer related to HPV 6, 11, 16, or 18 | 1 | 11656 | Odds Ratio (M-H, Random, 95% CI) | 0.33 [0.01, 8.19] |
| 10 Cervical intraepithelial neoplasia 3, adenocarcinoma in situ, and cervical cancer related to HPV 31, 33, 45, 52, or 58 | 1 | 11892 | Odds Ratio (M-H, Random, 95% CI) | 0.07 [0.00, 1.16] |

Comparison of different human papillomavirus (HPV) vaccine types and dose schedules for prevention of HPV-related disease in females and males (Review)
Copyright © 2019 The Authors. Cochrane Database of Systematic Reviews published by John Wiley & Sons, Ltd. on behalf of The Cochrane Collaboration.
| Outcome or subgroup title                                                                 | No. of studies | No. of participants | Statistical method | Effect size  |
|-----------------------------------------------------------------------------------------|----------------|---------------------|--------------------|--------------|
| Total cancer related to HPV 31, 33, 45, 52, or 58                                       |                |                     |                    |              |
| 11 Overall local/injection site adverse events                                            | 3              | 15863               | Risk Ratio (M-H, Random, 95% CI) | 1.07 [1.05, 1.08] |
| 11.1 9- to 15-year-old females                                                            | 1              | 599                 | Risk Ratio (M-H, Random, 95% CI) | 1.04 [0.98, 1.09] |
| 11.2 16- to 26-year-old females                                                           | 1              | 14764               | Risk Ratio (M-H, Random, 95% CI) | 1.07 [1.05, 1.08] |
| 11.3 16- to 26-year-old males                                                             | 1              | 500                 | Risk Ratio (M-H, Random, 95% CI) | 1.10 [1.00, 1.22] |
| 12 Pain at injection site                                                                 | 3              | 15863               | Risk Ratio (M-H, Random, 95% CI) | 1.06 [1.02, 1.11] |
| 12.1 9- to 15-year-old females                                                            | 1              | 599                 | Risk Ratio (M-H, Random, 95% CI) | 1.01 [0.96, 1.07] |
| 12.2 16- to 26-year-old females                                                           | 1              | 14764               | Risk Ratio (M-H, Random, 95% CI) | 1.07 [1.06, 1.09] |
| 12.3 16- to 26-year-old males                                                             | 1              | 500                 | Risk Ratio (M-H, Random, 95% CI) | 1.12 [1.01, 1.24] |
| 13 Swelling at injection site                                                              | 3              | 15863               | Risk Ratio (M-H, Random, 95% CI) | 1.37 [1.31, 1.44] |
| 13.1 9- to 15-year-old females                                                            | 1              | 599                 | Risk Ratio (M-H, Random, 95% CI) | 1.33 [1.10, 1.60] |
| 13.2 16- to 26-year-old females                                                           | 1              | 14764               | Risk Ratio (M-H, Random, 95% CI) | 1.38 [1.31, 1.44] |
| 13.3 16- to 26-year-old males                                                             | 1              | 500                 | Risk Ratio (M-H, Random, 95% CI) | 1.58 [0.96, 2.58] |
| 14 Redness at injection site                                                               | 3              | 15863               | Risk Ratio (M-H, Random, 95% CI) | 1.20 [1.00, 1.44] |
| 14.1 9- to 15-year-old females                                                            | 1              | 599                 | Risk Ratio (M-H, Random, 95% CI) | 1.16 [0.92, 1.47] |
| 14.2 16- to 26-year-old females                                                           | 1              | 14764               | Risk Ratio (M-H, Random, 95% CI) | 1.32 [1.26, 1.39] |
| 14.3 16- to 26-year-old males                                                             | 1              | 500                 | Risk Ratio (M-H, Random, 95% CI) | 0.89 [0.60, 1.33] |
| 15 Overall systemic events and general symptoms                                            | 3              | 15863               | Risk Ratio (M-H, Random, 95% CI) | 1.01 [0.98, 1.04] |
| 15.1 9- to 15-year-old females                                                            | 1              | 599                 | Risk Ratio (M-H, Random, 95% CI) | 0.91 [0.78, 1.07] |
### Outcome or subgroup title

| Outcome or subgroup title | No. of studies | No. of participants | Statistical method                                      | Effect size          |
|--------------------------|----------------|---------------------|--------------------------------------------------------|----------------------|
| 15.2 16- to 26-year-old females | 1              | 14764               | Risk Ratio (M-H, Random, 95% CI)                       | 1.01 [0.98, 1.04]    |
| 15.3 16- to 26-year-old males | 1              | 500                 | Risk Ratio (M-H, Random, 95% CI)                       | 1.02 [0.82, 1.26]    |
| 16 Serious adverse events (overall) | 3              | 15863               | Odds Ratio (M-H, Random, 95% CI)                       | 0.60 [0.14, 2.61]    |
| 16.1 9- to 15-year-old females | 1              | 599                 | Odds Ratio (M-H, Random, 95% CI)                       | 0.5 [0.05, 5.54]     |
| 16.2 16- to 26-year-old females | 1              | 14764               | Odds Ratio (M-H, Random, 95% CI)                       | 1.22 [1.00, 1.48]    |
| 16.3 16- to 26-year-old males | 1              | 500                 | Odds Ratio (M-H, Random, 95% CI)                       | 0.08 [0.00, 1.35]    |
| 17 Deaths                | 3              | 15248               | Odds Ratio (M-H, Random, 95% CI)                       | 1.20 [0.37, 3.94]    |
| 17.1 9- to 15-year old females | 1              | 599                 | Odds Ratio (M-H, Random, 95% CI)                       | 0.0 [0.0, 0.0]       |
| 17.2 16- to 26-year-old females | 1              | 14149               | Odds Ratio (M-H, Random, 95% CI)                       | 1.20 [0.37, 3.94]    |
| 17.3 16- to 26-year-old males | 1              | 500                 | Odds Ratio (M-H, Random, 95% CI)                       | 0.0 [0.0, 0.0]       |

### Analysis 5.1. Comparison 5 Nonavalent HPV vaccine versus quadrivalent HPV vaccine in 9- to 26-year-olds, Outcome 1 High-grade cervical epithelial neoplasia, adenocarcinoma in situ, and cervical cancer.

| Study or subgroup | Nonavalent vaccine | Quadrivalent vaccine | Odds Ratio (M-H, Random, 95% CI) | Weight | Odds Ratio (M-H, Random, 95% CI) |
|-------------------|--------------------|----------------------|----------------------------------|--------|----------------------------------|
| Joura 2015        | 325/6882           | 326/6871             | 1 [0.85, 1.16]                  | 100%   | 1 [0.85, 1.16]                  |

Total (95% CI): 6882/6871

Favours nonavalent: 0.01 0.1 1 10 100 1000 5000

Favours quadrivalent: 0.01 0.1 1 10 100 1000 5000

Heterogeneity: $\tau^2=0$; $\chi^2=0$, df=0($p<0.0001$); $R^2=100$

Test for overall effect: Z=0.06($p=0.95$)
### Analysis 5.2. Comparison 5 Nonavalent HPV vaccine versus quadrivalent HPV vaccine in 9- to 26-year-olds, Outcome 2 High-grade cervical, vulval, and vaginal disease.

| Study or subgroup | Nonavalent vaccine | Quadriivalent vaccine | Odds Ratio | Weight | Odds Ratio |
|-------------------|--------------------|-----------------------|------------|--------|------------|
|                    | n/N                | n/N                   | M-H, Random, 95% CI |        | M-H, Random, 95% CI |
| Joura 2015         | 340/7027           | 344/7027              | 100%       | 0.99 [0.85, 1.15] |
| Total (95% CI)     | 7027               | 7027                  | 100%       | 0.99 [0.85, 1.15] |

Total events: 340 (Nonavalent vaccine), 344 (Quadriivalent vaccine)
Heterogeneity: Tau²=0; Chi²=0, df=0(P=0.0001); I²=100%
Test for overall effect: Z=0.16(P=0.88)

Favours nonavalent 0.01 0.1 1 10 100 Favours quadriivalent

### Analysis 5.3. Comparison 5 Nonavalent HPV vaccine versus quadrivalent HPV vaccine in 9- to 26-year-olds, Outcome 3 High-grade cervical disease related to HPV 6, 11, 16, or 18.

| Study or subgroup | Nonavalent vaccine | Quadriivalent vaccine | Odds Ratio | Weight | Odds Ratio |
|-------------------|--------------------|-----------------------|------------|--------|------------|
|                    | n/N                | n/N                   | M-H, Random, 95% CI |        | M-H, Random, 95% CI |
| Joura 2015         | 1/5824             | 1/5832                | 100%       | 1 [0.06, 16.01] |
| Total (95% CI)     | 5824               | 5832                  | 100%       | 1 [0.06, 16.01] |

Total events: 1 (Nonavalent vaccine), 1 (Quadriivalent vaccine)
Heterogeneity: Not applicable
Test for overall effect: Z=0(P=1)

Favours nonavalent 0.01 0.1 1 10 100 Favours quadriivalent

### Analysis 5.4. Comparison 5 Nonavalent HPV vaccine versus quadrivalent HPV vaccine in 9- to 26-year-olds, Outcome 4 High-grade vulval and vaginal disease related to HPV 6, 11, 16, or 18.

| Study or subgroup | Nonavalent vaccine | Quadriivalent vaccine | Odds Ratio | Weight | Odds Ratio |
|-------------------|--------------------|-----------------------|------------|--------|------------|
|                    | n/N                | n/N                   | M-H, Random, 95% CI |        | M-H, Random, 95% CI |
| Joura 2015         | 0/5876             | 3/5893                | 100%       | 0.14 [0.01, 2.77] |
| Total (95% CI)     | 5876               | 5893                  | 100%       | 0.14 [0.01, 2.77] |

Total events: 0 (Nonavalent vaccine), 3 (Quadriivalent vaccine)
Heterogeneity: Not applicable
Test for overall effect: Z=1.29(P=0.2)
### Analysis 5.5. Comparison 5 Nonavalent HPV vaccine versus quadrivalent HPV vaccine in 9- to 26-year-olds, Outcome 5 High-grade cervical disease related to HPV 31, 33, 45, 52, or 58.

| Study or subgroup | Nonavalent vaccine | Quadrivalent vaccine | Odds Ratio | Weight | Odds Ratio |
|-------------------|--------------------|----------------------|------------|--------|------------|
|                   | n/N                | n/N                  | M-H, Random, 95% CI |        | M-H, Random, 95% CI |
| Joura 2015        | 1/5949             | 35/5943              | 100%       | 0.03[0.03,0.21] |
| Total (95% CI)    | 5949               | 5943                 | 100%       | 0.03[0.03,0.21] |

Total events: 1 (Nonavalent vaccine), 35 (Quadrivalent vaccine)
Heterogeneity: Not applicable
Test for overall effect: Z=3.51 (P=0)

### Analysis 5.6. Comparison 5 Nonavalent HPV vaccine versus quadrivalent HPV vaccine in 9- to 26-year-olds, Outcome 6 High-grade vulval and vaginal disease related to HPV 31, 33, 45, 52, or 58.

| Study or subgroup | Nonavalent vaccine | Quadrivalent vaccine | Odds Ratio | Weight | Odds Ratio |
|-------------------|--------------------|----------------------|------------|--------|------------|
|                   | n/N                | n/N                  | M-H, Random, 95% CI |        | M-H, Random, 95% CI |
| Joura 2015        | 0/6009             | 3/6012               | 100%       | 0.14[0.01,2.77] |
| Total (95% CI)    | 6009               | 6012                 | 100%       | 0.14[0.01,2.77] |

Total events: 0 (Nonavalent vaccine), 3 (Quadrivalent vaccine)
Heterogeneity: Not applicable
Test for overall effect: Z=1.29 (P=0.2)

### Analysis 5.7. Comparison 5 Nonavalent HPV vaccine versus quadrivalent HPV vaccine in 9- to 26-year-olds, Outcome 7 Cervical intraepithelial neoplasia 2 related to HPV 6, 11, 16, or 18.

| Study or subgroup | Nonavalent vaccine | Quadrivalent vaccine | Odds Ratio | Weight | Odds Ratio |
|-------------------|--------------------|----------------------|------------|--------|------------|
|                   | n/N                | n/N                  | M-H, Random, 95% CI |        | M-H, Random, 95% CI |
| Joura 2015        | 1/5824             | 0/5832               | 100%       | 3[0.12,73.77] |
| Total (95% CI)    | 5824               | 5832                 | 100%       | 3[0.12,73.77] |

Total events: 1 (Nonavalent vaccine), 0 (Quadrivalent vaccine)
Heterogeneity: Not applicable
Test for overall effect: Z=0.67 (P=0.5)
Analysis 5.8. Comparison 5 Nonavalent HPV vaccine versus quadrivalent HPV vaccine in 9- to 26-year-olds, Outcome 8 Cervical intraepithelial neoplasia 2 related to HPV 31, 33, 45, 52, or 58.

| Study or subgroup | Nonavalent vaccine n/N | Quadrivalent vaccine n/N | Odds Ratio M-H, Random, 95% CI | Weight | Odds Ratio M-H, Random, 95% CI |
|------------------|------------------------|--------------------------|------------------------------|--------|-------------------------------|
| Joura 2015       | 1/5949                 | 32/5943                  | 0.03 [0.0, 0.23]             | 0.01   | 0.01                          |
| Total (95% CI)   | 5949                   | 5943                     | 0.03 [0.0, 0.23]             | 100%   | 100%                          |

Total events: 1 (Nonavalent vaccine), 32 (Quadrivalent vaccine)
Heterogeneity: Not applicable
Test for overall effect: Z=3.42 (P=0)

Favours nonavalent 0.01 0.1 1 10 100 Favours quadrivalent

Analysis 5.9. Comparison 5 Nonavalent HPV vaccine versus quadrivalent HPV vaccine in 9- to 26-year-olds, Outcome 9 Cervical intraepithelial neoplasia 3, adenocarcinoma in situ, and cervical cancer related to HPV 6, 11, 16, or 18.

| Study or subgroup | Nonavalent vaccine n/N | Quadrivalent vaccine n/N | Odds Ratio M-H, Random, 95% CI | Weight | Odds Ratio M-H, Random, 95% CI |
|------------------|------------------------|--------------------------|------------------------------|--------|-------------------------------|
| Joura 2015       | 0/5824                 | 1/5832                   | 0.33 [0.01, 8.19]            | 0.01   | 0.01                          |
| Total (95% CI)   | 5824                   | 5832                     | 0.33 [0.01, 8.19]            | 100%   | 100%                          |

Total events: 0 (Nonavalent vaccine), 1 (Quadrivalent vaccine)
Heterogeneity: Not applicable
Test for overall effect: Z=0.67 (P=0.5)

Favours nonavalent 0.01 0.1 1 10 100 Favours quadrivalent

Analysis 5.10. Comparison 5 Nonavalent HPV vaccine versus quadrivalent HPV vaccine in 9- to 26-year-olds, Outcome 10 Cervical intraepithelial neoplasia 3, adenocarcinoma in situ, and cervical cancer related to HPV 31, 33, 45, 52, or 58.

| Study or subgroup | Nonavalent vaccine n/N | Quadrivalent vaccine n/N | Odds Ratio M-H, Random, 95% CI | Weight | Odds Ratio M-H, Random, 95% CI |
|------------------|------------------------|--------------------------|------------------------------|--------|-------------------------------|
| Joura 2015       | 0/5949                 | 7/5943                   | 0.07 [0.0, 1.16]             | 0.01   | 0.01                          |
| Total (95% CI)   | 5949                   | 5943                     | 0.07 [0.0, 1.16]             | 100%   | 100%                          |

Total events: 0 (Nonavalent vaccine), 7 (Quadrivalent vaccine)
Heterogeneity: Not applicable
Test for overall effect: Z=1.86 (P=0.06)

Favours nonavalent 0.01 0.1 1 10 100 Favours quadrivalent
## Analysis 5.11. Comparison 5 Nonavalent HPV vaccine versus quadrivalent HPV vaccine in 9- to 26-year-olds, Outcome 11 Overall local/injection site adverse events.

| Study or subgroup | Nonavalent vaccine | Quadrivalent vaccine | Risk Ratio | Weight | Risk Ratio |
|-------------------|--------------------|----------------------|------------|--------|------------|
|                   | n/N                | n/N                  |            |        |            |
| **5.11.1 9- to 15-year-old females** |                    |                      |            |        |            |
| Vesikari 2015     | 274/299            | 265/300              |            | 4.87%  | 1.04[0.98,1.09] |
| **Subtotal (95% CI)** | 299                | 300                  | 4.87%      | 1.04[0.98,1.09] |
| Total events: 274 (Nonavalent vaccine), 265 (Quadrivalent vaccine) | | | | | |
| Heterogeneity: Not applicable | | | | | |
| Test for overall effect: Z=1.35(P=0.18) | | | | | |

5.11.2 16- to 26-year-old females

| Study or subgroup | Nonavalent vaccine | Quadrivalent vaccine | Risk Ratio | Weight | Risk Ratio |
|-------------------|--------------------|----------------------|------------|--------|------------|
|                   | n/N                | n/N                  |            |        |            |
| Joura 2015        | 6961/7686          | 6009/7078            | 93.78%     | 1.07[1.05,1.08] |
| **Subtotal (95% CI)** | 7686 | 7078 | 93.78%  | 1.07[1.05,1.08] |
| Total events: 6961 (Nonavalent vaccine), 6009 (Quadrivalent vaccine) | | | | | |
| Heterogeneity: Not applicable | | | | | |
| Test for overall effect: Z=10.4(P<0.0001) | | | | | |

5.11.3 16- to 26-year-old males

| Study or subgroup | Nonavalent vaccine | Quadrivalent vaccine | Risk Ratio | Weight | Risk Ratio |
|-------------------|--------------------|----------------------|------------|--------|------------|
|                   | n/N                | n/N                  |            |        |            |
| van Damme 2016    | 196/249            | 179/251              | 1.35%      | 1.1[1.12] |
| **Subtotal (95% CI)** | 249                | 251                  | 1.35%      | 1.1[1.12] |
| Total events: 196 (Nonavalent vaccine), 179 (Quadrivalent vaccine) | | | | | |
| Heterogeneity: Not applicable | | | | | |
| Test for overall effect: Z=1.9(P=0.06) | | | | | |

| Total (95% CI) | 8234 | 7629 | 100% | 1.07[1.05,1.08] |
|----------------|------|------|------|----------------|
| Total events: 7431 (Nonavalent vaccine), 6453 (Quadrivalent vaccine) | | | | |
| Heterogeneity: Tau^2=0; Chi^2=1.47, df=2(P=0.48); I^2=0% | | | | |
| Test for overall effect: Z=10.59(P<0.0001) | | | | |
| Test for subgroup differences: Chi^2=1.46, df=1 (P=0.48), I^2=0% | | | | |

Favours nonavalent Favours quadrivalent

## Analysis 5.12. Comparison 5 Nonavalent HPV vaccine versus quadrivalent HPV vaccine in 9- to 26-year-olds, Outcome 12 Pain at injection site.

| Study or subgroup | Nonavalent vaccine | Quadrivalent vaccine | Risk Ratio | Weight | Risk Ratio |
|-------------------|--------------------|----------------------|------------|--------|------------|
|                   | n/N                | n/N                  |            |        |            |
| **5.12.1 9- to 15-year-old females** |                    |                      |            |        |            |
| Vesikari 2015     | 269/299            | 266/300              | 30.53%     | 1.01[0.96,1.07] |
| **Subtotal (95% CI)** | 299                | 300                  | 30.53%     | 1.01[0.96,1.07] |
| Total events: 269 (Nonavalent vaccine), 266 (Quadrivalent vaccine) | | | | | |
| Heterogeneity: Not applicable | | | | | |
| Test for overall effect: Z=0.51(P=0.61) | | | | | |

5.12.2 16- to 26-year-old females

| Study or subgroup | Nonavalent vaccine | Quadrivalent vaccine | Risk Ratio | Weight | Risk Ratio |
|-------------------|--------------------|----------------------|------------|--------|------------|
|                   | n/N                | n/N                  |            |        |            |
| Joura 2015        | 6900/7686          | 5911/7078            | 56.1%      | 1.07[1.06,1.09] |
| **Subtotal (95% CI)** | 7686 | 7078 | 56.1%  | 1.07[1.06,1.09] |
| Total events: 6900 (Nonavalent vaccine), 5911 (Quadrivalent vaccine) | | | | | |
| Heterogeneity: Not applicable | | | | | |

Favours nonavalent Favours quadrivalent

Comparison of different human papillomavirus (HPV) vaccine types and dose schedules for prevention of HPV-related disease in females and males (Review)

Copyright © 2019 The Authors. Cochrane Database of Systematic Reviews published by John Wiley & Sons, Ltd. on behalf of The Cochrane Collaboration.
### Analysis 5.13. Comparison 5 Nonavalent HPV vaccine versus quadrivalent HPV vaccine in 9- to 26-year-olds, Outcome 13 Swelling at injection site.

