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Efficacy of behaviour change interventions to influence human papillomavirus (HPV) vaccine uptake: a systematic review and behaviour change techniques analysis

Harriet Bland[1,2*], James Harwood[3], Jamie Chua[4], Nia Roberts[5], Tharin Azad[4], Joseph Jonathan Lee[2] and Charlotte Albury[2]

Abstract

Background Behaviour change interventions that increase human papillomavirus (HPV) vaccine uptake in school children have been identified, but not which behaviour change techniques (BCTs) make them effective, or whether interventions are best targeted towards adolescents or their parent/carer(s). We aimed to assess the efficacy of behaviour change interventions to increase HPV vaccination compared to usual care according to BCTs implemented, and to identify whether parent/carer(s), adolescents or both are the optimal intervention target population.

Methods We searched Central, Embase, Medline and Eric databases from 1st September 2008 to 17th July 2023 for randomised controlled trials (RCTs) reporting on HPV vaccine uptake following behaviour change interventions. We coded BCTs in interventions using the BCT taxonomy (v1). Random-effects meta-analyses and subgroup analyses were performed with data from studies that provided count data on HPV vaccine uptake by BCTs implemented and intervention target population.

Results One thousand three hundred sixty-three unique records were identified, of which eight were eligible for inclusion. Implementing any behaviour change intervention was associated with a borderline significant increase in HPV vaccine uptake (OR 1.2 95% CI 1.0 to 1.4), interventions that implemented 'Instruction on how to perform the behaviour' (BCT 4.1) and 'Information about health consequences' (BCT 5.1) were not associated with increased HPV vaccine uptake (OR 1.7 95% CI 0.8 to 3.5), but analysis of two interventions implementing 'Adding objects to the environment' (BCT 12.5) in addition showed that this combination may be associated with significantly greater HPV vaccination (OR 13.6 95% CI 3.9 to 46.5). We found that interventions targeting parent/carer(s)-only were associated with a small significant increase in HPV vaccine uptake (OR 1.3 95% CI 1.1 to 1.5), but adolescent-only or parent/carer(s) and adolescent targeted interventions were not.

Conclusions To our knowledge this is the first systematic review and meta-analysis to quantify the efficacy of behaviour change interventions to increase HPV vaccine uptake according to BCTs implemented. We have

*Correspondence:
Harriet Bland
harriet.bland@jesus.ox.ac.uk

Full list of author information is available at the end of the article

demonstrated that implementing any behaviour change intervention marginally increases HPV vaccine uptake, and have identified a combination of BCTs that may be associated with significantly increased HPV vaccine uptake. Our work provides compelling evidence that public health interventions must be specific and evidence-based and calls for the implementation of changes to usual care in school-based vaccination programmes.

Keywords Behaviour change techniques, HPV, Vaccine, Adolescents, Systematic review, Meta-analysis

Background

Human papillomavirus (HPV) defines a group of sexually transmitted viruses with serious health consequences including cervical cancer and other cancers including anal, vulval and vaginal cancer [1]. Vaccination prior to HPV exposure is most effective at preventing both disease and transmission [2]. Vaccination occurs in early adolescence, primarily in schools. Global HPV vaccine coverage is significantly lower than the target of 90% to eliminate cervical cancer, with only 56% of girls in high income countries vaccinated [3]. Improving vaccine uptake is important to reduce associated morbidity and mortality [4].

Behaviour change intervention trials to improve HPV vaccine uptake have yielded mixed results. Previous systematic reviews have identified these trials but failed to effectively account for the heterogeneity of interventions [5, 6]. Identified trials vary in the intervention components included. Examples include instructing an individual on how to become HPV vaccinated, or informing an individual of the health consequences of HPV infection. It is currently unclear which, if any, intervention components make them effective. Behaviour change techniques (BCTs) are the active components of complex interventions. They can be classified using the behaviour change technique taxonomy (v1), a framework of 93 techniques hierarchically clustered into 16 domains [7]. Identifying and classifying the BCTs used across trials offers a method to identify the intervention components that are most likely to be effective.