| Study or subgroup | Nonavalent vaccine | Quadrivalent vaccine | Risk Ratio | Weight | Risk Ratio |
|-------------------|--------------------|----------------------|------------|--------|------------|
|                   | n/N                | n/N                  | M-H, Random, 95% CI |        | M-H, Random, 95% CI |        |
| 5.13.1 9- to 15-year-old females |                   |                      |               |        |             |
| Vesikari 2015     | 144/299            | 109/300              | 5.45%        | 1.33[1.1,1.6] |             |
| Subtotal (95% CI) | 299                | 300                  | 5.45%        | 1.33[1.1,1.6] |             |
|                   | Total events: 144 (Nonavalent vaccine), 109 (Quadrivalent vaccine) |                   |               |        |             |
|                   | Heterogeneity: Not applicable |                   |               |        |             |
|                   | Test for overall effect: Z=2.9(P=0) |                   |               |        |             |
| 5.13.2 16- to 26-year-old females |                   |                      |               |        |             |
| Joura 2015        | 3039/7686          | 2035/7078            | 93.73%       | 1.38[1.31,1.44] |             |
| Subtotal (95% CI) | 7686               | 7078                | 93.73%       | 1.38[1.31,1.44] |             |
|                   | Total events: 3039 (Nonavalent vaccine), 2035 (Quadrivalent vaccine) |                   |               |        |             |
|                   | Heterogeneity: Not applicable |                   |               |        |             |
|                   | Test for overall effect: Z=13.6(P<0.0001) |                   |               |        |             |
| 5.13.3 16- to 26-year-old males |                   |                      |               |        |             |
| van Damme 2016    | 36/249             | 23/251               | 0.81%        | 1.58[0.96,2.58] |             |
| Subtotal (95% CI) | 249                | 251                  | 0.81%        | 1.58[0.96,2.58] |             |
|                   | Total events: 36 (Nonavalent vaccine), 23 (Quadrivalent vaccine) |                   |               |        |             |
|                   | Heterogeneity: Tau²=0; Chi²=0.44, df=2(P=0.8); I²=0% |                   |               |        |             |
|                   | Test for overall effect: Z=1.81(P=0.07) |                   |               |        |             |
|                   | Total (95% CI)     | 8234                 | 7629        | 100%   | 1.37[1.31,1.44] |             |
|                   | Total events: 3219 (Nonavalent vaccine), 2167 (Quadrivalent vaccine) |                   |               |        |             |
|                   | Heterogeneity: Tau²=0; Chi²=0.44, df=2(P=0.8); I²=0% |                   |               |        |             |
|                   | Test for overall effect: Z=14.01(P<0.0001) |                   |               |        |             |
|                   | Test for subgroup differences: Chi²=0.44, df=1 (P=0.5), I²=0% |                   |               |        |             |

| Favours nonavalent | 1 |
| Favours quadrivalent | 

Comparison of different human papillomavirus (HPV) vaccine types and dose schedules for prevention of HPV-related disease in females and males (Review)
### Analysis 5.14. Comparison 5 Nonavalent HPV vaccine versus quadrivalent HPV vaccine in 9- to 26-year-olds, Outcome 14 Redness at injection site.

| Study or subgroup | Nonavalent vaccine | Quadrivalent vaccine | Risk Ratio | Weight | Risk Ratio |
|------------------|---------------------|----------------------|------------|--------|-----------|
|                  | n/N                 | n/N                  |            |        | M-H, Random, 95% CI |
| **5.14.1 9- to 15-year-old females** | | | | | |
| Vesikari 2015    | 102/299             | 88/300               |            | 29.52% | 1.16[0.92,1.47] |
| Subtotal (95% CI)| 299                 | 300                  |            | 29.52% | 1.16[0.92,1.47] |
| Total events:   | 102 (Nonavalent vaccine), 88 (Quadrivalent vaccine) |         |         |        |           |
| Heterogeneity:   | Not applicable      |          |         |        |           |
| Test for overall effect: | Z=1.25(P=0.21) |         |         |        |           |
| **5.14.2 16- to 26-year-old females** | | | | | |
| Joura 2015       | 2602/7686           | 1810/7078           |            | 55.01% | 1.32[1.26,1.39] |
| Subtotal (95% CI)| 7686                | 7078                |            | 55.01% | 1.32[1.26,1.39] |
| Total events:   | 2602 (Nonavalent vaccine), 1810 (Quadrivalent vaccine) |         |         |        |           |
| Heterogeneity:   | Not applicable      |          |         |        |           |
| Test for overall effect: | Z=10.88(P<0.0001) |         |         |        |           |
| **5.14.3 16- to 26-year-old males** | | | | | |
| van Damme 2016   | 38/249              | 43/251              |            | 15.47% | 0.89[0.6,1.33] |
| Subtotal (95% CI)| 249                 | 251                 |            | 15.47% | 0.89[0.6,1.33] |
| Total events:   | 38 (Nonavalent vaccine), 43 (Quadrivalent vaccine) |         |         |        |           |
| Heterogeneity:   | Not applicable      |          |         |        |           |
| Test for overall effect: | Z=0.57(P=0.57) |         |         |        |           |
| **Total (95% CI)** | 8234                | 7629                |            | 100%   | 1.2[1,1.44] |
| Total events:   | 2742 (Nonavalent vaccine), 1941 (Quadrivalent vaccine) |         |         |        |           |
| Heterogeneity:   | Tau²=0; Chi²=4.72, df=1 (P=0.09), I²=57.64% | |
| Test for overall effect: | Z=1.93(P=0.05) |         |         |        |           |
| Test for subgroup differences: | Chi²=4.72, df=1 (P=0.09), I²=57.63% | |

**Favours nonavalent: 1**

**Favours quadrivalent: 1**

### Analysis 5.15. Comparison 5 Nonavalent HPV vaccine versus quadrivalent HPV vaccine in 9- to 26-year-olds, Outcome 15 Overall systemic events and general symptoms.

| Study or subgroup | Nonavalent vaccine | Quadrivalent vaccine | Risk Ratio | Weight | Risk Ratio |
|------------------|---------------------|----------------------|------------|--------|-----------|
|                  | n/N                 | n/N                  |            |        | M-H, Random, 95% CI |
| **5.15.1 9- to 15-year-old females** | | | | | |
| Vesikari 2015    | 142/299             | 156/300              |            | 3.08%  | 0.91[0.78,1.07] |
| Subtotal (95% CI)| 299                 | 300                  |            | 3.08%  | 0.91[0.78,1.07] |
| Total events:   | 142 (Nonavalent vaccine), 156 (Quadrivalent vaccine) |         |         |        |           |
| Heterogeneity:   | Tau²=0; Chi²=0, df=0(P=0.0001); I²=100% | |
| Test for overall effect: | Z=1.1(P=0.27) |         |         |        |           |
| **5.15.2 16- to 26-year-old females** | | | | | |
| Joura 2015       | 4268/7686           | 3886/7078           |            | 95.15% | 1.01[0.98,1.04] |
| Subtotal (95% CI)| 7686                | 7078                |            | 95.15% | 1.01[0.98,1.04] |

**Favours nonavalent: 1**

**Favours quadrivalent: 1**

---

Comparison of different human papillomavirus (HPV) vaccine types and dose schedules for prevention of HPV-related disease in females and males (Review)

Copyright © 2019 The Authors. Cochrane Database of Systematic Reviews published by John Wiley & Sons, Ltd. on behalf of The Cochrane Collaboration.
### Analysis 5.16. Comparison 5 Nonavalent HPV vaccine versus quadrivalent HPV vaccine in 9- to 26-year-olds, Outcome 16 Serious adverse events (overall).

| Study or subgroup | Nonavalent vaccine | Quadrivalent vaccine | Odds Ratio | Weight | Odds Ratio |
|-------------------|--------------------|----------------------|------------|--------|------------|
|                   | n/N                | n/N                  | M-H, Random, 95% CI |        | M-H, Random, 95% CI |
| **5.16.1 9- to 15-year-old females** | | | | | |
| Vesikari 2015     | 1/299             | 2/300                | 22.92%      | 0.50[0.05,5.54] |
| Subtotal (95% CI) | 299               | 300                  | 22.92%      | 0.50[0.05,5.54] |
|                   |                   |                      | Test for overall effect: Z=0.56(P=0.57) |
| **5.16.2 16- to 26-year-old females** | | | | | |
| Joura 2015        | 242/7686          | 184/7078             | 59%         | 1.22[1.1,1.48] |
| Subtotal (95% CI) | 7686              | 7078                 | 59%         | 1.22[1.1,1.48] |
|                   |                   |                      | Test for overall effect: Z=1.99(P=0.05) |
| **5.16.3 16- to 26-year-old males** | | | | | |
| van Damme 2016    | 0/249             | 6/251                | 18.08%      | 0.08[0.1,1.35] |
| Subtotal (95% CI) | 249               | 251                  | 18.08%      | 0.08[0.1,1.35] |
|                   |                   |                      | Test for overall effect: Z=1.76(P=0.08) |
| Total (95% CI)    | 8234              | 7629                 | 100%        | 0.60[0.14,2.61] |

Favours nonavalent 0.01 0.1 1 10 100  Favours quadrivalent
### Analysis 5.17. Comparison 5 Nonavalent HPV vaccine versus quadrivalent HPV vaccine in 9- to 26-year-olds, Outcome 17 Deaths.

| Study or subgroup | Nonavalent vaccine n/N | Quadrivalent vaccine n/N | Odds Ratio | Weight | Odds Ratio |
|-------------------|------------------------|--------------------------|------------|--------|------------|
| **5.17.1 9- to 15-year old females** | | | | | |
| Vesikari 2015     | 0/299                  | 0/300                    |            | 299    | Not estimable |
| Subtotal (95% CI) | 299                    | 300                      |            |        | Not estimable |
| Total events: 0 (Nonavalent vaccine), 0 (Quadrivalent vaccine) | | | | | |
| Heterogeneity: Not applicable | | | | | |
| Test for overall effect: Not applicable | | | | | |
| **5.17.2 16- to 26-year-old females** | | | | | |
| Joura 2015        | 6/7071                 | 5/7078                   |            | 7071   | 1.2[0.37,3.94] |
| Subtotal (95% CI) | 7071                   | 7078                     |            |        | 1.2[0.37,3.94] |
| Total events: 6 (Nonavalent vaccine), 5 (Quadrivalent vaccine) | | | | | |
| Heterogeneity: Not applicable | | | | | |
| Test for overall effect: Z=0.3(P=0.76) | | | | | |
| **5.17.3 16- to 26-year-old males** | | | | | |
| van Damme 2016    | 0/249                  | 0/251                    |            | 249    | Not estimable |
| Subtotal (95% CI) | 249                    | 251                      |            |        | Not estimable |
| Total events: 0 (Nonavalent vaccine), 0 (Quadrivalent vaccine) | | | | | |
| Heterogeneity: Not applicable | | | | | |
| Test for overall effect: Not applicable | | | | | |
| Total (95% CI)    | 7619                   | 7629                     |            |        | 1.2[0.37,3.94] |
| Total events: 6 (Nonavalent vaccine), 5 (Quadrivalent vaccine) | | | | | |
| Heterogeneity: Not applicable | | | | | |
| Test for overall effect: Z=0.3(P=0.76) | | | | | |
| Test for subgroup differences: Not applicable | | | | | |

### Comparison 6. Quadrivalent HPV vaccine versus control in people living with HIV

| Outcome or subgroup title | No. of studies | No. of participants | Statistical method | Effect size |
|---------------------------|----------------|---------------------|-------------------|-------------|
| 1 High-grade anal intraepithelial neoplasia | 1 | | Risk Ratio (M-H, Random, 95% CI) | Subtotals only |
| 1.1 ≥ 27-year-old females and males with HIV | 1 | 574 | Risk Ratio (M-H, Random, 95% CI) | 1.02 [0.70, 1.48] |
| Outcome or subgroup title | No. of studies | No. of participants | Statistical method | Effect size |
|---------------------------|----------------|---------------------|-------------------|-------------|
| 2 Recurrence of anogenital warts | 1 | | Risk Ratio (M-H, Random, 95% CI) | Subtotals only |
| 2.1 18- to 65-year-old females and males with HIV treated for anogenital warts | 1 | 12 | Risk Ratio (M-H, Random, 95% CI) | 0.71 [0.06, 8.90] |
| 3 Abnormal anal cytology | 1 | | Risk Ratio (M-H, Random, 95% CI) | Subtotals only |
| 3.1 ≥ 27-year-old females and males with HIV | 1 | 262 | Risk Ratio (M-H, Random, 95% CI) | 0.82 [0.64, 1.05] |
| 4 Overall local/injection site adverse events | 1 | | Risk Ratio (M-H, Random, 95% CI) | Subtotals only |
| 4.1 7- to 12-year-old children with HIV | 1 | 126 | Risk Ratio (M-H, Random, 95% CI) | 2.19 [0.70, 6.83] |
| 5 Overall systemic event and general symptoms | 1 | | Odds Ratio (M-H, Random, 95% CI) | Subtotals only |
| 5.1 7- to 12-year-old children with HIV | 1 | 126 | Odds Ratio (M-H, Random, 95% CI) | 0.62 [0.05, 7.05] |
| 6 Serious adverse events (overall) | 2 | | Odds Ratio (M-H, Random, 95% CI) | Subtotals only |
| 6.1 ≥ 27 year old females and males with HIV | 1 | 575 | Odds Ratio (M-H, Random, 95% CI) | 0.68 [0.42, 1.10] |
| 6.2 ≥ 18-year-old MSM with HIV | 1 | 129 | Odds Ratio (M-H, Random, 95% CI) | 0.0 [0.0, 0.0] |
| 7 Deaths | 2 | | Odds Ratio (M-H, Random, 95% CI) | Subtotals only |
| 7.1 ≥ 27-year-old females and males with HIV | 1 | 575 | Odds Ratio (M-H, Random, 95% CI) | 0.49 [0.12, 1.99] |
| 7.2 ≥ 18-year-old MSM with HIV | 1 | 129 | Odds Ratio (M-H, Random, 95% CI) | 0.0 [0.0, 0.0] |

### Analysis 6.1. Comparison 6 Quadrivalent HPV vaccine versus control in people living with HIV, Outcome 1 High-grade anal intraepithelial neoplasia.

| Study or subgroup | Quadrivalent vaccine | Control | Risk Ratio | Weight | Risk Ratio |
|------------------|----------------------|---------|------------|--------|------------|
| 6.1.1 ≥ 27-year-old females and males with HIV | Wilkin 2018 | 46/288 | 45/286 | M-H, Random, 95% CI | 1.02 (0.7, 1.48) |

Comparison of different human papillomavirus (HPV) vaccine types and dose schedules for prevention of HPV-related disease in females and males (Review)

Copyright © 2019 The Authors. Cochrane Database of Systematic Reviews published by John Wiley & Sons, Ltd. on behalf of The Cochrane Collaboration.
### Analysis 6.2. Comparison 6 Quadrivalent HPV vaccine versus control in people living with HIV, Outcome 2 Recurrence of anogenital warts.

| Study or subgroup | Quadrivalent vaccine | Control | Risk Ratio | Weight | Risk Ratio |
|-------------------|----------------------|---------|------------|--------|------------|
|                   | n/N                  | n/N     | M-H, Random, 95% CI | M-H, Random, 95% CI |
| Subtotal (95% CI) | 288                  | 286     | 100%       | 1.02  | [0.7,1.48] |

- Total events: 46 (Quadrivalent vaccine), 45 (Control)
- Heterogeneity: Not applicable
- Test for overall effect: Z=0.08 (P=0.94)

Favours quadrivalent 0.5 | 0.7 | 1 | 1.5 | 2 |
Favours control

### Analysis 6.3. Comparison 6 Quadrivalent HPV vaccine versus control in people living with HIV, Outcome 3 Abnormal anal cytology.

| Study or subgroup | Quadrivalent vaccine | Control | Risk Ratio | Weight | Risk Ratio |
|-------------------|----------------------|---------|------------|--------|------------|
|                   | n/N                  | n/N     | M-H, Random, 95% CI | M-H, Random, 95% CI |
| Subtotal (95% CI) | 58/130               | 72/132  | 100%       | 0.82  | [0.64,1.05] |

- Total events: 58 (Quadrivalent vaccine), 72 (Control)
- Heterogeneity: Not applicable
- Test for overall effect: Z=1.6 (P=0.11)

Favours quadrivalent 0.01 | 0.1 | 1 | 10 | 100 |
Favours control

### Analysis 6.4. Comparison 6 Quadrivalent HPV vaccine versus control in people living with HIV, Outcome 4 Overall local/injection site adverse events.

| Study or subgroup | Quadrivalent vaccine | Control | Risk Ratio | Weight | Risk Ratio |
|-------------------|----------------------|---------|------------|--------|------------|
|                   | n/N                  | n/N     | M-H, Random, 95% CI | M-H, Random, 95% CI |
| Subtotal (95% CI) | 21/96                | 3/30    | 100%       | 2.19  | [0.7,6.83] |

- Total events: 21 (Quadrivalent vaccine), 3 (Control)

Favours quadrivalent 0.01 | 0.1 | 1 | 10 | 100 |
Favours control
### Analysis 6.5. Comparison 6 Quadrivalent HPV vaccine versus control in people living with HIV, Outcome 5 Overall systemic event and general symptoms.

| Study or subgroup | Quadrivalent vaccine | Control | Risk Ratio | Weight | Risk Ratio |
|-------------------|----------------------|---------|------------|--------|------------|
|                   | n/N                  | n/N     | M-H, Random, 95% CI |        | M-H, Random, 95% CI |
| 6.5.1 7- to 12-year-old children with HIV | | | | | |
| Levin 2010        | 2/96                 | 1/30    | 100%       | 0.62   | [0.05, 7.05] |
| Subtotal (95% CI) | 96                   | 30      | 100%       | 0.62   | [0.05, 7.05] |
| Total events:     | 2 (Quadrivalent vaccine), 1 (Control) |
| Heterogeneity:    | Not applicable |
| Test for overall effect: Z = 1.35 (P = 0.18) |

Favours quadrivalent 0.01 0.1 1 10 100 Favours control

### Analysis 6.6. Comparison 6 Quadrivalent HPV vaccine versus control in people living with HIV, Outcome 6 Serious adverse events (overall).

| Study or subgroup | Quadrivalent vaccine | Control | Odds Ratio | Weight | Odds Ratio |
|-------------------|----------------------|---------|------------|--------|------------|
|                   | n/N                  | n/N     | M-H, Random, 95% CI |        | M-H, Random, 95% CI |
| 6.6.1 ≥ 27 year old females and males with HIV | | | | | |
| Wilkin 2018       | 33/288               | 46/287  | 100%       | 0.68   | [0.42, 1.1] |
| Subtotal (95% CI) | 288                  | 287     | 100%       | 0.68   | [0.42, 1.1] |
| Total events:     | 33 (Quadrivalent vaccine), 46 (Control) |
| Heterogeneity:    | Not applicable |
| Test for overall effect: Z = 1.58 (P = 0.11) |

Favours quadrivalent 0.01 0.1 1 10 100 Favours control

| Study or subgroup | Quadrivalent vaccine | Control | Odds Ratio | Weight | Odds Ratio |
|-------------------|----------------------|---------|------------|--------|------------|
|                   | n/N                  | n/N     | M-H, Random, 95% CI |        | M-H, Random, 95% CI |
| 6.6.2 ≥ 18-year-old MSM with HIV | | | | | |
| Hidalgo-Tenorio 2017 | 0/66                | 0/63    | Not estimable |       | Not estimable |
| Subtotal (95% CI)  | 66                   | 63      | Not estimable |       | Not estimable |
| Total events:     | 0 (Quadrivalent vaccine), 0 (Control) |
| Heterogeneity:    | Not applicable |
| Test for overall effect: Not applicable |
| Test for subgroup differences: Not applicable |

Favours quadrivalent 0.01 0.1 1 10 100 Favours control

Comparison of different human papillomavirus (HPV) vaccine types and dose schedules for prevention of HPV-related disease in females and males (Review)

Copyright © 2019 The Authors. Cochrane Database of Systematic Reviews published by John Wiley & Sons, Ltd. on behalf of The Cochrane Collaboration.
Analysis 6.7. Comparison 6 Quadrivalent HPV vaccine versus control in people living with HIV, Outcome 7 Deaths.

| Study or subgroup | Quadrivalent vaccine | Control | Odds Ratio | Weight | Odds Ratio |
|-------------------|----------------------|---------|------------|--------|------------|
|                   | n/N                  | n/N     | M-H, Random, 95% CI |        | M-H, Random, 95% CI |
| 6.7.1 ≥ 27-year-old females and males with HIV | Wilkin 2018 | 3/288 | 6/287 | 100% | 0.49 [0.12, 1.99] |
|                   | Subtotal (95% CI)    | 288     | 287 | 100% | 0.49 [0.12, 1.99] |
| Total events: 3 (Quadrivalent vaccine), 6 (Control) | Heterogeneity: Not applicable |
| Test for overall effect: Z=0.99 (P=0.32) |

6.7.2 ≥ 18-year-old MSM with HIV

| Study or subgroup | Quadrivalent vaccine | Control | Odds Ratio | Weight | Odds Ratio |
|-------------------|----------------------|---------|------------|--------|------------|
|                   | n/N                  | n/N     | M-H, Random, 95% CI |        | M-H, Random, 95% CI |
| Hidalgo-Tenorio 2017 | 0/66     | 0/63 | Not estimable | Not estimable |
| Subtotal (95% CI) | 66 | 63 | Not estimable | Not estimable |
| Total events: 0 (Quadrivalent vaccine), 0 (Control) | Heterogeneity: Not applicable |
| Test for overall effect: Not applicable |
| Test for subgroup differences: Not applicable |

Comparison 7. Bivalent HPV vaccine versus control in 18- to 25-year-old females with HIV

| Outcome or subgroup title | No. of studies | No. of participants | Statistical method | Effect size |
|---------------------------|----------------|---------------------|--------------------|-------------|
| 1 Pain at injection site  | 1              | 120                 | Risk Ratio (M-H, Random, 95% CI) | 1.86 [1.38, 2.51] |
| 2 Swelling at injection site | 1          | 120                 | Risk Ratio (M-H, Random, 95% CI) | 9.19 [2.24, 37.73] |
| 3 Serious adverse events (overall) | 1          | 120                 | Odds Ratio (M-H, Random, 95% CI) | 1.47 [0.24, 9.15] |
| 4 Deaths                  | 1              | 120                 | Odds Ratio (M-H, Random, 95% CI) | 0.0 [0.0, 0.0] |

Analysis 7.1. Comparison 7 Bivalent HPV vaccine versus control in 18- to 25-year-old females with HIV, Outcome 1 Pain at injection site.

| Study or subgroup | Bivalent vaccine | Control | Risk Ratio | Weight | Risk Ratio |
|-------------------|------------------|---------|------------|--------|------------|
|                   | n/N              | n/N     | M-H, Random, 95% CI |        | M-H, Random, 95% CI |
| Denny 2013        | 52/61            | 27/59   | 1.86 [1.38, 2.51] | 100% | 1.86 [1.38, 2.51] |
| Total (95% CI)    | 61               | 59      | 100%       | 1.86 [1.38, 2.51] |
| Total events: 52 (Bivalent vaccine), 27 (Control) | Heterogeneity: Not applicable |
| Test for overall effect: Z=4.11 (P<0.0001) |

Comparison of different human papillomavirus (HPV) vaccine types and dose schedules for prevention of HPV-related disease in females and males (Review)
Copyright © 2019 The Authors. Cochrane Database of Systematic Reviews published by John Wiley & Sons, Ltd. on behalf of The Cochrane Collaboration.
### Analysis 7.2. Comparison 7 Bivalent HPV vaccine versus control in 18- to 25-year-old females with HIV, Outcome 2 Swelling at injection site.

| Study or subgroup | Bivalent vaccine | Control | Risk Ratio | Weight | Risk Ratio |
|-------------------|------------------|---------|------------|--------|------------|
| Denny 2013        | 19/61            | 2/59    | M-H, Random, 95% CI | 100%   | 9.19[2.24,37.73] |
| Total (95% CI)    | 61               | 59      | M-H, Random, 95% CI | 100%   | 9.19[2.24,37.73] |

- Total events: 19 (Bivalent vaccine), 2 (Control)
- Heterogeneity: Not applicable
- Test for overall effect: Z=3.08 (P=0)

Favours bivalent

### Analysis 7.3. Comparison 7 Bivalent HPV vaccine versus control in 18- to 25-year-old females with HIV, Outcome 3 Serious adverse events (overall).

| Study or subgroup | Bivalent vaccine | Control | Odds Ratio | Weight | Odds Ratio |
|-------------------|------------------|---------|------------|--------|------------|
| Denny 2013        | 3/61             | 2/59    | M-H, Random, 95% CI | 100%   | 1.47[0.24,9.15] |
| Total (95% CI)    | 61               | 59      | M-H, Random, 95% CI | 100%   | 1.47[0.24,9.15] |

- Total events: 3 (Bivalent vaccine), 2 (Control)
- Heterogeneity: Not applicable
- Test for overall effect: Z=0.42 (P=0.68)

Favours bivalent

### Analysis 7.4. Comparison 7 Bivalent HPV vaccine versus control in 18- to 25-year-old females with HIV, Outcome 4 Deaths.

| Study or subgroup | Bivalent vaccine | Control | Odds Ratio | Weight | Odds Ratio |
|-------------------|------------------|---------|------------|--------|------------|
| Denny 2013        | 0/61             | 0/59    | M-H, Random, 95% CI | Not estimable | Not estimable |
| Total (95% CI)    | 61               | 59      | M-H, Random, 95% CI | Not estimable | Not estimable |

- Total events: 0 (Bivalent vaccine), 0 (Control)
- Heterogeneity: Not applicable
- Test for overall effect: Not applicable

Favours bivalent

### Comparison 8. Bivalent HPV vaccine versus quadrivalent HPV vaccine in people living with HIV

| Outcome or subgroup title | No. of studies | No. of participants | Statistical method | Effect size |
|---------------------------|----------------|---------------------|--------------------|-------------|
| 1 Overall local/injection site adverse events | 1 | | Risk Ratio (M-H, Random, 95% CI) | Subtotals only |

Comparison of different human papillomavirus (HPV) vaccine types and dose schedules for prevention of HPV-related disease in females and males (Review)

Copyright © 2019 The Authors. Cochrane Database of Systematic Reviews published by John Wiley & Sons, Ltd. on behalf of The Cochrane Collaboration.
### Outcome or subgroup title

| Outcome or subgroup title                             | No. of studies | No. of participants | Statistical method                  | Effect size                  |
|-------------------------------------------------------|----------------|---------------------|-------------------------------------|-----------------------------|
| 1.1 ≥ 18-year-old females and males with HIV           | 1              | 92                  | Risk Ratio (M-H, Random, 95% CI)    | 1.31 [1.06, 1.62]            |
| 2 Serious adverse events (overall)                     | 2              |                     | Odds Ratio (M-H, Random, 95% CI)    | Subtotals only              |
| 2.1 ≥ 18-year-old females and males with HIV           | 1              | 92                  | Odds Ratio (M-H, Random, 95% CI)    | 0.0 [0.0, 0.0]               |
| 2.2 15- to 25-year-old females with HIV                | 1              | 332                 | Odds Ratio (M-H, Random, 95% CI)    | 0.99 [0.38, 2.55]            |

### Analysis 8.1. Comparison 8 Bivalent HPV vaccine versus quadrivalent HPV vaccine in people living with HIV, Outcome 1 Overall local/injection site adverse events.

| Study or subgroup                                      | Bivalent vaccine | Quadrivalent vaccine | Risk Ratio | Weight | Risk Ratio |
|--------------------------------------------------------|------------------|----------------------|------------|--------|------------|
| 8.1.1 ≥ 18-year-old females and males with HIV         |                  |                      | M-H, Random, 95% CI |        | M-H, Random, 95% CI |
| Toft 2014                                              | 42/46            | 32/46                | 1.31       | 100%   | 1.31 [1.06, 1.62] |
| Subtotal (95% CI)                                      | 46               | 46                   |            | 100%   | 1.31 [1.06, 1.62] |

Total events: 42 (Bivalent vaccine), 32 (Quadrivalent vaccine)
Heterogeneity: Not applicable
Test for overall effect: Z=2.53 (P=0.01)

### Analysis 8.2. Comparison 8 Bivalent HPV vaccine versus quadrivalent HPV vaccine in people living with HIV, Outcome 2 Serious adverse events (overall).

| Study or subgroup                                      | Bivalent vaccine | Quadrivalent vaccine | Odds Ratio | Weight | Odds Ratio |
|--------------------------------------------------------|------------------|----------------------|------------|--------|------------|
| 8.2.1 ≥ 18-year-old females and males with HIV         |                  |                      | M-H, Random, 95% CI |        |            |
| Toft 2014                                              | 0/46             | 0/46                 | Not estimable |        |            |
| Subtotal (95% CI)                                      | 46               | 46                   |            |        |            |

Total events: 0 (Bivalent vaccine), 0 (Quadrivalent vaccine)
Heterogeneity: Not applicable
Test for overall effect: Not applicable

| 8.2.2 15- to 25-year-old females with HIV              |                  |                      | M-H, Random, 95% CI |        |            |
|--------------------------------------------------------|------------------|----------------------|------------|--------|------------|
| NCT01031069 2017                                       | 9/167            | 9/165                | 0.99       | 100%   | 0.99 [0.38, 2.55] |
| Subtotal (95% CI)                                      | 167              | 165                  |            | 100%   | 0.99 [0.38, 2.55] |

Total events: 9 (Bivalent vaccine), 9 (Quadrivalent vaccine)
Heterogeneity: Not applicable
Test for overall effect: Z=0.03 (P=0.98)
Test for subgroup differences: Not applicable

Favours bivalent 0.01 0.1 1 10 100 Favours quadrivalent
### ADDITIONAL TABLES

**Table 1. Serious adverse events**

| Study          | Group                                      | Number of participants with serious adverse events | Details of serious adverse events* |
|----------------|--------------------------------------------|---------------------------------------------------|-----------------------------------|
| Denny 2013     | Vaccine (bivalent)                         | 3/61                                              | Gastroenteritis, bacterial pneumonia, migraine |
|                | Control                                    | 2/59                                              | Lobar pneumonia, skull fracture    |
| Dobson 2013    | Vaccine (quadrivalent; 2-dose)             | 0/259                                             |                                    |
|                | Vaccine (quadrivalent; 3-dose)             | 0/261                                             |                                    |
| Giuliano 2011  | Vaccine (quadrivalent)                     | 8/2020                                            | 8 participants with 12 events: cardiac arrest, non-cardiac chest pain, hypersensitivity, appendicitis, cellulitis, varicella infection, cervical vertebral fracture, gunshot wound, road traffic accident, traumatic brain injury, traumatic intracranial haemorrhage, convulsion |
|                | Control                                    | 11/2033                                           | 11 participants with 13 events: myocardial ischaemia, pericardial haemorrhage, accidental overdose, chemical poisoning, contusion, gunshot wound (3), head injury, multiple drug overdose, road traffic accident, completed suicide (2) |
| NCT01031069 2017 | Vaccine (bivalent)                        | 9/167                                             | 9 participants with 10 events: immune thrombocytopenic purpura, gastritis, meningitis tuberculous, pneumonia, pneumonia mycoplasmal, tonsillitis, viral infection, road traffic accident, miscarriage, renal failure |
|                | Vaccine (quadrivalent)                     | 9/165                                             | 9 participants with 10 events: appendicitis (2), pneumonia bacterial, pulmonary tuberculosis, tonsillitis, urinary tract infection, monoarthritis, abortion spontaneous complete, pre-eclampsia, suicide attempt |
| NCT01862874 2018 | Vaccine (quadrivalent)                  | 0/554                                             |                                    |
|                | Control                                    | 1/559                                             | Completed suicide                  |
| Hidalgo-Tenorio 2017   | Vaccine (quadrivalent)                   | 0/66                                              |                                    |
|                | Control                                    | 0/66                                              |                                    |
| Iversen 2016   | Vaccine (nonavalent; 2-dose, 6-month interval in females) | 6/301                                             | 6 participants with 7 events: abdominal pain (2), appendicitis, dengue fever, pharyngitis, foreign body injury, ovarian cyst |
|                | Vaccine (nonavalent; 2-dose, 6-            | 9/301                                             | 9 participants with 10 events: Wolff-Parkinson-White syndrome, diarrhoea, animal bite, appendicitis, rotavirus gastroenteritis, |
### Table 1. Serious adverse events (Continued)

| Vaccine (nonavalent; 2-dose, 12-month interval in males and females) | 3(6)/301 | 1 female participant with atopic dermatitis  
2 male participants with appendicitis, forearm fracture  
At 37 month follow-up there were 3 additional serious adverse events: gastritis, oral herpes, radiculopathy (disaggregated data by sex were not available) |
| --- | --- | --- |
| Vaccine (nonavalent; 3-dose in females) | 6/301 | 6 participants with 8 events: cardiac arrest, appendicitis, subcutaneous abscess, papillary thyroid cancer, encephalitis autoimmune, status epilepticus, depression, ovarian cyst |
| Joura 2015 Vaccine (nonavalent) | 242/7686 | 242 participants with 269 events: Anaemia, aortic valve incompetence, postural orthostatic tachycardia syndrome, vertigo positional, anal fistula, coeliac disease, Crohn’s disease, diarrhoea, gastritis, haemorrhoids, inguinal hernia, irritable bowel syndrome, pyrexia, sudden death, cholangitis, cholecystitis, cholelithiasis, allergy to vaccine, anaphylactic reaction, hypersensitivity, sarcoidosis, jaw abscess, appendicitis (10), cholecystitis infiltrative, chronic tonsillitis, dengue fever, infectious enteritis (2), gastroenteritis, viral gastroenteritis, haemorrhagic fever, infectious mononucleosis, influenza, pharyngitis, pylonephritis (2), pylonephritis acute, septic shock, tonsillitis, tonsillitis streptococcal, urinary tract infection (3), urosepsis, wound infection, bladder injury, burns second degree, craniofacial injury, femur fracture, humerus fracture (2), ligament rupture, lower limb fracture, multiple injuries (2), pubis fracture, road traffic accident, spinal compression fracture, hyperglycaemia, myalgia, osteoarthritis, acute lymphocytic leukaemia, acute promyelocytic leukaemia, adenocarcinoma of the cervix, brain neoplasm, ependymoma, leukaemic infiltration brain, malignant melanoma (2), malignant melanoma in situ, nasal cavity cancer, ovarian neoplasm, diabetic coma, epilepsy, hypomnia, Intracranial venous sinus thrombosis, migraine, multiple sclerosis (2), presyncope, sciatica, sensory disturbance, syncope (2), tension headache, abortion spontaneous (40), abortion spontaneous incomplete, blighted ovum, cephalo-pelvic disproportion (4), cervix dystocia, false labour, foetal death (2), foetal distress syndrome (5), labour complication, pre-eclampsia (2), premature labour, premature rupture of membranes (4), prolonged labour (2), uterine contractions during pregnancy, anorexia and bulimia syndrome, bipolar disorder (3), completed suicide, major depression, calculus ureteric, calculus urinary, nephrolithiasis, renal failure (2), bartholinitis, cervical dysplasia (5), cervix haemorrhage uterine, endometriosis (2), ovarian cyst, pelvic pain, asthmatic crisis, pneumonia aspiration, pneumothorax, respiratory failure, vocal cord polyp, abortion induced (79), deep vein thrombosis, hypovolaemic shock (2) |
| Vaccine (quadrivalent) | 184/7078 | 184 participants with 197 events: Anaemia, cleft lip and palate, Meckel’s diverticulum, abdominal pain (2), abdominal pain lower, colitis ulcerative, enterocolitis, gastritis, inguinal hernia, omental infection, cholecystitis, cholelithiasis (2), appendicitis (16), bronchitis (2), cellulitis, conjunctivitis, gastroenteritis (2), influenza, pelvic inflammatory disease, post abortion infection, pylonephritis, pylonephritis acute (2), urinary tract infection (2), viral pharyngitis, foreign body in eye, fracture dis- |
| vaccine | patients | serious adverse events |
|---------|----------|-----------------------|
| Vaccine (quadrivalent) | 58/2436 | Splenomegaly, vitello-intestinal duct remnant, abdominal pain, colitis ulcerative, constipation, food poisoning, chest pain, pyrexia, cholesystitis, appendicitis, appendicitis perforated, infectious mononucleosis, peritonsillar abscess, pneumonia, pneumonia bacterial, salmonellosis, tonsillitis, alcohol poisoning, alcoholic, renal failure acute, cervical dysplasia, dysmenorrhoea, endometriosis, fallopian tube cyst, ovarian cyst, dyspareunia, nasal polyps, abortion induced |
| Vaccine (control, HBV) | 25/1267 | Appendicitis, appendicitis perforated, bronchitis, gastroenteritis bacterial, infectious mononucleosis, peritonsillar abscess, sinusitis, sinusitis bacterial, alcohol poisoning, foot fracture, forearm fracture, hand fracture, joint dislocation, splenic rupture, tibia fracture, traumatic renal injury, type 1 diabetes mellitus, astrocytoma low grade, depression, panic disorder, suicide attempt, dyspnoea |
| Vaccine (bivalent; 2-dose) | 11/358 | Abdominal pain lower, mouth cyst, appendicitis, gastroenteritis viral, lung abscess, peritonitis, viral infection, joint dislocation, teratoma, epilepsy, seizure, asthma, eczema |
| Vaccine (bivalent; 3-dose) | 14/358 | Lymphadenitis, vertigo positional, abdominal pain, anaphylactic shock, upper respiratory tract infection, pneumonia, influenza, vulval ulceration, ankle fracture, overdose, tendon injury, presyncope, tension headache, abortion spontaneous incomplete, completed suicide, depression, menorrhagia |
| Vaccine (quadrivalent) | 0/96 | |
| Control | 0/30 | |
| Study            | Vaccine Schedule                  | Events | Events Description |
|------------------|-----------------------------------|--------|--------------------|
| Lin 2014         | Vaccine (quadrivalent; 10-month interval) | 0/111  | Pericardial effusion, abdominal mass, abdominal pain, anal fistula, colitis, chest pain, death, appendicitis, cellulitis, chlamydial infection, gastroenteritis viral, influenza, meningitis viral, peritonislar abscess, pneumonia, pneumonia pneumococcal, pseudomembranous colitis, sepsis, lower limb fracture, multiple injuries, stab wound, anal cancer, basal cell carcinoma, Hodgkin’s disease, prostate cancer, transitional cell carcinoma, cerebrovascular accident, seizure, acute psychosis, alcohol withdrawal syndrome, depression, suicide attempt, acute respiratory failure, alveolitis allergic, asthma, pleural effusion, intervertebral disc operation |
|                 | Vaccine (quadrivalent; 4-month interval) | 0/109  | Not reported |
| NCT00941889 2016 | Vaccine (quadrivalent)             | Not reported | Not reported |
|                 | Control                            | Not reported | Not reported |
| Wilkin 2018      | Vaccine (quadrivalent)             | 33/288 | 33 participants with 40 events: Pericardial effusion, abdominal mass, abdominal pain, anal fistula, colitis, chest pain, death, appendicitis, cellulitis, chlamydial infection, gastroenteritis viral, influenza, meningitis viral, peritonislar abscess, pneumonia, pneumonia pneumococcal, pseudomembranous colitis, sepsis, lower limb fracture, multiple injuries, stab wound, anal cancer, basal cell carcinoma, Hodgkin’s disease, prostate cancer, transitional cell carcinoma, cerebrovascular accident, seizure, acute psychosis, alcohol withdrawal syndrome, depression, suicide attempt, acute respiratory failure, alveolitis allergic, asthma, pleural effusion, intervertebral disc operation |
|                 | Control                            | 46/287 | 46 participants with 79 events: Acute myocardial infarction, coronary artery disease, myocardial infarction, abdominal pain, gastrointestinal haemorrhage, large intestine perforation, pancreatitis, pancreatitis acute, pancreatitis chronic, small intestinal obstruction, chest pain, pyrexia, cholelithiasis, bronchitis, diverticulitis, gastroenteritis, gastroenteritis viral, influenza, orchitis, perirectal abscess, pneumonia, pneumonia streptococcal, primary syphilis, pyelonephritis, scrotal abscess, sepsis, viral infection, fall, foot fracture, overdose, radius fracture, road traffic accident, weight decreased, dehydration, osteoarthritis, anal cancer, anal squamous cell carcinoma, B-cell lymphoma, basal cell carcinoma, follicle centre lymphoma diffuse small cell lymphoma, oesophageal adenocarcinoma, pancreatic carcinoma metastatic, prostate cancer, renal cell carcinoma, squamous cell carcinoma of head and neck, haemorrhagic stroke, syncope, alcohol withdrawal syndrome, completed suicide, mental status changes, psychotic disorder, substance abuse, suicide attempt, genital ulceration, chronic obstructive pulmonary disease, dyspnoea, pleural effusion, pulmonary hypertension, hypotension |
| Petaja 2009      | Vaccine (bivalent)                 | 3/181  | Crohn’s disease, appendicitis, epilepsy |
| Control (HBV)    | 1/89                               | Osteochondrosis |
| Puthanakit 2016  | Vaccine (bivalent; 2-dose, 6-month interval) | 20/550 | 20 participants with 34 events: Lymphadenitis, autoimmune thyroiditis, strabismus, abdominal strangulated hernia, abdominal pain, anal haemorrhage, gastritis, nausea, chronic gastritis, anaphylactic reaction, cholelithiasis, infections and infestations, injury, poisoning and procedural complications, type 1 diabetes mellitus, cholesteatoma, convulsion, seizure, IgA nephropathy, respiratory disorder |
### Table 1. Serious adverse events (Continued)

| Vaccine (bivalent; 2-dose, 12-month interval) | 24/415 |
|-----------------------------------------------|--------|
| 24 participants with 38 events: Lymphadenitis, supraventricular tachycardia, abdominal pain lower, constipation, dyspepsia, faecaloma, drug hypersensitivity, infections and infestations (25), injury, poisoning and procedural complications, hypovolaemia, systemic lupus erythematosus, VIIth nerve paralysis, tonsillar hypertrophy, circulatory collapse |