Given the adolescent age at which vaccination is commonly administered, a parent/carer must give consent for adolescents to be vaccinated. There are hence complex psychosocial factors at play between consenting parent/carer(s) and potential adolescent vaccinees. Previous studies have explored perspectives of parents and adolescents in the decision-making process [8], but it is unclear which group of people is the most powerful intervention target population.

Despite the questions raised by contradicting or unequivocal research on these fronts, no previous study, to our knowledge, has attempted to systematically identify components of interventions that are associated with effectiveness in terms of increasing vaccination, or whom interventions should be targeted towards. In this study we aimed to understand which BCTs may be effective at increasing HPV vaccine uptake in 11–17 year-olds in schools. To meet this aim our objectives were to:

1. Identify BCTs used in behaviour change intervention trials aiming to improve HPV vaccine uptake
2. Identify BCTs that are associated with effectiveness in terms of increasing HPV vaccination
3. Determine whether targeting BCTs towards the adolescent, parent/carer(s), or both is associated with effectiveness in terms of increasing HPV vaccination

Methods

Selection criteria

The protocol for this review was pre-published on GitHub on 27th June 2023 [9] and updated and published on Open Science Framework on 12th December 2023 [10]. We included randomised and cluster-randomised controlled trials, in high income countries (as defined in the World Bank 2023 list [11]), that reported the efficacy of a behaviour change intervention at increasing HPV vaccine uptake in 11–17 year-olds in schools. Studies implemented in low- or middle-income countries were excluded due to significant differences in their public health infrastructure compared to high-income countries, which would have unacceptably increased the heterogeneity between the interventions implemented. Including only high-income countries provides a meaningful basis for comparison and synthesis, enhancing the applicability of our findings with minimal risk of oversimplification due to excessive heterogeneity. Only school-based vaccination programs were included, as this setting facilitates systematic communication between adolescents and their parent/carer(s), providing a consistent and accessible setting for public health interventions. Only studies that provided count data on HPV vaccine uptake following a behaviour change intervention were included in the meta-analysis. All other study designs were excluded, as were non-peer-reviewed studies, to reduce risk of bias. Studies not published in English were excluded. The study inclusion and exclusion criteria are available in Additional File A.

Search strategy

We searched the Cochrane Central Register of Controlled Trials (Cochrane Library, Wiley) [Issue 7 of 12, July 2023], Medline (OvidSP) [1946-], Embase (OvidSP) [1974-] and ERIC (EBSCOHost) [1966-] from 1st

September 2008 (when the school-based HPV vaccination program was first implemented in the UK) to 17th July 2023, when searches were conducted. Our search string combined a comprehensive list of keywords and MeSH terms, with the Cochrane RCT filter [12] used (see Additional File B for full search strategy). The search strategy was developed in consultation with an information specialist (NR). Search results were imported into Rayyan [13] and authors were contacted where studies were unobtainable.

Reviewers HB and JC independently screened titles and abstracts for inclusion. Disagreements during screening were resolved by consensus or referred to a third reviewer (CA or JL). HB and JC followed the same process for full-text screening. Reviewer HB then performed backwards citation searching of eligible studies to identify additional relevant studies.