| Vaccine (bivalent; 3-dose) | 28/482 |
|----------------------------|--------|
| 28 participants with 53 events: Infections and infestations (32), injury, poisoning and procedural complications (3), hypovolaemia (2), synovial cyst, medulloblastoma, synovial sarcoma, uterine leiomyoma, hyperemesis gravidarum, premature baby, abortion threatened, postpartum haemorrhage, stillbirth, schizoaffective disorder (3), psychotic disorder, ovarian cyst ruptured, transient tachypnoea of the newborn, ectopic pregnancy termination |

| Romanowski 2011 Vaccine (bivalent; 3-dose) | 15/239 |
|---------------------------------------------|--------|
| 15 participants with 20 events: Basedow’s disease, abdominal pain, appendix disorder, gastroenteritis, appendicitis, pharyngitis streptococcal, tonsillitis (2), urinary tract infection, ligament rupture, multiple injuries, ligament laxity, polyarthritis, migraine with aura, abortion spontaneous incomplete, abnormal behaviour, depression, renal colic, renal disorder, erythema multiforme |

| Vaccine (bivalent; 2-dose) | 16/241 |
|----------------------------|--------|
| 16 participants with 26 events: Abdominal pain, umbilical hernia (2), obstructive vomiting, gastroenteritis viral, cholecystitis acute, acute tonsillitis, appendicitis (2), endometritis decidual, vestibular neuritis, rib fracture, contusion, fall, fibroma, fibrosarcoma, pre-eclampsia, premature baby, abortion missed, depression, major depression, psychotic disorder, suicide attempt, cystitis haemorrhagic, hyperventilation, circulatory collapse |

| Vaccine (bivalent; 2-dose, 6-month interval) | 19/240 |
|----------------------------------------------|--------|
| 19 participants with 23 events: Atrial septal defect, spina bifida, bile duct stone, appendicitis (4), tonsillitis bacterial, humerus fracture, road traffic accident, rib fracture, upper limb fracture, malignant melanoma stage IV, basilar artery thrombosis, cerebrovascular accident, abortion spontaneous, abortion spontaneous incomplete (2), foetal distress syndrome, anorexia nervosa, bulimia nervosa, depression, circulatory collapse |

| Vaccine (bivalent; 2-dose, 2-month interval) | 14/240 |
|---------------------------------------------|--------|
| 14 participants with 16 events: Abdominal pain (3), hepatomegaly, pilonidal cyst, urinary tract infection, vestibular neuritis, concussion, stab wound, coccydynia, uterine leiomyoma, benign hydatidiform mole, abortion spontaneous, ectopic pregnancy, adenomyosis, ovarian cyst |

| Toft 2014 Vaccine (bivalent) | 0/46 |
|-----------------------------|------|
| | |
| Vaccine (quadrivalent) | 0/46 |

| van Damme 2016 Vaccine (nonavalent) | 0/249 |
|-------------------------------------|-------|
| | |
| Vaccine (quadrivalent) | 6/251 |
| | Joint dislocation, ligament injury, ligament rupture, foot fracture, concussion, cytomegalovirus infection |
Table 1. Serious adverse events (Continued)

| Vaccine (nonavalent) | 1/299 | One participant with two events: Anaemia and pulmonary vasculitis |
|----------------------|-------|------------------------------------------------------------------|
| Vaccine (quadrivalent) | 2/300 | Complex partial seizures, Henoch-Schonlein purpura |

Abbreviations
*For each event, n = 1 unless otherwise stated.

HBV: hepatitis B vaccine

Table 2. Characteristic of licensed prophylactic HPV vaccines

| Bivalent vaccine | Quadrivalent vaccine | Nonavalent vaccine |
|------------------|----------------------|--------------------|
| **Manufacturer** | GlaxoSmithKline (GSK, Rixensart, Belgium) | Merck, Sharp & Dome (Merck & Co, Whitehouse Station, NJ, USA) |
| **Antigens** | L1 VLPs of HPV16 (20 μg) and HPV18 (20 μg) | L1 VLPs of HPV6 (20 μg), HPV11 (40 μg), HPV16 (40 μg) and HPV18 (20 μg) |
| **Vaccination schedule** | 3 doses: at day 1, month 1, and month 6 | 3 doses: at day 1, month 2, and month 6 |
| **Adjuvant** | AS04: 500 μg aluminium hydroxide, 50 μg 3-deacylated monophosphoryl lipid A (MPL) | 225 μg amorphous aluminium hydroxyl-phosphate sulphate |
| **Trade name** | Cervarix | Gardasil, Silgard |
| **Produced by recombinant technology using** | Baculovirus in Trichoplusia in insect cells | Saccharomyces cerevisiae (Baker’s yeast) |
| **Produced by recombinant technology using** | Saccharomyces cerevisiae (Baker’s yeast) |

Abbreviations
HPV: human papillomavirus
MPL: monophosphoryl lipid
VLP: virus-like particle

Table 3. Summary of findings: Quadrivalent HPV vaccine compared with control in children, adults, and MSM with HIV

Quadrivalent HPV vaccine compared with control in children, adults, and MSM with HIV

**Patient or population:** children (7 to 12 years old) with HIV, adults (≥ 18 years old) with HIV, and MSM (≥ 18 years old) with HIV

**Settings:** Brazil, Puerto Rico, Spain, the USA

**Intervention:** quadrivalent HPV vaccine (3 doses at 0, 2, and 6 months)

**Comparison:** control (3 doses at 0, 2 and 6 months; not specified whether placebo contained vaccine adjuvant)
Table 3. Summary of findings: Quadrivalent HPV vaccine compared with control in children, adults, and MSM with HIV (Continued)

| Outcomes                                                                 | Population                                                                 | Anticipated absolute effects* (95% CI) | Relative effect (95% CI) | No of Participants (studies) | Quality of the evidence (GRADE) |
|--------------------------------------------------------------------------|---------------------------------------------------------------------------|---------------------------------------|--------------------------|-----------------------------|--------------------------------|
| High-grade anal intraepithelial neoplasia at 4-year follow-up             | Females and males with HIV (≥ 27 years)                                    | Risk with control: 157 per 1000         | Risk with quadrivalent HPV vaccine: 160 per 1000 (110 to 233) | RR 1.02 (0.70 to 1.48)      | 574 (1 study)                  | ☯☯☯☯ VERY LOW1,2 |
| Recurrence of anogenital warts at 18-month follow-up                      | Females and males with HIV treated for anogenital warts (18-65 years)      | Risk with control: 200 per 1000         | Risk with quadrivalent HPV vaccine: 143 per 1000 (7 to 778) | RR 0.71 (0.06 to 8.90)      | 12 (1 study)                   | ☯☯☯☯ VERY LOW2,3 |
| Abnormal anal cytology at 4-year follow-up                               | Females and males with HIV (≥ 27 years)                                    | Risk with control: 545 per 1000         | Risk with quadrivalent HPV vaccine: 447 per 1000 (349 to 573) | RR 0.82 (0.64 to 1.05)      | 262 (1 study)                  | ☯☯☯☯ VERY LOW1,4 |
| Overall local/injection site adverse events at 15-day follow-up          | Children with HIV (7-12 years)                                             | Risk with control: 100 per 1000         | Risk with quadrivalent HPV vaccine: 219 per 1000 (70 to 683) | RR 2.19 (0.70 to 6.83)      | 126 (1 study)                  | ☯☯☯☯ VERY LOW1,2 |
| Overall systemic events and general symptoms at 15-day follow-up         | Children with HIV (7-12 years)                                             | Risk with control: 33 per 1000          | Risk with quadrivalent HPV vaccine: 21 per 1000 (2 to 235) | RR 0.62 (0.05 to 7.05)      | 126 (1 study)                  | ☯☯☯☯ VERY LOW1,2,6 |
| Serious adverse events at 4-year follow-up (adults) or 7-month follow-up | Females and males with HIV (≥ 27 years)                                    | Risk with control: 160 per 1000         | Risk with quadrivalent HPV vaccine: 115 per 1000 (74 to 174) | OR 0.68 (0.42 to 1.10)      | 575 (1 study)                  | ☯☯☯☯ VERY LOW1,4,6,7 |
| MSM with HIV (≥ 18 years)                                                | Risk with control: 0 per 1000                                             | Risk with quadrivalent HPV vaccine: 0 per 1000 (0 to 0) | Not estimable, no events were reported | 129 (1 study) | ☯☯☯☯ VERY LOW5,6,7 |
| Mortality at 4-year follow-up (adults) or 7-month follow-up (MSM)       | Females and males with HIV (≥ 27 years)                                    | Risk with control: 21 per 1000          | Risk with quadrivalent HPV vaccine: 10 per 1000 (3 to 41) | OR 0.49 (0.12 to 1.99)      | 575 (1 study)                  | ☯☯☯☯ VERY LOW1,2 |
| MSM with HIV (≥ 18 years)                                                | Risk with control: 0 per 1000                                             | Risk with quadrivalent HPV vaccine: 0 per 1000 (0 to 0) | Not estimable, no events were reported | 129 (1 study) | ☯☯☯☯ LOW5 |

*The risk in the intervention group (and its 95% confidence interval) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI).

CI: confidence interval; HIV: human immunodeficiency virus; HPV: human papillomavirus; MSM: men who have sex with men; OR: odds ratio; RR: risk ratio

GRADE Working Group grades of evidence

**High quality:** Further research is very unlikely to change our confidence in the estimate of effect.

**Moderate quality:** Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.

**Low quality:** Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
Table 3. Summary of findings: Quadrivalent HPV vaccine compared with control in children, adults, and MSM with HIV
(Continued)

Very low quality: We are very uncertain about the estimate.

1Downgraded one level for risk of bias: details about how randomisation sequence was generated or how blinding was achieved were not reported.
2Downgraded two levels for serious imprecision: few events and a wide 95% confidence interval that incorporated a potentially beneficial effect and a potentially harmful effect.
3Downgraded two levels for serious risk of bias: data for 62.5% (20/32) of the participants enrolled were missing due to lack of follow-up. In addition, details about how randomisation, allocation concealment, and blinding were achieved were not reported.
4Downgraded two levels for imprecision: few events and wide 95% confidence interval that incorporated a potential beneficial effect and no effect.
5Downgraded two levels for serious imprecision: no events reported, the study was not powered to detect a difference in serious adverse events or mortality.
6Downgraded one level for indirectness: This outcome is a composite measure of events which may or may not be clinically relevant, may or may not be related to the vaccine and may occur outside a biologically plausible time frame relative to vaccine exposure. This outcome is considered to provide indirect evidence about vaccine safety.
7See Table 1 for details of each serious event.

Table 4. Summary of findings: Bivalent HPV vaccine compared with control in 18- to 25-year-old females with HIV

Bivalent HPV vaccine compared with control in 18- to 25-year-old females with HIV

Patient or population: 18- to 25-year-old females with HIV

Settings: South Africa

Intervention: bivalent HPV vaccine (3 doses at 0, 1, and 6 months)

Comparison: control (vaccine adjuvant-containing placebo) (3 doses at 0, 1 and 6 months)

| Outcomes                                                                 | Anticipated absolute effects* (95% CI) | Relative effect (95% CI) | No of Participants (studies) | Quality of the evidence (GRADE) |
|--------------------------------------------------------------------------|---------------------------------------|--------------------------|-----------------------------|--------------------------------|
| Risk with control                                                        | Risk with bivalent HPV vaccine        |                          |                             |                                |
| High-grade cervical epithelial neoplasia, adenocarcinoma in situ, and cervical cancer | No studies were identified that reported on this outcome. |                          |                             |                                |
| High-grade cervical, vulval, and vaginal disease                         | No studies were identified that reported on this outcome. |                          |                             |                                |
| Overall local/injection site adverse events                              | No studies were identified that reported on this outcome. Data for specific local adverse events (pain and swelling at injection site) are presented in the Data and analyses and Effects of interventions sections. |                          |                             |                                |
| Overall systemic events and general symptoms                             | No studies were identified that reported on this outcome. |                          |                             |                                |
| Serious adverse events at 12-month follow-up                             | 34 per 1000 (8 to 243)               | OR 1.47 (0.24 to 9.15)   | 120 (1 study)               | ⊕⊕⊕⊕ VER Y LOW1,3,4             |
| Mortality at 12-month follow-up                                          | 0 per 1000 (0 to 0)                   | Not estimable, no events were reported | 120 (1 study)               | ⊕⊕ LO W2                           |
The risk in the intervention group (and its 95% confidence interval) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI).

CI: confidence interval; HIV: human immunodeficiency virus; HPV: human papillomavirus; OR: odds ratio

GRADE Working Group grades of evidence
High quality: Further research is very unlikely to change our confidence in the estimate of effect.
Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
Very low quality: We are very uncertain about the estimate.

1 Downgraded two levels for serious imprecision: few events and a wide 95% confidence interval that incorporated a potentially large beneficial effect and a potentially large harmful effect.
2 Downgraded two levels for serious imprecision: no events reported, the study was not powered to detect a difference in mortality.
3 Downgraded one level for indirectness: This outcome is a composite measure of events which may or may not be clinically relevant, may or may not be related to the vaccine and may occur outside a biologically plausible time frame relative to vaccine exposure. This outcome is considered to provide indirect evidence about vaccine safety.
4 See Table 1 for details of each serious event.

Table 4. Summary of findings: Bivalent HPV vaccine compared with control in 18- to 25-year-old females with HIV (Continued)

Table 5. Summary of findings: Bivalent HPV vaccine compared with quadrivalent HPV vaccine in adults with HIV

| Outcomes                          | Population                                      | Anticipated absolute effects* (95% CI) | Relative effect (95% CI) | No of Participants (studies) | Quality of the evidence (GRADE) |
|-----------------------------------|------------------------------------------------|--------------------------------------|--------------------------|-----------------------------|-------------------------------|
| High-grade neoplasia, cancer      | Females and males with HIV (≥ 18 years)         | 696 per 1000 to 911 per 1000 (737 to 1000) | RR 1.31 (1.06 to 1.62)   | 92 (1 study)               | ⊕⊕⊝⊝ ⊝ ⊝ ⊝ ⊝ LOW1 |
| Overall local/injection site adverse events at 4-day follow-up            | Females and males with HIV (≥ 18 years)         | 0 per 1000 to 0 per 1000 (0 to 0)     | Not estimable, no events were reported | 92 (1 study)               | ⊕⊕⊝⊝ ⊝ ⊝ ⊝ ⊝ VERY LOW2,5,6 |
| Serious adverse events at 6-month follow-up (adults) and 7-month follow-up (females) | Females and males with HIV (≥ 18 years)         | 0 per 1000 to 0 per 1000 (0 to 0)     | Not estimable, no events were reported | 92 (1 study)               | ⊕⊕⊝⊝ ⊝ ⊝ ⊝ ⊝ VERY LOW2,5,6 |

Comparison of different human papillomavirus (HPV) vaccine types and dose schedules for prevention of HPV-related disease in females and males (Review)

Copyright © 2019 The Authors. Cochrane Database of Systematic Reviews published by John Wiley & Sons, Ltd. on behalf of The Cochrane Collaboration.
Table 5. Summary of findings: Bivalent HPV vaccine compared with quadrivalent HPV vaccine in adults with HIV (Continued)

| Mortality | No studies were identified that reported on this outcome. |

1The risk in the intervention group (and its 95% confidence interval) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI).

CI: confidence interval; HIV: human immunodeficiency virus; HPV: human papillomavirus; OR: odds ratio; RR: risk ratio

GRADE Working Group grades of evidence

High quality: Further research is very unlikely to change our confidence in the estimate of effect.

Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.

Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.

Very low quality: We are very uncertain about the estimate.

1Downgraded two levels for serious imprecision: few events reported.

2Downgraded two levels for serious imprecision: no events reported, the study was not powered to detect a difference in serious adverse events or mortality.

3Downgraded one level for risk of bias: details on how randomisation, allocation concealment, and blinding was achieved was not reported.

4Downgraded two levels for serious imprecision: few events and a wide 95% confidence interval that incorporate a potentially large beneficial effect and a potentially large harmful effect.

5Downgraded one level for indirectness: This outcome is a composite measure of events which may or may not be clinically relevant, may or may not be related to the vaccine and may occur outside a biologically plausible time frame relative to vaccine exposure. This outcome is considered to provide indirect evidence about vaccine safety.

6See Table 1 for details of each serious event.

APPENDICES

Appendix 1. Ovid MEDLINE search strategy

1. exp Papillomavirus Infections/

2. exp PAPILLOMAVIRIDAE/

3. (human papilloma virus or human papillomavirus).tw.

4. 1 or 2 or 3

5. exp Immunization/

6. (vaccin* or immuni*).tw.

7. 5 or 6

8. 4 and 7

9. exp Papillomavirus Vaccines/

10. (human papilloma virus adj (vaccin* or immuni*)).tw.

11. (human papillomavirus adj (vaccin* or immuni*)).tw.

12. HPV vaccin*.tw.

13. (cervarix or gardasil).tw.

14. 9 or 10 or 11 or 12 or 13
15. 8 or 14
16. randomised controlled trial.pt.
17. controlled clinical trial.pt.
18. randomized.ab.
19. placebo.ab.
20. clinical trials as topic.sh.
21. randomly.ab.
22. trial.ti.
23. 16 or 17 or 18 or 19 or 20 or 21 or 22
24. (animals not (humans and animals)).sh.
25. 23 not 24
26. 15 and 25

Appendix 2. Ovid Embase search strategy

1. exp papillomavirus infection/
2. exp Papillomaviridae/
3. (human papilloma virus or human papillomavirus).tw.
4. 1 or 2 or 3
5. exp immunization/
6. (vaccin* or immuni*).tw.
7. 5 or 6
8. 4 and 7
9. exp Wart virus vaccine/
10. (human papilloma virus adj (vaccin* or immuni*)).tw.
11. (human papillomavirus adj (vaccin* or immuni*)).tw.
12. HPV vaccin*.tw.
13. (cervarix or gardasil).tw.
14. 9 or 10 or 11 or 12 or 13
15. 8 or 14
16. crossover procedure/
17. double-blind procedure/
18. randomised controlled trial/
19. single-blind procedure/
20. random*.mp.
21. factorial*.mp.
22. (crossover* or cross over* or cross-over*).mp.
Appendix 3. The Cochrane Library search strategy

#1 MeSH descriptor: [Papillomavirus Infections] explode all trees
#2 MeSH descriptor: [Papillomaviridae] explode all trees
#3 (“human papilloma virus” or “human papillomavirus”).ti,ab,kw
#4 #1 or #2 or #3
#5 MeSH descriptor: [Immunization] explode all trees
#6 (vaccin* or immuni*):ti,ab,kw
#7 #5 or #6
#8 #4 and #7
#9 MeSH descriptor: [Papillomavirus Vaccines] explode all trees
#10 (human papilloma virus NEAR (vaccin* or immuni*)):ti,ab,kw
#11 (human papillomavirus NEAR (vaccin* or immuni*)):ti,ab,kw
#12 (HPV NEXT vaccin*):ti,ab,kw
#13 (cervarix or gardasil):ti,ab,kw
#14 (or #9-#13)
#15 #8 or #14

Appendix 4. Methods used to collect adverse event data

| Study   | Mode of data collection | Time frame | Attribution methods | Intensity of ascertain. | Harms-related monitoring and stopping rules | Frequency-based filter |
|---------|-------------------------|------------|---------------------|-------------------------|---------------------------------------------|------------------------|
| Denny 2013 | Proactive: trained field workers to visit subjects or instruct subjects to come back to a field station for the recording of solicited and unsolicited symptoms. Case | Time frame was specified. (Solicited AEs were recorded for 7 days after each vaccination. Unsolicited AEs | Not reported | Information relative to premature discontinuation of the investigational product was documented. | Stopping rules not reported | No filter used (“For the analysis of unsolicited AEs/SAEs/Medically significant conditions/” |
report forms were used. SAEs, medically significant AEs, new-onset chronic diseases (NOCDs), pregnancies and their outcome were recorded up to month 12).

The investigator was to document whether the decision to discontinue further vaccination was made by the subject or the investigator and which of the following possible reasons was responsible for withdrawal: SAE, non-serious AE, other (specified). No woman withdrew from the study due to AEs, however information on how withdrawals would have been handled in the analysis was not reported.

NOCDs/concomitant medication, all vaccinated subjects will be considered and subjects who did not report an event will be considered as subjects without an event).

| Dobson 2013 | Passive: “information on AEs was collected at the next visit or if the participant called with concerns” | Time frame was specified (“Because this was a post-licensure study, data were only collected on SAEs occurring within 30 days of each vaccination”). | Not reported | Not reported | Stopping rules not reported | Unclear. Results were reported narratively only (“Scheduled vaccine doses were received by 98.6% of study participants with no SAEs reported”). |
|---|---|---|---|---|---|---|
| Giuliano 2011 | Proactive and passive: subjects recorded AEs on vaccination report cards. SAEs were recorded by investigators | Time frame was specified (“any AEs occurring at the injection site on days 1 | Attribution made by investigators (“Vaccine-related AEs were those determined by the investigator to be possibly, probably, or definitely related to the vaccine”). | Number of withdrawals were reported, but without reasons. No information on how | Stopping rules not reported | Filter not used. AEs were reported as n/N. Study also reported number |
gators, including all deaths. through 5 after receiving each dose of vaccine or placebo”). They also recorded systemic AEs and all SAEs that occurred on days 1 to 15 after receiving each dose. All SAEs that investigators believed to be associated with the vaccine or the study procedure and all deaths were recorded during the entire study period.

### Hidalgo-Tenorio 2017

**Proactive for local reactions:** “Questionnaire that included the most frequent local reactions”

**Time frame** is unclear (possibly at 2 and 6 months).

**Attribution and blinding** not reported.

**Definition used** was provided (“Frequent local reactions included fever, nausea, vomiting, dizziness, syncope, headache and others such as allergic reaction, pruritus, difficulty breathing and/or wheezing. Rare occurrences included lymphadenopathies, chest and lower-limb pain, confusion, chills, muscle pain”, but it is unclear if they were predefined. “The AEs were graded on a scale of 1–4”)

**Reasons for discontinuation** were separated by arm.

**Attribution was not reported.**

**Monitoring stopping rules** were reported (“In case of AE grade 4, the blind of the vial administered was broken and, if the code identified the vaccine, the reaction was communicated immediately to the relevant drug vigilance authorities”)

**No filter used**

| Iversen 2016 | Proactive and passive: immediate reactions were proactively collected: “Participants were | Time frame was specified (“SAEs were to be reported immediately”)

**Attribution made by investigators (“Investigators were instructed to assign causality to adverse events on the basis of exposure, time course, likely...”)

**Reasons for discontinuation were separated by arm, and**

**Stopping rules not reported**

**No filter used**

---

*Comparison of different human papillomavirus (HPV) vaccine types and dose schedules for prevention of HPV-related disease in females and males (Review)*

Copyright © 2019 The Authors. Cochrane Database of Systematic Reviews published by John Wiley & Sons, Ltd. on behalf of The Cochrane Collaboration.
observed for 30 mins after each injection for any immediate reaction”.

Non-serious injection site and systemic events “were not actively solicited”.

Attribution was made by the investigator (“were deemed by the investigator”).

Blinding was not reported.

SAEs were predefined (“any AE that resulted in death, were deemed by the investigator to be life-threatening, resulted in a persistent or significant disability or incapacity, resulted in or prolonged an existing inpatient hospital stay, or were congenital anomalies, cancers, or other so-called important medical events”).

Time frame was specified (“Deaths and serious vaccine-related AEs were reported throughout the study. Other SAEs were reported from day 1 to 6 months following the last vaccination; events of fetal loss were reported as SAEs for any pregnancy with a last menstrual period before 6 months following the last vaccination”).

Active surveillance: • to 30 minutes after vaccination for rash and urticarial (diary card subset); • to 30 days after vaccination for rash and urticarial (diary card subset).

Active surveillance of SAEs, non-serious AEs and other events was only conducted for a small subset of male participants. Reasons for discontinuation were not reported.

No information on how withdrawals were handled in the analysis.

Mode of data collection was not reported.

R e a son s for discontinuation w e re not reported.

Joura 2015

Proactive and passive: for active safety surveillance, a small subset of male adolescents receiving either vaccine were selected to use diary cards.

Serious adverse events were actively monitored in the diary card subset.

Attribution by investigator, blinded to treatment.

Active surveillance of SAEs, non-serious AEs and other events was only conducted for a small subset of male participants. Reasons for discontinuation were not reported.

No filter used. AEs were reported as N/N. Study also reported number of participants with at least 1 event, but did not distinguish between participants with 1 or multiple AEs.

Lehtinen 2018

Comparison of different human papillomavirus (HPV) vaccine types and dose schedules for prevention of HPV-related disease in females and males (Review)

Copyright © 2019 The Authors. Cochrane Database of Systematic Reviews published by John Wiley & Sons, Ltd. on behalf of The Cochrane Collaboration.
and in other male participants in one cluster (90% HPV, 10% HBV) from month 1 to month 12.
Passive monitoring of SAEs and new-onset autoimmune diseases continued for all study participants during the whole follow-up period by linkage to inpatient and outpatient health care use recorded in the Care Register for Social Welfare and Health Care.

| Passive SAE and new-onset autoimmune disease surveillance: |
|------------------------------------------------------------|
| • for entire study period (to approximately 4 years). |

| Leung 2015 | Passive for solicited local and general symptoms: “diary cards” | Time frame was specified (“Solicited local and general symptoms were recorded for 7 days after each vaccination”; “Unsolicited symptoms were recorded for 30 days after each vaccination”); “SAEs, medically separated by arm and reported for withdrawals due to SAEs, non-serious AEs and other reasons. |
| Attribution and blinding were not reported. |
| No information on how withdrawals would have been handled in the analysis, however “no subject was withdrawn from the study due to an AE” |
| Attribution was not reported. | Stopping rules not reported | No filter used. Results reported as percentage of participants with symptoms, therefore did not distinguish between participants with 1 or multiple AEs. |
significant AEs, pIMDs and pregnancy were reported throughout the study; “SAEs up to month 36”)

Levin 2010: Proactive: “Subjects were observed in clinic for 30 minutes post vaccination. A report card of relevant signs and symptoms was maintained by the caregiver for 15 days after each injection. Body temperature was recorded for 5 days beginning after the injection. Telephone contact with the caregiver was made on the third day after each injection to inquire about reactions. The caregiver was instructed to immediately report unusual injection site reactions”; “Routine hematologic and chemistry screens were performed at the study site’s laboratory at entry, 4 weeks after the first dose, and just before and 4 weeks after the next 2 doses. CD4% and CD4 number were determined at entry, 8 weeks after the first dose, 4 weeks after the second dose, and just before and 4 weeks after the third dose”.

Time frame was specified (see methods of data collection).

Attribution was made by the study co-ordinator.

Blinding not reported.

The severity of AEs was done using the “Division of AIDS Table for Grading the Severity of Adverse Events”.

No information on how withdrawals were handled in the analysis.

Unclear. “A clinic visit was required within 24 hours whenever the study coordinator considered that a reaction might be ≥ grade 3”. However, clear rules regarding termination of the study were not reported.

Lin 2014: Unclear: “Following each vaccination visit, participants

Time frame is unclear.

Not reported

Reasons for discontinuation were separated

Stopping rules not reported

No filter used
were screened for adverse events”.

NCT00941889 2016
Not applicable, serious and/or other non-serious adverse events were not collected or assessed.

NCT01031069 2017
Mode of data collection was not reported.
Solicited local and general symptoms within 7 days after each and any vaccination; unsolicited symptoms within 30 days (days 0-29) after any vaccination; SAEs, medically significant conditions, pregnancy outcomes, clinically relevant abnormalities in haematological and biochemical parameters up to 30 days after the last dose of vaccine.

NCT01862874 2018
Mode of data collection was not reported, except that a vaccination report card was used.
Serious and other adverse events followed up for 36 months; in-

| NCT00941889 2016 | Not applicable, serious and/or other non-serious adverse events were not collected or assessed. | Not applicable | Not applicable | Not applicable | Not applicable |
|------------------|-------------------------------------------------------------------------------------------------|---------------|---------------|---------------|---------------|
| NCT01031069 2017 | Mode of data collection was not reported.                                                      | Solicited local and general symptoms within 7 days after each and any vaccination; unsolicited symptoms within 30 days (days 0-29) after any vaccination; SAEs, medically significant conditions, pregnancy outcomes, clinically relevant abnormalities in haematological and biochemical parameters up to 30 days after the last dose of vaccine. | Attribution, blinding or definitions were not reported. | Reasons for discontinuation were separated by arm. | Stopping rules not reported | No filter used |
| NCT01862874 2018 | Mode of data collection was not reported, except that a vaccination report card was used.      | Serious and other adverse events followed up for 36 months; in- | Attribution, blinding or definitions were not reported. | Reasons for discontinuation were separated by arm. | Stopping rules not reported | Threshold above which other adverse events are only report- ed narratively as proportions. P-value only reported for overall occurrence of AEs. Specific AEs were not report- ed separately by group. |

Comparison of different human papillomavirus (HPV) vaccine types and dose schedules for prevention of HPV-related disease in females and males (Review)

Copyright © 2019 The Authors. Cochrane Database of Systematic Reviews published by John Wiley & Sons, Ltd. on behalf of The Cochrane Collaboration.
| Study | Mode of data collection | Grade 3 or 4 AEs | Attribution | Reasons for discontinuation | Stopping rules | Filter used |
|-------|-------------------------|-----------------|-------------|----------------------------|----------------|-------------|
| Wilkin 2018 | Mode of data collection was not reported. | Grade 3 or 4 AEs that were possibly, probably, or definitely related to the vaccine: to participant's last study visit, for up to 4 years. | Attribution determined by the local investigator, blinding not reported. | Grade 3 or 4 adverse events were defined using the DAIDS Table for Grading the Severity of Adult and Pediatric Adverse Events. | Reasons for discontinuation were separated by arm. | Stopping rules not reported | No filter used |
| Petaja 2009 | Proactive and passive:  
“Participants used diary cards to report solicited local and general symptoms during a 7-day follow-up period after each vaccine dose”;  
“Unsolicited signs and symptoms were reported within 30 days after each dose”. | Time frame was specified: 7-day follow-up for local and general symptoms; 30 days for unsolicited signs and symptoms; SAEs, NOCDs and other medically significant conditions (MSCs) were reported throughout the study period (up to month 12). | Attribution method not explicitly described in methods section. However, it seems it was done by the investigator “Neither of the SAEs were fatal, and both events were considered by the investigator to be unrelated to study vaccination”; “the determination of whether a chronic disease is considered to be of new onset will be based on review of the subject’s pre-vaccination medical history”. | Blinding was not reported. | Outcome definition:  
• “Solicited local AEs included pain, redness, and swelling at the injection site”;  
• “Solicited general AEs included fever, headache, fatigue, gastrointestinal symptoms (i.e. nausea, vomiting, diarrhoea, abdominal pain), arthralgia, myalgia, rash, and urticaria” | Stopping rules not fully described, “Your participation in the study may be stopped the study doctor decides it is in the best interest of your health and welfare to discontinue participation in the study” | Filter not used. AEs were reported as n/N. GSK report lists all symptoms individually. Study did not distinguish between participants with 1 or multiple AEs. |
• “Grade 3 solicited AEs were defined as pain that prevented normal activity, redness or swelling larger than 50 mm, fever higher than 39.0 °C (axillary temperature), urticaria distributed on at least four body areas, or events that prevented normal, everyday activities. Urticaria or rash that appeared within 30 minutes of each vaccine dose was also documented by the investigator”

• “An SAE was defined as any untoward medical occurrence that resulted in death, was life-threatening, required hospitalization, resulted in disability or incapacity, was an important medical event or was a congenital anomaly/birth defect in the offspring of a study subject”

• “MSCs were defined as non-serious AEs prompting either emergency room or physician visits not related to either common diseases or routine visits for physical examination or vaccination, or SAEs not related to common diseases”

• “Common diseases included upper respiratory infections, sinusitis, pharyngitis, gastroenteritis, urinary tract infections, and injury”

| Puthanakit 2016 | Proactive and passive: “Solicited local and general symptoms were recorded on diary cards for 7 days after each vaccination. Unsolicited symptoms were recorded for 30 days after each vaccination. Pregnancies and outcomes, serious adverse events, medically significant adverse events, and potential immune-mediated diseases were Time frame was specified (see methods of data collection). Attribution and blinding not reported. Grade 3 symptoms were defined (as redness or swelling >50 mm in diameter, fever >39°C, urticaria distributed on ≥4 body areas, and, for other symptoms, as preventing normal activity”). Reasons for discontinuation were separated by arm, and after each dose administration. Attribution was not reported. No information on how withdrawals were handled in the analysis. Stopping rules not reported. |
|---|---|---|---|---|
| | | | | |

Comparison of different human papillomavirus (HPV) vaccine types and dose schedules for prevention of HPV-related disease in females and males (Review)

Copyright © 2019 The Authors. Cochrane Database of Systematic Reviews published by John Wiley & Sons, Ltd. on behalf of The Cochrane Collaboration.
Proactive and passive: “Solicited local symptoms (pain, redness or swelling at injection site) and general symptoms (fever, headache, fatigue, gastrointestinal symptoms, arthralgia, myalgia, rash or urticaria) occurring within 7 d after each vaccination were recorded by the subject or her parent/legally acceptable representative using a diary card. Investigators documented the presence or absence of urticaria/rash within 30 min after each vaccine. dose. Unsolicited AEs occurring within one month of each vaccine dose were documented by the investigator.

“SAEs and other medically significant conditions were reported in all subjects regardless of causal relationship to vaccination and intensity.”

Toft 2014

Proactive and passive: “Participants were observed for 30 minutes after each immunization to evaluate immediate AEs. Solicited AEs occurring during the first 4 days after each immunization (injection site pain, swelling, erythema, fever, headache, nausea, myalgia, arthralgia and rash) and other

| Study | Time frame was specified (see methods of data collection). | Attribution and blinding not reported. | Outcome definition reported ("Medically significant condition = AE prompting emergency room or physician visits that was not related to common diseases. New onset autoimmune diseases (which excluded allergy-related events or isolated signs and symptoms) were identified by comparing all reported AEs with a pre-defined list of potential chronic autoimmune events derived from the Medical Dictionary for Regulatory Activities"). | Attribution was not reported. | Stopping rules not reported. | No filter used. However, for many of the AEs, results were provided as number of participants with at least 1 event, therefore did not distinguish between participants with 1 or multiple AEs. |
|-------|---------------------------------------------------------------|--------------------------------------|---------------------------------------------------------------------------------|---------------------------------|----------------------------------|----------------------------------|
| Kowal 2011 | Reported through-out the study. | | | | | |

(Continued)
van Damme 2016

Proactive and passive: "Following each vaccination, participants were observed for 30 min for any untoward effects, including allergic reactions. All participants received a vaccination report card (VRC) at each vaccination visit. They were asked to record their oral temperature on the VRC from day 1 to day 5 after each vaccination (starting on the evening after vaccination), and any injection-site and systemic AEs for a total of 15 days including the day of vaccination … SAEs were collected for the entire duration of the study irrespective of cause".

Time frame was specified (see methods of data collection).

Attribution was made by investigators based on the information provided by the patients ("The study site personnel reviewed the VRC for completeness and could not alter the original information recorded by the participants on the VRC. The investigator determined the causality of systemic AEs reported on the VRC, and classified each AE reported on the VRC as a serious or non-serious AE").

Blinding was not reported.

Outcome definition was reported ("An oral temperature 37.8°C during the follow-up period was considered an elevated temperature (fever). For each AE, participants were asked to rate the symptom as mild (awareness of sign or symptom but easily tolerated), moderate (discomfort enough to cause interference with usual activities), or severe (incapacitating with inability to work or do usual activity); injection-site AEs of swelling and erythema were rated by size. Investigators were instructed to assign causality to AEs on the basis of exposure, time course, likely cause, and consistency with the vaccine's known profile. Serious AEs (SAEs) were predefined as any AE that resulted in death, deemed by the investigator to be life-threatening, or that resulted in a persistent or significant disability or incapacity, resulted in or prolonged an existing in-patient hospitalization, or was a congenital anomaly, a cancer, or an 'other important medical event').

Reasons for discontinuation were separated by arm.

Attribution was not reported.

No information provided about how withdrawals were handled in the analysis.

Stopping rules not reported

Filter not used. AEs were reported as n/N. Study also reported number of participants with no event, and number with at least 1 event, but did not distinguish between participants with 1 or multiple AEs.

Vesikari 2015

Proactive and passive: "Participants were observed for 30 mins after each vaccination. At least 1 day after each vaccination, participants recorded their oral temperature on the VRC from day 1 to day 5 after each vaccination (starting on the evening after vaccination), and any injection-site and systemic AEs. SAEs were collected for the entire duration of the study irrespective of cause".

Time frame was specified (see methods of data collection).

Attribution was made by the investigator ("Investigators assigned causality to AEs based on exposure, time course, like... other important medical event").

Reasons for discontinuation were separated.

Stopping rules not reported.

Filter not used. AEs were reported as n/N. Study also reported number of participants with no event, and number with at least 1 event, but did not distinguish between participants with 1 or multiple AEs.

Comparison of different human papillomavirus (HPV) vaccine types and dose schedules for prevention of HPV-related disease in females and males (Review)

Copyright © 2019 The Authors. Cochrane Database of Systematic Reviews published by John Wiley & Sons, Ltd. on behalf of The Cochrane Collaboration.
(Continued) Vaccination for any immediate reaction. All subjects received a vaccination report card at the day 1, month 2 and month 6 study vaccination visits. Oral temperature was reported from day 1 to day 5 after any vaccination, and injection-site reactions and systemic AEs were recorded on the vaccination report card from day 1 to day 15 after any vaccination. SAES were monitored throughout the study regardless of cause."

Blinding was not reported. Outcome definition was reported ("An elevated temperature (fever) was defined as maximum temperature ≥37.8°C. For each AE, participants rated the symptom as mild (awareness of symptom but easily tolerated), moderate (discomfort enough to cause interference with usual activities) or severe (incapacitating with inability to work or do usual activity); injection-site AEs of swelling and erythema were rated by size. SAES were predefined as any AE that resulted in death, were deemed by the investigator to be life-threatening, resulted in a persistent or significant disability or incapacity, resulted in or prolonged an existing in-patient hospitalization or was a congenital anomaly, a cancer or an "other important medical event".

Abbreviations

AE: adverse event
HBV: hepatitis B vaccine
HPV: human papillomavirus
NOCID: new onset chronic disease
pIMD: potentially immune mediated diseases
SAE: serious adverse event
VRC: vaccination report card

Appendix 5. Two versus three doses of HPV vaccine in 9- to 15-year old females - immunogenicity outcomes

| Outcome or subgroup | Follow-up | Studies | Participants | Statistical method | Effect estimate (95% CI) | Certainty of the evidence (GRADE) |
|---------------------|-----------|---------|--------------|--------------------|--------------------------|----------------------------------|
| 1.1 GMT of HPV 6 (mMU/mL) | 1 month after last dose | 2 (Dobson 2013; Iversen 2016) | 1001 | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs 1.13 (0.99 to 1.29) | ⊕⊕⊕⊕ HIGH |

Comparison of different human papillomavirus (HPV) vaccine types and dose schedules for prevention of HPV-related disease in females and males (Review)

Copyright © 2019 The Authors. Cochrane Database of Systematic Reviews published by John Wiley & Sons, Ltd. on behalf of The Cochrane Collaboration.
### Comparison of different human papillomavirus (HPV) vaccine types and dose schedules for prevention of HPV-related disease in females and males (Review)

| Study Details | Results | Notes |
|---------------|---------|-------|
| **1.1.1 Quadrivalent vaccine** | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs 1.18 (0.93 to 1.49) |
| 1 month after last dose | 1 (Dobson 2013) | 489 |
| **1.1.2 Nonavalent vaccine** | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs 1.11 (0.94 to 1.30) |
| 1 month after last dose | 1 (Iversen 2016) | 512 |
| **1.2 GMT of HPV 11 (mMU/mL)** | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs 1.12 (0.95 to 1.32) |
| 1 month after last dose | 2 (Dobson 2013; Iversen 2016) | 1006 |
| **1.2.1 Quadrivalent vaccine** | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs 1.06 (0.91 to 1.25) |
| 1 month after last dose | 1 (Dobson 2013) | 494 |
| **1.2.2 Nonavalent vaccine** | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs 1.14 (0.98 to 1.34) |
| 1 month after last dose | 1 (Iversen 2016) | 512 |
| **1.3 GMT of HPV 16** | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs 0.77 (0.69 to 0.87) |
| 1 month after last dose | 1 (Romanowski 2011) | 126 |
| **1.3.1 Bivalent vaccine** | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs 0.50 (0.38 to 0.66) |
| 1 month after last dose | 4 (Romanowski 2011; Dobson 2013; Iversen 2016; Leung 2015) | 1833 |
| **1.3.2 Quadrivalent vaccine** | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs 0.72 (0.64 to 0.81) |
| 1 month after last dose | 2 (Dobson 2013; Leung 2015) | 1159 |
| **1.3.3 Nonavalent vaccine** | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs 0.74 (0.57 to 0.97) |
| 1 month after last dose | 1 (Iversen 2016) | 541 |
| **1.4 GMT of HPV 18** | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs 0.77 (0.69 to 0.87) |
| 1 month after last dose | 1 (Romanowski 2011) | 132 |
| **1.4.1 Bivalent vaccine** | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs 0.72 (0.64 to 0.81) |
| 1 month after last dose | 1 (Romanowski 2011) | 132 |
| **1.4.2 Quadrivalent vaccine** | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs 0.72 (0.64 to 0.81) |
| 1 month after last dose | 2 (Dobson 2013; Leung 2015) | 1159 |