Data extraction and quality assessment

The lead author (HB) extracted information regarding the study design, participants, target population for the intervention, vaccine outcome data source, and components of the usual care arm. Reviewers HB and JC independently extracted vaccine uptake in control and intervention groups from each paper, and formed a frequency table for each intervention and usual care arm containing the total participants and frequency of HPV vaccine uptake. Discrepancies during extraction were resolved by consensus or referred to a third reviewer (JL). HPV vaccine initiation was chosen as the measure to best reflect HPV vaccine uptake, defined as receipt of at least one dose of the HPV vaccine. This accounts for variability in vaccine dosage between healthcare systems; typically one to three vaccine doses are recommended. There is now evidence that one vaccine dose is as effective as multiple doses of the HPV vaccine [14]. Vaccine uptake was extracted at the longest timeframe after the intervention, to account for longer-term interventions coded as 'Prompts/cues' (BCT 7.1), as well as vaccine receipt within a 'catch-up period'. Only individuals who hadn't previously received a HPV vaccine were included. Studies that reported the efficacy of a behaviour change intervention to increase HPV vaccine uptake and satisfied our inclusion criteria, but which did not provide sufficient count data are discussed in the systematic review but not included in the meta-analysis. Reviewers HB and TA independently assessed risk of bias using the Cochrane Risk of Bias 2 tool [15].

Behaviour change techniques coding

Studies were coded for the presence of specific BCTs by trained coders HB and JH using Michie's BCT taxonomy (v1) [7]; uncertainties were agreed by consensus. HB adapted Michie et al.'s extant codebook to include study-specific definitions and examples to ensure consistency of coding and mitigate the potential for coder drift.

Statistical analyses

Reviewer JL performed statistical analyses using Stata (StataCorp, College Station, Tx) with commands 'metan' and 'meta forestplot'. Random-effects meta-analyses (Maximum Likelihood REML) and subgroup analyses were performed of studies that provided count data on HPV vaccine uptake following a behaviour change intervention. Results are expressed as odds ratios (OR) with 95% confidence intervals (95%CI), with vaccination as the outcome measured. Where a study included more than one intervention arm, these were analysed separately with usual care arm participants and HPV vaccine uptake split equally between arms [16] to avoid double-counting and allow both intervention arms, and their respective BCT combinations, to be analysed separately. We accounted for cluster-randomised trials by multiplying the log standard error of the estimates by the square root of the design effect prior to meta-analysis [16]. We calculated the design effect for two level sampling (school and pupil) and three level sampling (school, classroom and pupil) according to the reported design [17, 18]. If the number of clusters at a level was not clear, we used the lower number. In the absence of studies reporting calculated intracluster correlation coefficients, we used figures from a systematic review of school based intracluster correlation coefficients; for schools, 0.0155, and for classrooms, 0.0190 [19]. Subgroups analysed were interventions including 'Instruction on how to perform the behaviour' (BCT 4.1) and 'Information about health consequences' (BCT 5.1) versus those not including this combination; interventions with the intervention target population adolescents-only versus those targeting parent/carer(s)-only, versus those targeting parent/carer(s) and adolescents; and interventions including 'Adding objects to the environment' (BCT 12.5) versus those not including this BCT. Heterogeneity was quantified using the I^2 statistic and p values from Cochran's Q test.

Results

Our searches identified 1363 studies and eight [20–27] were eligible for inclusion (Fig. 1). Table 1 shows the characteristics of included studies. The eight included studies [20–27] comprised 17,380 total participants. Seven studies' populations were male and female [20, 21, 23–27], while one study included only females [22]. Studies were conducted in five different high-income countries: Australia [20, 21, 24], UK [22], Sweden [23], U.S [25, 26], and a French overseas department [27]. Two studies' source of HPV vaccine uptake data was self-report [22, 23], five used a health record [20, 21, 27], immunisation registry [25] or database [24] and one used health records

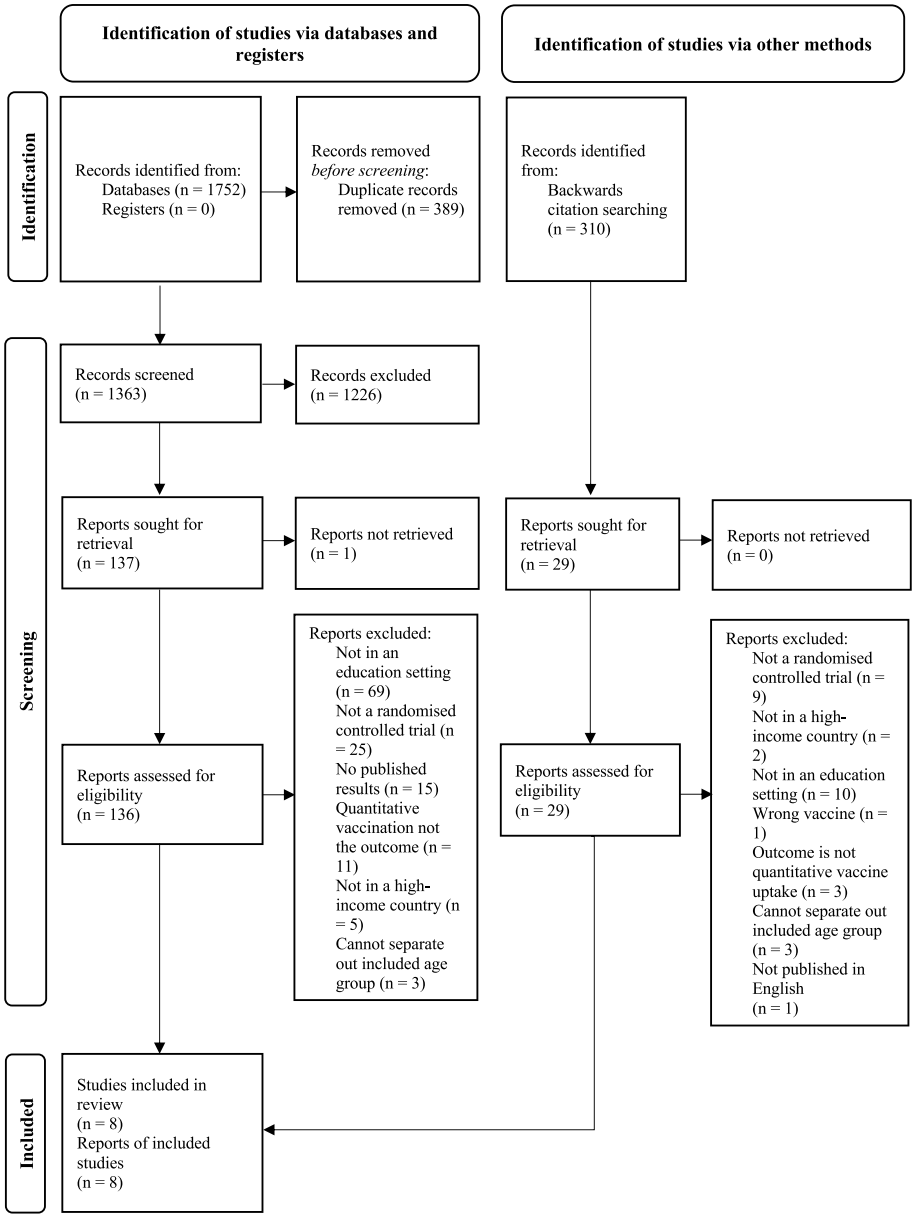

Fig. 1 PRISMA flowchart of literature search. n = number of studies. Adapted from Page et al. (2021) [28]

and parental report when records were unavailable [26]. Usual care varied from no information to the receipt of a vaccine consent form and some vaccine information. Two studies [24, 25] had two intervention arms. Six were cluster-RCTs [20–23, 25, 27] and two were individually-randomised parallel group trials [24, 26]. Two interventions targeted adolescents-only [22, 23], four targeted parent/carer(s)-only [24–26] and four targeted parent/carer(s) and adolescents [20, 21, 25, 27]. Two studies [21, 26] did not report count data on HPV vaccine uptake therefore were not included in meta-analyses; Epstein et al. (2021) [21] did not split vaccination data between usual care and intervention arms, and Santa Maria et al. (2021) [26] did not provide vaccination rates before intervention.