Not pooled due to considerable heterogeneity across studies ($I^2 = 89\%$).
| Comparison | Disease | Time after last dose | Reference | RR (M-H, random-effects, 95% CI) | Ratio of GMTs (IV, random-effects, 95% CI) |
|------------|---------|----------------------|-----------|---------------------------------|--------------------------------------------|
| 1.4.3 Nonavalent vaccine | 1 month after last dose | 1 (Iversen 2016) | 542 | Ratio of GMTs | 0.91 (0.76 to 1.09) |
| 1.5 GMT of HPV 31 (mMU/mL) | 1 month after last dose | 1 (Iversen 2016) | 543 | Ratio of GMTs | 0.82 (0.69 to 0.98) |
| 1.6 GMT of HPV 33 (mMU/mL) | 1 month after last dose | 1 (Iversen 2016) | 548 | Ratio of GMTs | 1.29 (1.10 to 1.52) |
| 1.7 GMT of HPV 45 (mMU/mL) | 1 month after last dose | 1 (Iversen 2016) | 549 | Ratio of GMTs | 0.54 (0.45 to 0.65) |
| 1.8 GMT of HPV 52 (mMU/mL) | 1 month after last dose | 1 (Iversen 2016) | 547 | Ratio of GMTs | 0.64 (0.55 to 0.74) |
| 1.9 GMT of HPV 58 (mMU/mL) | 1 month after last dose | 1 (Iversen 2016) | 543 | Ratio of GMTs | 1.02 (0.87 to 1.19) |
| 1.10 Seroconversion to HPV 6 | 1 month after last dose | 2 (Dobson 2013; Iversen 2016) | 1001 | RR | 1.00 (0.99 to 1.01) |
| 1.10.1 Quadrivalent vaccine | 1 month after last dose | 1 (Dobson 2013) | 489 | RR | 1.00 (0.99 to 1.01) |
| 1.10.2 Nonavalent vaccine | 1 month after last dose | 1 (Iversen 2016) | 512 | RR | 1.00 (0.99 to 1.02) |
| 1.11 Seroconversion to HPV 11 | 1 month after last dose | 2 (Dobson 2013; Iversen 2016) | 1006 | RR | 1.00 (0.99 to 1.01) |
| 1.11.1 Quadrivalent vaccine | 1 month after last dose | 1 (Dobson 2013) | 494 | RR | 1.00 (0.99 to 1.01) |
| 1.11.2 Nonavalent vaccine | 1 month after last dose | 1 (Iversen 2016) | 512 | RR | 1.00 (0.99 to 1.01) |
| 1.12 Seroconversion to HPV 16 | 1 month after last dose | 4 (Romanowski 2011; Dobson 2013; Iversen 2016; Leung 2015) | 1816 | RR | 1.00 (1.00 to 1.00) |
| 1.12.1 Bivalent vaccine | 1 month after last dose | 1 (Romanowski 2011) | 132 | RR | 1.00 (0.97 to 1.03) |
### 1.12 Quadrivalent vaccine

- **1 month after last dose**
  - 2 (Dobson 2013; Leung 2015)
  - **RR (M-H, random-effects, 95% CI)**: **1.00 (1.00 to 1.00)**

### 1.13 Nonavalent vaccine

- **1 month after last dose**
  - 1 (Iversen 2016)
  - **RR (M-H, random-effects, 95% CI)**: **1.00 (0.99 to 1.01)**

### 1.13 Seroconversion to HPV 18

- **1 month after last dose**
  - 4 (Romanowski 2011; Dobson 2013; Iversen 2016; Leung 2015)
  - **RR (M-H, random-effects, 95% CI)**: **1.00 (1.00 to 1.00)**

### 1.13.1 Bivalent vaccine

- **1 month after last dose**
  - 1 (Romanowski 2011)
  - **RR (M-H, random-effects, 95% CI)**: **1.00 (0.97 to 1.03)**

### 1.13.2 Quadrivalent vaccine

- **1 month after last dose**
  - 2 (Dobson 2013; Leung 2015)
  - **RR (M-H, random-effects, 95% CI)**: **1.00 (1.00 to 1.00)**

### 1.13.3 Nonavalent vaccine

- **1 month after last dose**
  - 1 (Iversen 2016)
  - **RR (M-H, random-effects, 95% CI)**: **1.00 (0.99 to 1.01)**

### 1.14 Seroconversion to HPV 31

- **1 month after last dose**
  - 1 (Iversen 2016)
  - **RR (M-H, random-effects, 95% CI)**: **1.00 (0.99 to 1.01)**

### 1.15 Seroconversion to HPV 33

- **1 month after last dose**
  - 1 (Iversen 2016)
  - **RR (M-H, random-effects, 95% CI)**: **1.00 (0.99 to 1.01)**

### 1.16 Seroconversion to HPV 45

- **1 month after last dose**
  - 1 (Iversen 2016)
  - **RR (M-H, random-effects, 95% CI)**: **1.00 (0.99 to 1.01)**

### 1.17 Seroconversion to HPV 52

- **1 month after last dose**
  - 1 (Iversen 2016)
  - **RR (M-H, random-effects, 95% CI)**: **1.00 (0.99 to 1.01)**

### 1.18 Seroconversion to HPV 58

- **1 month after last dose**
  - 1 (Iversen 2016)
  - **RR (M-H, random-effects, 95% CI)**: **1.00 (0.99 to 1.01)**

### 1.19 GMT of HPV 6 (mMU/mL)

- **60 months after first dose**
  - 1 (Dobson 2013)
  - **Ratio of GMTs (IV, random-effects, 95% CI)**: **0.73 (0.50 to 1.06)**
  - **Ratio of GMTs (IV, random-effects, 95% CI)**: **0.90 (0.76 to 1.08)**

### 1.20 GMT of HPV 11 (mMU/mL)

---

**Comparison of different human papillomavirus (HPV) vaccine types and dose schedules for prevention of HPV-related disease in females and males (Review)**

Copyright © 2019 The Authors. Cochrane Database of Systematic Reviews published by John Wiley & Sons, Ltd. on behalf of The Cochrane Collaboration.
### 1.20 Quadrivalent vaccine

**60 months after first dose**

- **1 (Dobson 2013)**
  - Ratio of GMTs (IV, random-effects, 95% CI): 0.99 (0.68 to 1.44)
  - Score: ⊕⊕⊝⊝ LOW

**36 months after first dose**

- **1 (Iversen 2016)**
  - Ratio of GMTs (IV, random-effects, 95% CI): 1.14 (0.76 to 1.73)
  - Score: ⊕⊕⊝⊝ LOW

### 1.21 Nonavalent vaccine

**60 months after first dose**

- **1 (Dobson 2013)**
  - Ratio of GMTs (IV, random-effects, 95% CI): 0.84 (0.70 to 1.01)
  - Score: ⊕⊕⊕⊕ HIGH

**36 months after first dose**

- **1 (Iversen 2016)**
  - Ratio of GMTs (IV, random-effects, 95% CI): 0.85 (0.69 to 1.04)
  - Score: ⊕⊕⊕⊕ HIGH

### 1.22 GMT of HPV 16 (mMU/mL)

**60 months after first dose**

- **1 (Romanowski 2011)**
  - Ratio of GMTs (IV, random-effects, 95% CI): 0.51 (0.34 to 0.72)
  - Score: ⊕⊕⊝⊝ LOW

**36 months after first dose**

- **1 (Iversen 2016)**
  - Ratio of GMTs (IV, random-effects, 95% CI): 0.77 (0.65 to 0.91)
  - Score: ⊕⊕⊕⊕ HIGH

### 1.23 GMT of HPV 18 (mMU/mL)

**60 months after first dose**

- **1 (Romanowski 2011)**
  - Ratio of GMTs (IV, random-effects, 95% CI): 0.69 (0.47 to 1.02)
  - Score: ⊕⊕⊝⊝ LOW

**36 months after first dose**

- **1 (Iversen 2016)**
  - Ratio of GMTs (IV, random-effects, 95% CI): 0.77 (0.65 to 0.91)
  - Score: ⊕⊕⊕⊕ HIGH

### 1.24 GMT of HPV 31 (mMU/mL)

**36 months after first dose**

- **1 (Iversen 2016)**
  - Ratio of GMTs (IV, random-effects, 95% CI): 0.62 (0.51 to 0.75)
  - Score: ⊕⊕⊕⊕ HIGH

### 1.25 GMT of HPV 33 (mMU/mL)

**36 months after first dose**

- **1 (Iversen 2016)**
  - Ratio of GMTs (IV, random-effects, 95% CI): 0.46 (0.39 to 0.56)
  - Score: ⊕⊕⊝⊝ HIGH

### 1.26 GMT of HPV 45 (mMU/mL)

**36 months after first dose**

- **1 (Iversen 2016)**
  - Ratio of GMTs (IV, random-effects, 95% CI): 0.57 (0.49 to 0.67)
  - Score: ⊕⊕⊝⊝ HIGH

### 1.27 GMT of HPV 52 (mMU/mL)

**36 months after first dose**

- **1 (Iversen 2016)**
  - Ratio of GMTs (IV, random-effects, 95% CI): 0.88 (0.74 to 1.05)
  - Score: ⊕⊕⊝⊝ HIGH

**1.28 GMT of HPV 58 (mMU/mL)**

- **1 (Iversen 2016)**
  - Ratio of GMTs (IV, random-effects, 95% CI): 0.86 (0.74 to 1.00)
  - Score: ⊕⊕⊝⊝ HIGH

---

Comparison of different human papillomavirus (HPV) vaccine types and dose schedules for prevention of HPV-related disease in females and males (Review)

Copyright © 2019 The Authors. Cochrane Database of Systematic Reviews published by John Wiley & Sons, Ltd. on behalf of The Cochrane Collaboration.
### 1.28 Seropositivity to HPV 6

| Quadrivalent vaccine | 60 months after first dose | 1 (Dobson 2013) | 101 | RR (M-H, random-effects, 95% CI) | RR 0.98 (0.91 to 1.05) | ⊕⊕⊝⊝ LOW³,⁴ |
|----------------------|---------------------------|----------------|-----|---------------------------------|------------------------|----------------|
| Nonavalent vaccine   | 36 months after first dose | 1 (Iversen 2016) | 476 | RR (M-H, random-effects, 95% CI) | RR 0.97 (0.94 to 1.01) | ⊕⊕★ HIGH |

### 1.29 Seropositivity to HPV 11

| Quadrivalent vaccine | 60 months after first dose | 1 (Dobson 2013) | 101 | RR (M-H, random-effects, 95% CI) | RR 1.00 (95% CI not estimable, all participants were seropositive) | ⊕⊕⊝⊝ LOW³,⁴ |
|----------------------|---------------------------|----------------|-----|---------------------------------|-----------------------------------------------------------------|----------------|
| Nonavalent vaccine   | 36 months after first dose | 1 (Iversen 2016) | 476 | RR (M-H, random-effects, 95% CI) | RR 0.95 (0.92 to 0.99) | ⊕⊕⊕⊕ HIGH |

### 1.30 Seropositivity to HPV 16

| Bivalent vaccine     | 60 months after first dose | 1 (Romanowski 2011) | 490 | RR (M-H, random-effects, 95% CI) | RR 1.00 (95% CI not estimable, all participants were seropositive) | ⊕⊕⊕⊕ HIGH |
|----------------------|---------------------------|---------------------|-----|---------------------------------|-----------------------------------------------------------------|----------------|
| Quadrivalent vaccine | 60 months after first dose | 1 (Dobson 2013)     | 101 | RR (M-H, random-effects, 95% CI) | RR 1.00 (95% CI not estimable, all participants were seropositive) | ⊕⊕⊝⊝ LOW³,⁴ |
| Nonavalent vaccine   | 36 months after first dose | 1 (Iversen 2016)    | 503 | RR (M-H, random-effects, 95% CI) | RR 0.98 (0.96 to 1.00) | ⊕⊕⊝⊝ HIGH |

### 1.31 Seropositivity to HPV 18

| Bivalent vaccine     | 60 months after first dose | 1 (Romanowski 2011) | 480 | RR (M-H, random-effects, 95% CI) | RR 1.00 (99% to 1.01) | ⊕⊕⊝⊝ HIGH |
|----------------------|---------------------------|---------------------|-----|---------------------------------|------------------------|----------------|
| Quadrivalent vaccine | 60 months after first dose | 1 (Dobson 2013)     | 101 | RR (M-H, random-effects, 95% CI) | RR 0.89 (0.78 to 1.03) | ⊕⊕⊝⊝ LOW³,⁴ |
| Nonavalent vaccine   | 36 months after first dose | 1 (Iversen 2016)    | 504 | RR (M-H, random-effects, 95% CI) | RR 0.98 (0.95 to 1.02) | ⊕⊕⊝⊝ HIGH |

### 1.32 Seropositivity to HPV 31

| 36 months after first dose | 1 (Iversen 2016) | 506 | RR (M-H, random-effects, 95% CI) | RR 0.96 (0.93 to 1.00) | ⊕⊕⊝⊝ HIGH |
### Table 1: Seropositivity to HPV 33, 45, 52, and 58

| Comparison | Time After First Dose | Reference | GMT | RR (M-H, random-effects, 95% CI) | GRADE |
|------------|-----------------------|-----------|-----|----------------------------------|--------|
| 1.33 Seropositivity to HPV 33 | 36 months | 1 (Iversen 2016) | 510 | RR 0.96 (0.92 to 0.99) | HIGH |
| 1.34 Seropositivity to HPV 45 | 36 months | 1 (Iversen 2016) | 511 | RR 0.92 (0.86 to 0.98) | HIGH |
| 1.35 Seropositivity to HPV 52 | 36 months | 1 (Iversen 2016) | 509 | RR 0.96 (0.92 to 0.99) | HIGH |
| 1.36 Seropositivity to HPV 58 | 36 months | 1 (Iversen 2016) | 505 | RR 0.99 (0.97 to 1.01) | HIGH |

*Results were stratified into subgroups by type of HPV vaccine and time point. GMTs and seropositivity to HPV 31, 33, 45, 52, and 58 are only measured in nonavalent vaccine trials (Iversen 2016).*

1. **GRADE** rating applies to specific vaccine type and outcome
2. **Downgraded one level for inconsistency:** moderate heterogeneity ($I^2 > 30\%$)
3. **Downgraded one level for risk of bias:** high loss to follow up
4. **Downgraded one level for imprecision:** small sample size

**Abbreviations**

- CI: confidence interval
- GMT: geometric mean titre
- HPV: human papillomavirus
- IV: inverse variance
- M-H: Mantel-Haenszel
- RR: risk ratio
- SMD: standard mean difference
- mMU: milli-Merck unit
## Appendix 6. Two doses of HPV vaccine with longer interval versus two doses of HPV vaccine with shorter interval in 9- to 14-year old females and males - immunogenicity outcomes

| Outcome or subgroup* | Population | Follow-up | Studies | Participants | Statistical method | Effect estimate (95% CI) | Certainty of the evidence (GRADE) |
|----------------------|------------|-----------|---------|-------------|-------------------|--------------------------|--------------------------------|
| **3.1 GMT of HPV 6 (mMU/mL)** | | | | | | | |
| 3.1.1 Nonavalent vaccine (0 and 6 months) vs (0 and 12 months) | 9- to 14-year-old females | 1 month after last dose | 1 (Iversen 2016) | 381 | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs 1.62 (1.32 to 1.98) | ⊕⊕⊕⊕ HIGH |
| 3.1.2 Nonavalent vaccine (0 and 6 months) vs (0 and 12 months) | 9- to 14-year-old males | 1 month after last dose | 1 (Iversen 2016) | 397 | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs 1.72 (1.41 to 2.09) | ⊕⊕⊕⊕ HIGH |
| **3.2 GMT of HPV 11 (mMU/mL)** | | | | | | | |
| 3.2.1 Nonavalent vaccine (0 and 6 months) vs (0 and 12 months) | 9- to 14-year-old females | 1 month after last dose | 1 (Iversen 2016) | 381 | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs 2.10 (1.82 to 2.40) | ⊕⊕⊕⊝ MODERATE¹ |
| 3.2.2 Nonavalent vaccine (0 and 6 months) vs (0 and 12 months) | 9- to 14-year-old males | 1 month after last dose | 1 (Iversen 2016) | 398 | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs 2.08 (1.71 to 2.53) | ⊕⊕⊕⊕ HIGH |
| **3.3 GMT of HPV 16 (EU/mL or mMU/mL)** | | | | | | | |
| 3.3.1 Bivalent vaccine (0 and 2 months) vs (0 and 6 months) | 9- to 14-year-old females | 1 month after last dose | 1 (Romanowski 2011) | 136 | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs 2.06 (1.60 to 2.64) | ⊕⊕⊕⊝ MODERATE¹ |
| 3.3.2 Bivalent vaccine (0 and 6 months) vs (0 and 12 months) | 9- to 14-year-old females | 1 month after last dose | 1 (Puthanakit 2016) | 835 | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs 1.22 (1.10 to 1.34) | ⊕⊕⊕⊕ HIGH |
| 3.3.3 Nonavalent vaccine (0 and 6 months) vs (0 and 12 months) | 9- to 14-year-old females | 1 month after last dose | 1 (Iversen 2016) | 401 | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs 1.73 (1.42 to 2.10) | ⊕⊕⊕⊕ HIGH |
| 3.3.4 Nonavalent vaccine (0 and 6 months) vs (0 and 12 months) | 9- to 14-year-old males | 1 month after last dose | 1 (Iversen 2016) | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs (IV, random-effects, 95% CI) | ⊕⊕⊕⊕ HIGH |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| 3.4 GMT of HPV 18 (EU/mL or mMU/mL) | | | | | | |
| 3.4.1 Bivalent vaccine (0 and 2 months) vs (0 and 6 months) | 9- to 14-year-old females | 1 month after last dose | 1 (Romanowski 2011) | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs (IV, random-effects, 95% CI) | MODERATE |
| 3.4.2 Bivalent vaccine (0 and 6 months) vs (0 and 12 months) | 9- to 14-year-old females | 1 month after last dose | 1 (Puthanakit 2016) | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs (IV, random-effects, 95% CI) | HIGH |
| 3.4.3 Nonavalent vaccine (0 and 6 months) vs (0 and 12 months) | 9- to 14-year-old females | 1 month after last dose | 1 (Iversen 2016) | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs (IV, random-effects, 95% CI) | HIGH |
| 3.4.4 Nonavalent vaccine (0 and 6 months) vs (0 and 12 months) | 9- to 14-year-old males | 1 month after last dose | 1 (Iversen 2016) | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs (IV, random-effects, 95% CI) | HIGH |
| 3.5 GMT of HPV 31 (mMU/mL) | | | | | | |
| 3.5.1 Nonavalent vaccine (0 and 6 months) vs (0 and 12 months) | 9- to 14-year-old females | 1 month after last dose | 1 (Iversen 2016) | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs (IV, random-effects, 95% CI) | HIGH |
| 3.5.2 Nonavalent vaccine (0 and 6 months) vs (0 and 12 months) | 9- to 14-year-old males | 1 month after last dose | 1 (Iversen 2016) | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs (IV, random-effects, 95% CI) | HIGH |
| 3.6 GMT of HPV 33 (mMU/mL) | | | | | | |
| 3.6.1 Nonavalent vaccine (0 and 6 months) vs (0 and 12 months) | 9- to 14-year-old females | 1 month after last dose | 1 (Iversen 2016) | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs (IV, random-effects, 95% CI) | HIGH |
| 3.6.2 Nonavalent vaccine (0 and 6 months) vs (0 and 12 months) | 9- to 14-year-old males | 1 month after last dose | 1 (Iversen 2016) | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs (IV, random-effects, 95% CI) | HIGH |
### 3.7 GMT of HPV 45 (mMU/mL)

| 3.7.1 Nonavalent vaccine (0 and 6 months) vs (0 and 12 months) | 9- to 14-year-old females | 1 month after last dose | 1 (Iversen 2016) | 406 | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs (IV, random-effects, 95% CI) |
|---|---|---|---|---|---|---|
| | | | | | 1.23 (0.98 to 1.54) | ⊗⊗⊗⊗ HIGH |

| 3.7.2 Nonavalent vaccine (0 and 6 months) vs (0 and 12 months) | 9- to 14-year-old males | 1 month after last dose | 1 (Iversen 2016) | 409 | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs (IV, random-effects, 95% CI) |
|---|---|---|---|---|---|---|
| | | | | | 1.13 (0.90 to 1.41) | ⊗⊗⊗⊗ HIGH |

### 3.8 GMT of HPV 52 (mMU/mL)

| 3.8.1 Nonavalent vaccine (0 and 6 months) vs (0 and 12 months) | 9- to 14-year-old females | 1 month after last dose | 1 (Iversen 2016) | 403 | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs (IV, random-effects, 95% CI) |
|---|---|---|---|---|---|---|
| | | | | | 1.77 (1.47 to 2.13) | ⊗⊗⊗⊗ HIGH |

| 3.8.2 Nonavalent vaccine (0 and 6 months) vs (0 and 12 months) | 9- to 14-year-old males | 1 month after last dose | 1 (Iversen 2016) | 410 | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs (IV, random-effects, 95% CI) |
|---|---|---|---|---|---|---|
| | | | | | 1.91 (1.59 to 2.29) | ⊗⊗⊗⊗ HIGH |