Risk of bias results are shown in Fig. 2. Four studies had low, two, some concerns, and two, high risk of bias. A funnel plot and Egger's test were not used to assess publication bias given that fewer than ten intervention arms were eligible for inclusion in the meta-analysis. Overall, heterogeneity between interventions according to the I^2 test was low (3.83%). Heterogeneity was also estimated to be low in the analysis of interventions implementing 'Adding objects to the environment' (BCT 12.5) in both the BCT-positive group (0.0%) and the BCT-negative group (0.0%), as well as in the parent/carer(s)-only targeted intervention analysis (0.0%). Heterogeneity was estimated to be considerable amongst all other analyses.

Table 1 Study characteristics

Intervention arm (n = 10)	n = total participants	Study design	Population	Country	Intervention target population	Outcome data source	Usual care
Davies (2023) [20]	6967	Cluster-RCT (40 schools)	Male and female	Australia	Parent/carer(s) and adolescent	Health record	'Standard practice' not described
Epstein (2021) [21]	2754	Cluster-RCT (19 schools)	Male and female	Australia	Parent/carer(s) and adolescent	Health record	Information about vaccination. Consent form
Forster (2017) [22]	437	Cluster-RCT (6 schools)	Female-only	UK	Adolescent-only	Self-report (return of consent form)	Leaflet about vaccination. Consent form
Grandahl (2016) [23]	170	Cluster-RCT (18 schools, 113 classes)	Male and female	Sweden	Adolescent-only	Self-report (questionnaire)	'General information' not described
Santa Maria (2021) [26]	508	Individually-randomised parallel group trial	Male and female	U.S	Parent/carer(s) -only	Immunisation registry (85%) followed by parental report (15%)	Nothing
Tran (2022) [27]	176	Cluster-RCT (2 schools, 24 classes)	Male and female	French overseas department	Parent/carer(s) and adolescent	Health record	Nothing
Tull (2019) Motivational SMS [24]	2205	Individually-randomised parallel group trial	Male and female	Australia	Parent/carer(s) -only	Database	Nothing
Tull (2019) Self-regulatory SMS [24]	2181		Male and female		Parent/carer(s) -only		Nothing
Underwood (2019) Parent-only [25]	980	Cluster-RCT (11 schools)	Male and female	U.S	Parent/carer(s) -only	Immunisation registry	Nothing
Underwood (2019) Parent & adoles. [25]	1002		Male and female		Parent/carer(s) and adolescent		Nothing

Objective 1: identify BCTs used in behaviour change intervention trials aiming to improve HPV vaccine uptake

A total of 15 BCTs, across 8 taxonomy domains, were used across the included studies. On average, 3.6 BCTs were used per intervention (range 1–7). The most common BCT, implemented in eight arms, was 'Instruction on how to perform the behaviour' (BCT 4.1); 'Information about health consequences' (BCT 5.1) was implemented in seven arms, all of which also implemented 'Instruction on how to perform the behaviour' (BCT 4.1). Two intervention arms implemented 'Adding objects to the environment' (BCT 12.5). Objects added were condoms [23] and a flipchart with pictures and information [27]—a leaflet was not sufficient for this BCT, and was included in many usual care arms. Table 2 provides definitions and examples for each BCT present, and Table 3 shows BCTs identified in each arm.

Objective 2: identify BCTs that are associated with effectiveness in terms of increasing HPV vaccination

Overall, we find evidence of a borderline significant association between using any behaviour change intervention and increased HPV vaccine uptake compared to usual care in meta-analysis of 8 arms, with an odds ratio of 1.2 (1.0, 1.4) (Fig. 3). Two interventions were associated with significantly increased HPV vaccine uptake: Tran (2022) [27] with an odds ratio of 12.8 (3.3, 49.4) and Tull (2019) Self-regulatory SMS [24] with an odds ratio of 1.3 (1.0, 1.8). Of the two studies without sufficient data for meta-analysis, Santa Maria et al. (2021) [26] reported a significant increase in HPV vaccine initiation after six months in the intervention arm compared to usual care (p = 0.02) and Epstein et al. (2021) [21] reported no significant difference between arms. Meta-regression to determine the relationship between the number of BCTs employed and HPV vaccine uptake was not conducted to avoid overfitting as there were fewer than 10 included arms.