### 3.9 GMT of HPV 58 (mMU/mL)

| 3.9.1 Nonavalent vaccine (0 and 6 months) vs (0 and 12 months) | 9- to 14-year-old females | 1 month after last dose | 1 (Iversen 2016) | 399 | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs (IV, random-effects, 95% CI) |
|---|---|---|---|---|---|---|
| | | | | | 1.79 (1.48 to 2.17) | ⊗⊗⊗⊗ HIGH |

| 3.9.2 Nonavalent vaccine (0 and 6 months) vs (0 and 12 months) | 9- to 14-year-old males | 1 month after last dose | 1 (Iversen 2016) | 406 | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs (IV, random-effects, 95% CI) |
|---|---|---|---|---|---|---|
| | | | | | 2.00 (1.66 to 2.41) | ⊗⊗⊗⊗ HIGH |

### 3.10 Seroconversion to HPV16

| 3.10.1 Bivalent vaccine (0 and 6 months) vs (0 and 12 months) | 9- to 14-year-old females | 1 month after last dose | 1 (Puthanakit 2016) | 835 | RR (M-H, random-effects, 95% CI) | RR (M-H, random-effects, 95% CI) |
|---|---|---|---|---|---|---|
| | | | | | 1.00 (1.00 to 1.00) | 1.00 (1.00 to 1.00) |

### 3.11 Seroconversion to HPV 18

| 3.11.1 Bivalent vaccine (0 and 6 months) vs (0 and 12 months) | 9- to 14-year-old females | 1 month after last dose | 1 (Puthanakit 2016) | 854 | RR (M-H, random-effects, 95% CI) | RR (M-H, random-effects, 95% CI) |
|---|---|---|---|---|---|---|
| | | | | | 1.00 (1.00 to 1.00) | 1.00 (1.00 to 1.00) |
| 3.11.1 Bivalent vaccine (0 and 6 months) vs (0 and 12 months) | 9- to 14-year-old females | 1 month after last dose | 1 (Puthanakit 2016) | 854 | RR (M-H, random-effects, 95% CI) | RR 1.00 (1.00 to 1.00) |
|---------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| 3.12 GMT of HPV 6 (mMU/mL)† | 3.12.1 Nonavalent vaccine (0 and 6 months) vs (0 and 12 months) | 9- to 14-year-old males and females long interval (0, 12 months) | 36 months after first dose | 1 (Iversen 2016) | 246 | Mean GMT (95% CI) | Mean 401.2 (354.8 to 453.7) |
| | | | | | | | | |
| | | 9- to 14-year-old females short interval (0, 6 months) | | | 236 | | Mean 209.6 (184.9 to 237.6) |
| | | 9- to 14-year-old males short interval (0, 6 months) | | | 254 | | Mean 160.1 (141.9 to 180.7) |
| | 3.13 GMT of HPV 11 (mMU/mL)† | 3.13.1 Nonavalent vaccine (0 and 6 months) vs (0 and 12 months) | 9- to 14-year-old males and females long interval (0, 12 months) | 36 months after first dose | 1 (Iversen 2016) | 246 | Mean GMT (95% CI) | Mean 308.2 (271.8 to 349.6) |
| | | | | | | | | |
| | | 9- to 14-year-old females short interval (0, 6 months) | | | 236 | | Mean 133.7 (117.6 to 152.1) |
| | | 9- to 14-year-old males short interval (0, 6 months) | | | 255 | | Mean 115.2 (101.8 to 130.3) |
| | 3.14 GMT of HPV 16 (mMU/mL)† | 3.14.1 Bivalent vaccine (0 and 6 months) vs (0 and 12 months) | 9- to 14-year-old females | 36 months after first dose | 1 (Puthanakit 2016) | 817 | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs 1.29 (1.15 to 1.44) |
| | | | | | | | | |
| | | 3.14.3 Nonavalent vaccine (0 and 6 months) vs (0 and 12 months) | 9- to 14-year-old males and females long interval (0, 12 months) | 36 months after first dose | 1 (Iversen 2016) | 253 | Mean GMT (95% CI) | Mean 1534.3 (1328.8 to 1771.5) |
### 3.15 GMT of HPV 18 (mMU/mL)†

| 9- to 14-year-old females short interval (0, 6 months) | 263 | Mean 673.8 (582.8 to 779.1) |
|------------------------------------------------------|-----|-----------------------------|
| 9- to 14-year-old males short interval (0, 6 months) | 248 | Mean 592.6 (514.7 to 682.4) |

| 3.15.1 Bivalent vaccine (0 and 6 months) vs (0 and 12 months) | 9- to 14-year-old females | 36 months after first dose | 1 (Puthanakit 2016) | 794 | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs (IV, random-effects, 95% CI) |
|---------------------------------------------------------------|---------------------------|---------------------------|---------------------|-----|------------------------------------------|------------------------------------------|
|                                                              | 9-14 year old males and females long interval (0, 12 months) | 36 months after first dose | 1 (Iversen 2016) | 255 | Mean GMT (95% CI) | Mean 276.4 (245.3 to 311.6) |

| 3.15.3 Nonavalent vaccine (0 and 6 months) vs (0 and 12 months) | 9- to 14-year-old females short interval (0, 6 months) | 248 | Mean 592.6 (514.7 to 682.4) |
| 9- to 14-year-old males short interval (0, 6 months) | 262 | Mean 141.7 (125.9 to 159.4) |

| 3.16 GMT of HPV 31 (mMU/mL)†

| 3.16.1 Nonavalent vaccine (0 and 6 months) vs (0 and 12 months) | 9- to 14-year-old males and females long interval (0, 12 months) | 36 months after first dose | 1 (Iversen 2016) | 257 | Mean GMT (95% CI) | Mean 218.0 (190.6 to 249.4) |

| 9- to 14-year-old females short interval (0, 6 months) | 248 | Mean 127.8 (111.4 to 146.5) |
| 9- to 14-year-old males short interval (0, 6 months) | 261 | Mean 106.9 (93.5 to 122.1) |

| 3.17 GMT of HPV 33 (mMU/mL)†

(Continued)
| 3.20 GMT of HPV 58 (mMUm/L)† | 3.19 GMT of HPV 52 (mMUm/L)† | 3.18 GMT of HPV 45 (mMUm/L)† |
|-----------------------------|-----------------------------|-----------------------------|
| 9- to 14-year-old males     | 9- to 14-year-old males     | 9- to 14-year-old males     |
| short interval (0, 6 months)| short interval (0, 6 months)| short interval (0, 6 months)|
| Mean 263                   | Mean 248                    | Mean 257                    |
| 9- to 14-year-old males     | and females long interval (0, 12 months)| and females long interval (0, 12 months)|
| Mean 257                   | Mean 263                    | Mean 257                    |
| 9- to 14-year-old males     | short interval (0, 12 months)| short interval (0, 12 months)|
| Mean 263                   | Mean 257                    | Mean 257                    |
| 36 months after first dose  | 36 months after first dose  | 36 months after first dose  |
| (Iversen 2016)             | (Iversen 2016)              | (Iversen 2016)              |
| Mean GMT (95% CI)          | Mean GMT (95% CI)           | Mean GMT (95% CI)           |
| Mean 36.4 (26.8 to 46.0)   | Mean 36.4 (26.8 to 46.0)    | Mean 36.4 (26.8 to 46.0)    |
| to 70.7                    | to 70.7                     | to 70.7                     |
| 5- to 14-year-old males     | 5- to 14-year-old females   | 5- to 14-year-old males     |
| and females long interval   | short interval (0, 12 months)| short interval (0, 12 months)|
| (0, 12 months)             | (0, 12 months)              | (0, 12 months)              |
| Mean 143.2 (138.3 to 148.1)| Mean 143.2 (138.3 to 148.1)| Mean 143.2 (138.3 to 148.1)|
| to 159.9                   | to 159.9                    | to 159.9                    |
| 3.19.1 Nonavalent vaccine  | 3.19.1 Nonavalent vaccine   | 3.19.1 Nonavalent vaccine   |
| (0 and 6 months)           | (0 and 6 months)            | (0 and 6 months)            |
| and females long interval   | and females long interval   | and females long interval   |
| (0, 12 months)             | (0, 12 months)              | (0, 12 months)              |
| Mean 30.6 (24.9 to 35.1)   | Mean 30.6 (24.9 to 35.1)    | Mean 30.6 (24.9 to 35.1)    |
| to 35.1                    | to 35.1                     | to 35.1                     |
| 36 months after first dose  | 36 months after first dose  | 36 months after first dose  |
| (Iversen 2016)             | (Iversen 2016)              | (Iversen 2016)              |
| Mean 95.7 (85.1 to 105.7)  | Mean 95.7 (85.1 to 105.7)   | Mean 95.7 (85.1 to 105.7)   |
| to 120.3                   | to 120.3                    | to 120.3                    |
| 3.20 GMT of HPV 58 (mMUm/L)†| 3.19 GMT of HPV 52 (mMUm/L)†| 3.18 GMT of HPV 45 (mMUm/L)†|
### 2.1.1 Nonavalent vaccine (0 and 6 months) vs (0 and 12 months)

| 9- to 14-year-old females long interval (0, 12 months) | Mean GMT (95% CI) | 3.20.1 | 255 |
|-------------------------------------------------------|-------------------|------|-----|
| 9- to 14-year-old males long interval (0, 12 months) | Mean GMT (95% CI) | 138  | 246 |
| 9- to 14-year-old females short interval (0, 6 months) | Mean GMT (95% CI) | 125.8 (111.1) | 299 (8) |

(Continued)
*Results were stratified into subgroups by type of HPV vaccine, gender, schedule, and time point

†Data for nonavalent vaccine at 36 month follow-up (Iversen 2016) was not disaggregated for gender, therefore only mean values (95% CI) are presented per group.

¹Downgraded one level for imprecision: small sample size

Abbreviations

CI: confidence interval  
EU: enzyme-linked immunosorbent assay (ELISA) unit  
GMT: geometric mean titre  
HPV: human papillomavirus  
IV: inverse variance  
M-H: Mantel-Haenszel  
RR: risk ratio  
mMU: milli-Merck unit

Appendix 7. Summary of findings: Longer interval versus shorter interval between second and third doses of quadrivalent HPV vaccine in 18- to 25-year-old males

| Patient or population: 18- to 25-year-old males |
| Settings: community health centres in the USA |
| Intervention: quadrivalent HPV vaccine (3 doses at 0, 2 and 6 months) |
| Comparison: quadrivalent HPV vaccine (3 doses at 0, 2 and 12 months) |

| Outcomes | Anticipated absolute effects* (95% CI) | Relative effect (95% CI) | No of participants (studies) | Certainty of the evidence (GRADE) |
|----------|----------------------------------------|--------------------------|-----------------------------|----------------------------------|
|          | Risk with longer interval | Risk with shorter interval |
| Invasive anal or penile cancer | No studies were identified that reported on this outcome |
| Penile or anal intraepithelial neoplasia | No studies were identified that reported on this outcome |
| External genital lesions (any genotype) | No studies were identified that reported on this outcome |
| Overall local/injection site adverse events | Adverse events data not reported separately for each arm |
| Overall systemic events and general symptoms | Adverse events data not reported separately for each arm |
| Serious adverse events at 13-month follow-up | 0 per 1000 0 per 1000 Not estimable, no events were reported 220 (1 study) VERY LOW¹,²,³ |
| Mortality | No studies were identified that reported on this outcome |

*The risk in the intervention group (and its 95% confidence interval) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI).
GRADE Working Group grades of evidence

High certainty: we are very confident that the true effect lies close to that of the estimate of the effect
Moderate certainty: we are moderately confident in the effect estimate: the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different
Low certainty: our confidence in the effect estimate is limited: the true effect may be substantially different from the estimate of the effect
Very low certainty: we have very little confidence in the effect estimate: the true effect is likely to be substantially different from the estimate of effect

Footnotes

1 Downgraded one level for risk of bias: allocation concealment was not reported and the trial was open label.
2 Downgraded two levels for serious imprecision: no events reported, the study was not powered to detect a difference in serious adverse events.
3 Downgraded one level for indirectness: This outcome is a composite measure of events which may or may not be clinically relevant, may or may not be related to the vaccine and may occur outside a biologically plausible time frame relative to vaccine exposure. This outcome is considered to provide indirect evidence about vaccine safety.

Appendix 8. Three doses of HPV vaccine with shorter interval versus three doses of HPV vaccine with longer interval in 18- to 25-year-old males - immunogenicity outcomes

| Outcome | Follow-up | Studies | Participants | Statistical method | Effect estimate (95% CI) |
|---------|-----------|---------|--------------|-------------------|-------------------------|
| 7.1 GMT of HPV 6 | 1 month after last dose | 1 (Lin 2014) | 170 | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs 1.31 (0.88 to 1.96) |
| 7.2 GMT of HPV 11 | 1 month after last dose | 1 (Lin 2014) | 172 | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs 1.83 (1.18 to 2.84) |
| 7.3 GMT of HPV 16 | 1 month after last dose | 1 (Lin 2014) | 173 | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs 1.32 (0.90 to 1.93) |
| 7.4 GMT of HPV 18 | 1 month after last dose | 1 (Lin 2014) | 174 | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs 1.35 (0.65 to 2.78) |

Abbreviations

CI: confidence interval
GMT: geometric mean titre
HPV: human papillomavirus
IV: inverse variance

Appendix 9. Quadrivalent HPV vaccine compared to control in 16- to 26-year old males - secondary outcomes

Comparison of different human papillomavirus (HPV) vaccine types and dose schedules for prevention of HPV-related disease in females and males (Review)
Copyright © 2019 The Authors. Cochrane Database of Systematic Reviews published by John Wiley & Sons, Ltd. on behalf of The Cochrane Collaboration.
4.1 Persistent infection of HPV 6, 11, 16, or 18
1 (Giuliano 2011)
2790
Rate ratio (IV, random-effects, 95% CI)
Rate ratio 0.14 (0.08 to 0.26)

4.2 Persistent infection of HPV 6, 11, 16, or 18
1 (NCT01862874 2018)
995
Rate ratio (IV, random-effects, 95% CI)
Rate ratio 0.14 (0.04 to 0.47)

4.3 Combined persistent HPV type 6-, 11-, 16-, or 18-related infection or disease (HPV type 6, 11, 16, or 18-related condyloma acuminate, penile, perianal, or perineal intraepithelial neoplasia or cancer)
1 (NCT01862874 2018)
996
Rate ratio (IV, random-effects, 95% CI)
Rate ratio 0.13 (0.04 to 0.45)

Abbreviations
CI: confidence interval
HPV: human papillomavirus
IV: inverse variance

Appendix 10. Bivalent HPV vaccine versus control vaccine in 10- to 18-year-old males - immunogenicity outcomes

| Outcome | Follow-up | Studies | Participants | Statistical method | Effect estimate (95% CI) |
|---------|-----------|---------|--------------|--------------------|--------------------------|
| 5.1 Seroconversion to HPV 16 | 1 month after last dose | 1 (Petaja 2009) | 10- to 18-year-old males | RR (M-H, random-effects, 95% CI) | RR 55.83 (11.43 to 272.67) |
| 5.2 Seroconversion to HPV 18 | 1 month after last dose | 1 (Petaja 2009) | 10- to 18-year-old males | RR (M-H, random-effects, 95% CI) | RR 34.68 (10.22 to 117.68) |
| 5.3 GMT of HPV 16 | 1 month after last dose | 1 (Petaja 2009) | 10- to 18-year-old males | SMD (IV, random-effects, 95% CI) | SMD 1.50 (1.21 to 1.79) |
| 5.4 GMT of HPV 18 | 1 month after last dose | 1 (Petaja 2009) | 10- to 18-year-old males | SMD (IV, random-effects, 95% CI) | SMD 1.36 (1.07 to 1.64) |

Abbreviations
CI: confidence interval
GMT: geometric mean titre
HPV: human papillomavirus
IV: inverse variance
M-H: Mantel-Haenszel
RR: risk ratio
SMD: standard mean difference

Appendix 11. Nonavalent HPV vaccine versus quadrivalent HPV vaccine in females - secondary outcomes

| Outcome or subgroup* | Follow-up | Studies | Participants | Statistical method | Effect estimate (95% CI) |
|----------------------|-----------|---------|--------------|--------------------|--------------------------|
| 2.1 GMT of HPV 6 (mMU/mL) | | | | | |
### 2.1.1 9- to 15-year olds
1 month after last dose
1. (Vesikari 2015) 534
Ratio of GMTs (IV, random-effects, 95% CI)
Ratio of GMTs 1.07 (0.93 to 1.24)

### 2.1.2 16- to 26-year olds
1 month after last dose
1. (Joura 2015) 7968
Ratio of GMTs (IV, random-effects, 95% CI)
Ratio of GMTs 1.02 (0.99 to 1.06)

### 2.2 GM T of HPV 11 (mMU/mL)

#### 2.2.1 9- to 15-year olds
1 month after last dose
1. (Vesikari 2015) 534
Ratio of GMTs (IV, random-effects, 95% CI)
Ratio of GMTs 0.93 (0.80 to 1.08)

#### 2.2.2 16- to 26-year olds
1 month after last dose
1. (Joura 2015) 7977
Ratio of GMTs (IV, random-effects, 95% CI)
Ratio of GMTs 0.80 (0.77 to 0.83)

### 2.3 GM T of HPV 16 (mMU/mL)

#### 2.3.1 9- to 15-year olds
1 month after last dose
1. (Vesikari 2015) 546
Ratio of GMTs (IV, random-effects, 95% CI)
Ratio of GMTs 0.98 (0.85 to 1.12)

#### 2.3.2 16- to 26-year olds
1 month after last dose
1. (Joura 2015) 8094
Ratio of GMTs (IV, random-effects, 95% CI)
Ratio of GMTs 0.99 (0.96 to 1.03)

### 2.4 GM T of HPV 18 (mMU/mL)

#### 2.4.1 9- to 15-year olds
1 month after last dose
1. (Vesikari 2015) 545
Ratio of GMTs (IV, random-effects, 95% CI)
Ratio of GMTs 1.09 (0.91 to 1.31)

#### 2.4.2 16- to 26-year olds
1 month after last dose
1. (Joura 2015) 9080
Ratio of GMTs (IV, random-effects, 95% CI)
Ratio of GMTs 1.19 (1.14 to 1.23)

### 2.5 Seroconversion to HPV 6
1 month after last dose
2. (Joura 2015; Vesikari 2015) 8502
RR (M-H, random-effects, 95% CI)
RR 1.00 (1.00 to 1.00)

#### 2.5.1 9- to 15-year olds
1 month after last dose
1. (Vesikari 2015) 534
RR (M-H, random-effects, 95% CI)
RR 1.00 (0.99 to 1.01)

#### 2.5.2 16- to 26-year olds
1 month after last dose
1. (Joura 2015) 7968
RR (M-H, random-effects, 95% CI)
RR 1.00 (1.00 to 1.00)

### 2.6 Seroconversion to HPV 11
1 month after last dose
2. (Joura 2015; Vesikari 2015) 8511
RR (M-H, random-effects, 95% CI)
RR 1.00 (1.00 to 1.00)

#### 2.6.1 9- to 15-year olds
1 month after last dose
1. (Vesikari 2015) 534
RR (M-H, random-effects, 95% CI)
RR 1.00 (0.99 to 1.01)

#### 2.6.2 16- to 26-year olds
1 month after last dose
1. (Joura 2015) 7977
RR (M-H, random-effects, 95% CI)
RR 1.00 (1.00 to 1.00)

### 2.7 Seroconversion to HPV 16
1 month after last dose
2. (Joura 2015; Vesikari 2015) 8640
RR (M-H, random-effects, 95% CI)
RR 1.00 (1.00 to 1.00)
2.7.1 9- to 15-year olds
1 month after last dose
1 (Vesikari 2015)
546
RR (M-H, random-effects, 95% CI)
RR 1.00 (0.99 to 1.01)

2.7.2 16- to 26-year olds
1 month after last dose
1 (Joura 2015)
8094
RR (M-H, random-effects, 95% CI)
RR 1.00 (1.00 to 1.00)

2.8 Seroconversion to HPV 18
1 month after last dose
1 (Vesikari 2015; Joura 2015)
9625
RR (M-H, random-effects, 95% CI)
RR 1.00 (1.00 to 1.00)

2.8.1 9- to 15-year olds
1 month after last dose
1 (Vesikari 2015)
545
RR (M-H, random-effects, 95% CI)
RR 1.00 (0.99 to 1.01)

2.8.2 16- to 26-year olds
1 month after last dose
1 (Joura 2015)
9080
RR (M-H, random-effects, 95% CI)
RR 1.00 (1.00 to 1.00)

2.9 GM T of HPV 6 (mM U/mL)

2.9.1 16- to 26-year olds
42 months after first dose
1 (Joura 2015)
1367
Ratio of GMTs (IV, random-effects, 95% CI)
Ratio of GMTs 1.02 (0.92 to 1.13)