Seven interventions implemented 'Information about health consequences' (BCT 5.1). These all also implemented 'Instruction on how to perform the behaviour' (BCT 4.1). There was no evidence of an association between this combination and increased HPV vaccine uptake compared to usual care in meta-analysis of six arms, with an odds ratio of 1.7 (0.8, 3.5) (Fig. 4). One study not included in the meta-analyses (Santa Maria et al. (2021) [26]), which stated that there was a significant increase in HPV vaccine initiation after six months in the intervention arm compared to the usual care arm (p = 0.02), implemented this combination of BCTs.

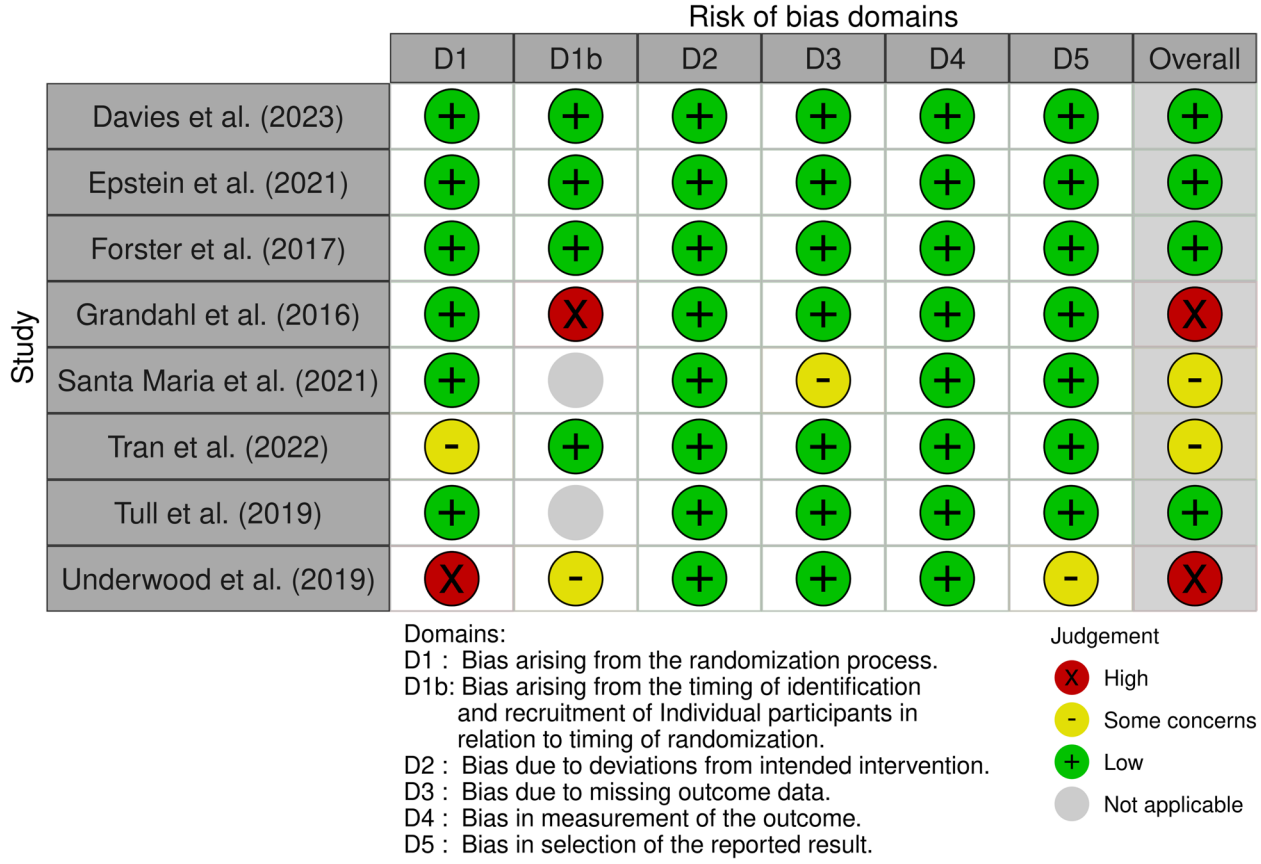

Fig. 2 Traffic light plot of risk of bias results [29]

Table 2 Examples of BCTs implemented

Domain	BCT	Example from study
1 Goals and planning	1.4 Action planning	Planning how to get to the vaccination on time [24]
3 Social support	3.1 Social support (unspecified)	Improving parent/carer-adolescent shared decision making [20]
	3.2 Social support (practical)	Healthcare professional helping parents/carers to schedule a time to talk with adolescent [26]
	3.3 Social support (emotional)	Encouraging parent/carer-adolescent discussion about emotions [26]
4 Shaping knowledge	4.1 Instruction on how to perform the behaviour	Instruction on how to be HPV vaccinated [23]
5 Natural consequences	5.1 Information about health consequences	Information about HPV symptoms and cervical cancer [23]
	5.2 Salience of consequences	PowerPoint presentation including HPV infection complications [25]
	5.3 Information about social and environmental consequences	Manual with information about social consequences of premature sexual behaviours [26]
	5.6 Information about emotional consequences	Adolescent in-class education about psychosocial outcomes of vaccination [20]