2.10 GM T of HPV 11 (mM U/mL)

2.10.1 16- to 26-year olds
42 months after first dose
1 (Joura 2015)
1367
Ratio of GMTs (IV, random-effects, 95% CI)
Ratio of GMTs 0.82 (0.74 to 0.90)

2.11 GM T of HPV 16 (mM U/mL)

2.11.1 16- to 26-year olds
42 months after first dose
1 (Joura 2015)
1399
Ratio of GMTs (IV, random-effects, 95% CI)
Ratio of GMTs 0.96 (0.85 to 1.07)

2.12 GM T of HPV 18 (mM U/mL)

2.12.1 16- to 26-year olds
42 months after first dose
1 (Joura 2015)
1576
Ratio of GMTs (IV, random-effects, 95% CI)
Ratio of GMTs 1.17 (1.03 to 1.33)

2.13 Seropositivity to HPV 6

2.13.1 16- to 26-year olds
24 months after first dose
1 (Joura 2015)
1404
RR (M-H, random-effects, 95% CI)
RR 1.01 (0.99 to 1.02)

2.14 Seropositivity to HPV 11

2.14.1 16- to 26-year olds
24 months after first dose
1 (Joura 2015)
1497
RR (M-H, random-effects, 95% CI)
RR 1.00 (0.99 to 1.01)

2.15 Seropositivity to HPV 16

2.15.1 16- to 26-year olds
24 months after first dose
1 (Joura 2015)
1536
RR (M-H, random-effects, 95% CI)
RR 1.01 (1.00 to 1.01)
2.16 Seropositivity to HPV 18

| Outcome | Follow-up | Studies | Participants | Statistical method | Effect estimate (95% CI) |
|---------|-----------|---------|--------------|--------------------|-------------------------|
| 2.16.1 16- to 26-year olds | 24 months after first dose | 1 (Joura 2015) | 1732 | RR (M-H, random-effects, 95% CI) | RR 1.07 (1.02 to 1.11) |
| 2.17 6 months’ persistent infection of HPV 6, 11, 16, or 18 | median 4 years | 1 (Joura 2015) | 11,642 | RR (M-H, random-effects, 95% CI) | RR 0.72 (0.53 to 0.98) |
| 2.18 6 months’ persistent infection of HPV 31, 33, 45, 52, or 58 | median 4 years | 1 (Joura 2015) | 11,896 | RR (M-H, random-effects, 95% CI) | RR 0.04 (0.03 to 0.06) |
| 2.19 12 months’ persistent infection of HPV 6, 11, 16, or 18 | median 4 years | 1 (Joura 2015) | 11,642 | RR (M-H, random-effects, 95% CI) | RR 0.72 (0.43 to 1.20) |
| 2.20 12 months’ persistent infection of HPV 31, 33, 45, 52, or 58 | median 4 years | 1 (Joura 2015) | 11,896 | RR (M-H, random-effects, 95% CI) | RR 0.04 (0.02 to 0.05) |

*Results were stratified into subgroups by age group

**Abbreviations**
CI: confidence interval
GMT: geometric mean titre
HPV: human papillomavirus
IV: inverse variance
M-H: Mantel-Haenszel
RR: risk ratio
mMU: milli-Merck unit

**Appendix 12. Nonavalent HPV vaccine versus quadrivalent HPV vaccine in males - secondary outcomes**
(Continued)

| 6.7 GMT of HPV 45 | 1 month after last dose | 1 (van Damme 2016) | 468 | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs 105.16 (887.87 to 125.85) |
| 6.8 GMT of HPV 52 | 1 month after last dose | 1 (van Damme 2016) | 471 | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs 226.68 (194.71 to 263.90) |
| 6.9 GMT of HPV 58 | 1 month after last dose | 1 (van Damme 2016) | 465 | Ratio of GMTs (IV, random-effects, 95% CI) | Ratio of GMTs 121.23 (101.71 to 144.49) |

| 6.10 Seroconversion to HPV 6 | 1 month after last dose | 1 (van Damme 2016) | 454 | RR (M-H, random-effects, 95% CI) | RR 1.00 (0.97 to 1.02) |
| 6.11 Seroconversion to HPV 11 | 1 month after last dose | 1 (van Damme 2016) | 454 | RR (M-H, random-effects, 95% CI) | RR 1.00 (0.99 to 1.01) |
| 6.12 Seroconversion to HPV 16 | 1 month after last dose | 1 (van Damme 2016) | 471 | RR (M-H, random-effects, 95% CI) | RR 1.00 (0.99 to 1.01) |
| 6.13 Seroconversion to HPV 18 | 1 month after last dose | 1 (van Damme 2016) | 470 | RR (M-H, random-effects, 95% CI) | RR 1.00 (0.99 to 1.01) |
| 6.14 Seroconversion to HPV 31 | 1 month after last dose | 1 (van Damme 2016) | 471 | RR (M-H, random-effects, 95% CI) | RR 1.62 (1.47 to 1.79) |
| 6.15 Seroconversion to HPV 33 | 1 month after last dose | 1 (van Damme 2016) | 472 | RR (M-H, random-effects, 95% CI) | RR 5.84 (4.41 to 7.73) |
| 6.16 Seroconversion to HPV 45 | 1 month after last dose | 1 (van Damme 2016) | 468 | RR (M-H, random-effects, 95% CI) | RR 10.51 (7.09 to 15.57) |
| 6.17 Seroconversion to HPV 52 | 1 month after last dose | 1 (van Damme 2016) | 471 | RR (M-H, random-effects, 95% CI) | RR 36.38 (17.05 to 77.66) |
| 6.18 Seroconversion to HPV 58 | 1 month after last dose | 1 (van Damme 2016) | 465 | RR (M-H, random-effects, 95% CI) | RR 2.76 (2.33 to 3.28) |

**Abbreviations**

CI: confidence interval  
GMT: geometric mean titre  
HPV: human papillomavirus  
IV: inverse variance  
M-H: Mantel-Haenszel  
RR: risk ratio

**Appendix 13. HPV vaccines for people living with HIV - secondary outcomes**

| Outcome | Follow-up | Studies | Participants | Statistical method | Effect estimate (95% CI) | Certainty of the evidence (GRADE) |
|---------|-----------|---------|--------------|-------------------|-------------------------|---------------------------------|

*Comparison of different human papillomavirus (HPV) vaccine types and dose schedules for prevention of HPV-related disease in females and males (Review)*  
Copyright © 2019 The Authors. Cochrane Database of Systematic Reviews published by John Wiley & Sons, Ltd. on behalf of The Cochrane Collaboration.
| Section | Time after Last Dose | Study | Participants | Ratio of GM Ts (IV, random-effects, 95% CI) | Ratio of GM Ts | Significance |
|---------|----------------------|-------|--------------|---------------------------------------------|---------------|-------------|
| 8.1 GMT of HPV 6 | 1 month after last dose | 1 (Levin 2010) | 114 children with HIV (7 to 12 years old) | Ratio of GM Ts (IV, random-effects, 95% CI) | 123.8 (89.0 to 172.1) | LOW1,2 |
| | 24 months after first dose | 1 (Levin 2010) | 116 children with HIV (7 to 12 years old) | Ratio of GM Ts (IV, random-effects, 95% CI) | 50.44 (34.21 to 74.38) | LOW1,2 |
| 8.2 GMT of HPV 11 | 1 month after last dose | 1 (Levin 2010) | 117 children with HIV (7 to 12 years old) | Ratio of GM Ts (IV, random-effects, 95% CI) | 330.4 (261.6 to 417.2) | LOW1,2 |
| | 24 months after first dose | 1 (Levin 2010) | 116 children with HIV (7 to 12 years old) | Ratio of GM Ts (IV, random-effects, 95% CI) | 189.44 (129.29 to 277.59) | LOW1,2 |
| 8.3 GMT of HPV 16 | 1 month after last dose | 1 (Levin 2010) | 117 children with HIV (7 to 12 years old) | Ratio of GM Ts (IV, random-effects, 95% CI) | 935.8 (724.5 to 1208.7) | LOW1,2 |
| | 24 months after first dose | 1 (Levin 2010) | 116 children with HIV (7 to 12 years old) | Ratio of GM Ts (IV, random-effects, 95% CI) | 189.2 (132.8 to 269.7) | LOW1,2 |
| 8.4 GMT of HPV 18 | 1 month after last dose | 1 (Levin 2010) | 117 children with HIV (7 to 12 years old) | Ratio of GM Ts (IV, random-effects, 95% CI) | 18.6 (3.9 to 88.1) | LOW1,2 |
| | 24 months after first dose | 1 (Levin 2010) | 116 children with HIV (7 to 12 years old) | Ratio of GM Ts (IV, random-effects, 95% CI) | 29.57 (18.08 to 48.37) | LOW1,2 |
| 8.5 Seroconversion to HPV 6 | 1 month after last dose | 1 (Levin 2010) | 114 children with HIV (7 to 12 years old) | RR (M-H, random-effects, 95% CI) | 55.7 (3.6 to 868.4) | LOW1,2 |
| 8.6 Seroconversion to HPV 11 | 1 month after last dose | 1 (Levin 2010) | 117 children with HIV (7 to 12 years old) | RR (M-H, random-effects, 95% CI) | 55.7 (3.6 to 868.6) | LOW1,2 |
| 8.7 Seroconversion to HPV 16 | 1 month after last dose | 1 (Levin 2010) | 117 children with HIV (7 to 12 years old) | RR (M-H, random-effects, 95% CI) | 18.6 (3.9 to 88.1) | LOW1,2 |
| 8.8 Seroconversion to HPV 18 | 1 month after last dose | 1 (Levin 2010) | 117 children with HIV (7 to 12 years old) | RR (M-H, random-effects, 95% CI) | 53.9 (3.5 to 840.0) | LOW1,2 |
| 8.9 Seropositivity, HPV 6, 11, 16, 18 | 1 month after last dose | 1 (Hidalgo-Tenorio 2017) | 128 HIV-infected MSM (≥ 18 years old) | RR (M-H, random-effects, 95% CI) | 2.47 (1.66 to 3.68) | MODERATE1 |
| 8.10 GMT of HPV 16 | 1 month after last dose | 1 (Toft 2014) | 40 HIV-infected males and females | Ratio of GM Ts (IV, random-effects, 95% CI) | 0.79 (0.25 to 2.52) | LOW3 |
### 6 months after last dose

| Study                                                                 | HPV Type | Time after Dose | No. of Participants | GMT Ratio (IV, random-effects, 95% CI) | GRADE | Comments |
|----------------------------------------------------------------------|----------|-----------------|---------------------|----------------------------------------|-------|----------|
| 8.11 GMT of HPV 18                                                   |          | 1 month after last dose | 39 HIV-infected males and females | Ratio of GMTs 0.67 (0.21 to 2.08) | LOW | ⊕⊕⊝        |
|                                                                      |          | 6 months after last dose | 39 HIV-infected males and females | Ratio of GMTs 0.52 (0.16 to 1.76) | LOW | ⊕⊕⊝        |
| 8.12 Seropositivity at 12 months, HPV 16                             |          | 6 months after last dose | 91 HIV-infected males and females | Ratio of GMTs 0.67 (0.21 to 2.08) | MODERATE | ⊕⊕⊝        |
|                                                                      |          | 1 month after last dose | 91 HIV-infected males and females | Ratio of GMTs 0.67 (0.21 to 2.08) | MODERATE | ⊕⊕⊝        |
| 8.13 Seropositivity at 12 months, HPV 18                             |          | 6 months after last dose | 91 HIV-infected males and females | Ratio of GMTs 0.67 (0.21 to 2.08) | MODERATE | ⊕⊕⊝        |
|                                                                      |          | 1 month after last dose | 91 HIV-infected males and females | Ratio of GMTs 0.67 (0.21 to 2.08) | MODERATE | ⊕⊕⊝        |
| 8.14 Persistent anal infection (HPV 6, 11, 16, 18)                   |          | 6 months after last dose | 575 HIV-positive males and females | Ratio of GMTs 0.67 (0.21 to 2.08) | MODERATE | ⊕⊕⊝        |
|                                                                      |          | 1 month after last dose | 575 HIV-positive males and females | Ratio of GMTs 0.67 (0.21 to 2.08) | MODERATE | ⊕⊕⊝        |
| 8.16 GMT of HPV 16                                                   |          | 1 month after last dose | 82 HIV-positive females | Ratio of GMTs 0.67 (0.21 to 2.08) | MODERATE | ⊕⊕⊝        |
|                                                                      |          | 12 months after first dose | 78 HIV-positive females | Ratio of GMTs 0.67 (0.21 to 2.08) | MODERATE | ⊕⊕⊝        |
| 8.17 GMT of HPV 18                                                   |          | 1 month after last dose | 83 HIV-positive females | Ratio of GMTs 0.67 (0.21 to 2.08) | MODERATE | ⊕⊕⊝        |
|                                                                      |          | 12 months after first dose | 79 HIV-positive females | Ratio of GMTs 0.67 (0.21 to 2.08) | MODERATE | ⊕⊕⊝        |
| 8.18 Seroconversion to HPV 16                                        |          | 12 months after first dose | 79 HIV-positive females | Ratio of GMTs 0.67 (0.21 to 2.08) | MODERATE | ⊕⊕⊝        |
| 8.19 Seroconversion to HPV 18                                        |          | 12 months after first dose | 79 HIV-positive females | Ratio of GMTs 0.67 (0.21 to 2.08) | MODERATE | ⊕⊕⊝        |

*Results were stratified into subgroups by type of HPV vaccine and gender

1Downgraded one level for imprecision: small sample size.
2 Downgraded one level for risk of bias: details about how randomisation sequence was generated or how blinding was achieved were not reported.

3 Downgraded two levels for imprecision: small sample size and very wide 95% confidence interval that incorporates a potential large beneficial effect and a potential large harmful effect.

4 Downgraded one level for imprecision: wide 95% confidence interval that incorporates a potential beneficial effect and a potential harmful effect.

**Abbreviations**

CI: confidence interval  
GMT: geometric mean titre  
HPV: human papillomavirus  
IV: inverse variance  
M-H: Mantel-Haenszel  
RR: risk ratio

**Appendix 14. Sensitivity analysis using Peto odds ratio for outcomes with very rare events**

| Analysis number, outcome (subgroup) | Studies | Participants | Odds ratio (M-H, random-effects model, 95% CI) | Peto odds ratio (Peto, fixed-effect model, 95% CI) |
|--------------------------------------|---------|-------------|---------------------------------------------|-----------------------------------------------|
| 1.5.3 Deaths (nonavalent vaccine)    | 1       | 602         | 0.33 (0.01 to 8.19)                          | 0.14 (0.00 to 6.82)                          |
| 4.12 Serious adverse events (overall)| 2       | 5162        | 0.69 (0.29 to 1.66)                          | 0.67 (0.28 to 1.62)                          |
| 4.13 Deaths                         | 2       | 5173        | 0.30 (0.09 to 1.01)                          | 0.32 (0.11 to 0.91)                          |
| 6.2 High-grade cervical disease related to HPV 6 to 11, 16, or 18 | 1       | 11,656      | 1.00 (0.06 to 16.01)                         | 1.00 (0.06 to 16.01)                         |
| 6.3 High-grade vulval and vaginal disease related to HPV 6, 11, 16, or 18 | 1       | 11,769      | 0.14 (0.01 to 2.77)                          | 0.14 (0.01 to 1.30)                          |
| 6.4 High-grade cervical disease related to HPV 31, 33, 45, 52, or 58 | 1       | 11,892      | 0.03 (0.00 to 0.21)                          | 0.15 (0.08 to 0.29)                          |
| 6.5 High-grade vulval and vaginal disease related to HPV 31, 33, 45, 52, or 58 | 1       | 12,021      | 0.14 (0.01 to 2.77)                          | 0.14 (0.01 to 1.30)                          |
| 6.7 Cervical intraepithelial neoplasia 2 related to HPV 6, 11, 16, or 18 | 1       | 11,656      | 3.00 (0.12 to 73.77)                         | 7.40 (0.15 to 373.90)                        |
| 6.8 Cervical intraepithelial neoplasia 2 related to HPV 31, 33, 45, 52, or 58 | 1       | 11,892      | 0.03 (0.00 to 0.23)                          | 0.15 (0.08 to 0.30)                          |
| 6.9 Cervical intraepithelial neoplasia 3, adenocarcinoma in situ, and cervical cancer related to HPV 6, 11, 16, or 18 | 1       | 11,656      | 0.33 (0.01 to 8.19)                          | 0.14 (0.00 to 6.83)                          |
| 6.10 Cervical intraepithelial neoplasia 3, adenocarcinoma in situ, and cervical cancer related to HPV 31, 33, 45, 52, or 58 | 1       | 11,892      | 0.07 (0.00 to 1.16)                          | 0.14 (0.03 to 0.59)                          |
| 6.17.2 Deaths (16- to 26- year olds) | 1       | 14,149      | 1.00 (0.29 to 3.46)                          | 1.00 (0.29 to 3.46)                          |
8.2 Overall systemic events and general symptoms

|            |   |   |             |             |
|------------|---|---|-------------|-------------|
|            | 1 | 126| 0.62 (0.05 to 7.05) | 0.59 (0.04 to 8.54) |

Abbreviations
CI: confidence interval
HPV: human papillomavirus
M-H: Mantel-Haenszel

CONTRIBUTIONS OF AUTHORS
HB, NH, BSB, GV, JP, CG, and AXRB were involved in the conception and design of the protocol for this review. VL designed and ran the electronic database searches. HB, NH, BSB, GV, and JP were involved in screening abstracts and full-texts, data extraction and analysis. NH and HB drafted the review manuscript with assistance from NL. BSB, GV, JP, CG, AXRB, and NL provided critical input into the interpretation and intellectual content of the review. All authors read and approved the final version of the review.

DECLARATIONS OF INTEREST
None of the authors have a conflict of interest in relation to this review.

Cochrane Response, which is an evidence consultancy operated by The Cochrane Collaboration, was commissioned to perform part of this review for the WHO Initiative for Vaccine Research.

Hanna Bergman: HB works for Cochrane Response, an evidence services unit operated by the Cochrane Collaboration, and was paid by Cochrane Response for contributing to this review.

Brian S Buckley: BSB works for Cochrane Response, an evidence services unit operated by the Cochrane Collaboration, and was paid by Cochrane Response for contributing to this review.

Gemma Villanueva: GV works for Cochrane Response, an evidence services unit operated by the Cochrane Collaboration, and was paid by Cochrane Response for contributing to this review.

Jennifer Petkovic: JP works for Cochrane Response, an evidence services unit operated by the Cochrane Collaboration, and was paid by Cochrane Response for contributing to this review.

Chantelle Garritty: CG works as a consultant for Cochrane Response, an evidence services unit operated by Cochrane, and was paid by Cochrane Response for contributing to this review.

Vittoria Lutje: VL works as an independent consultant conducting literature searches for various research groups. None of them has any potential relevance to the submitted work.

Alina Ximena Riveros-Balta: AXRB is an employee of the WHO Initiative for Vaccine Research, which commissioned the review.

Nicola Low: NL was the principal author of the original systematic review of alternative HPV vaccination schedules (D’Addario 2017), which was commissioned by the WHO Initiative for Vaccine Research.

Nicholas Henschke: NH works for Cochrane Response, an evidence services unit operated by Cochrane, and was paid by Cochrane Response for contributing to this review.

SOURCES OF SUPPORT
Internal sources
• No sources of support supplied

External sources
• WHO Initiative for Vaccine Research, Switzerland.
  Commissioned Cochrane Response to complete the review
DIFFERENCES BETWEEN PROTOCOL AND REVIEW

The original protocol of this review was developed to match the needs of the WHO Initiative for Vaccine Research, and a number of comparisons investigated were not included in the current review.

The protocol did not include adverse events as outcomes, these were extracted and included in this version of the review. In addition, for this version of the review, immunogenicity outcomes were considered as secondary outcomes and included only as Appendices. The outcome of histologically confirmed high-grade disease was amended for males, to include all clinical outcomes.

We did not plan to assess the impact of statistical method to calculate odds ratios for very rare events in the protocol. We decided to assess the robustness of our analyses for very rare events (rates less than 1%) in view of the alternative statistical methods that can be used in this scenario (Bradburn 2007).

The following comparisons, for non-randomised immuno-bridging studies were included in the original protocol, but were not reported in the current review:

- fewer than three doses in adolescent girls (9 to 14 years) versus three doses in young women (15 to 26 years), using the same vaccine and the same dosage (three-dose arm using the WHO recommended schedule);
- one dose in adolescent girls (9 to 14 years) versus two doses in young women (15 to 26 years), using the same vaccine and the same dosage;
- males versus the same HPV vaccine type in females;
- any HPV vaccine type in men who have sex with men (MSM) versus the same vaccine type in females or heterosexual males;
- any HPV vaccine type in people with HIV infection compared with people without HIV infection.

INDEX TERMS

Medical Subject Headings (MeSH)

Dose-Response Relationship, Immunologic; Papillomavirus Infections [*prevention & control]; Papillomavirus Vaccines [*administration & dosage]; Randomized Controlled Trials as Topic; Uterine Cervical Neoplasms [prevention & control] [virology]

MeSH check words

Adolescent; Adult; Child; Female; Humans; Male; Young Adult