7 Associations	7.1 Prompts/cues	Encouraging catch-up of missed vaccine doses [20]
9 Comparison of outcomes	9.1 Credible source	Information from the Centers for Disease Control and Prevention (CDC) recommending vaccination [25]
10 Reward and threat	10.1 Material incentive (behaviour)	Informing adolescents they will receive a reward if consent form returned [21]
	10.2 Material reward (behaviour)	Giving adolescents a reward when they return their consent form [21]
12 Antecedents	12.1 Restructuring the physical environment	Implementing consent form return strategies [20]
	12.5 Adding objects to the environment	Providing a flipchart with pictures and information [23]

Table 3 BCTs in each intervention arm. BCT number identifiers as allocated in the BCT taxonomy (v1) [7]

	Davies (2023)[20]	Epstein (2021)[21]	Forster (2017)[22]	Grandahl (2016)[23]	Santa Maria (2021)[26]	Tran (2022)[27]	Tull (2019) Motivational SMS[24]	Tull (2019) Self-regulatory SMS[24]	Underwood (2019) Parent-only[25]	Underwood (2019) Parent & adoles.(25)	Total
1.4 Action planning								✓			1
3.1 Social support (unspecified)	✓										1
3.2 Social support (practical)					✓				✓	✓	3
3.3 Social support (emotional)					✓						1
4.1 Instruction on how to perform the behaviour	✓			✓	✓	✓	✓	✓	✓	✓	8
5.1 Information about health consequences	✓			✓	✓	✓	✓		✓	✓	7
5.2 Salience of consequences										✓	1
5.3 Information about social and environmental consequences	✓				✓						2
5.6 Information about emotional consequences	✓										1
7.1 Prompts/cues	✓										1
9.1 Credible source				✓					✓	✓	3
10.1 Material incentive (behaviour)		✓	✓								2
10.2 Material reward (behaviour)		✓								✓	2
12.1 Restructuring the physical environment	✓										1
12.5 Adding objects to the environment				✓		✓					2
Total	7	2	1	4	5	3	2	2	4	6	36

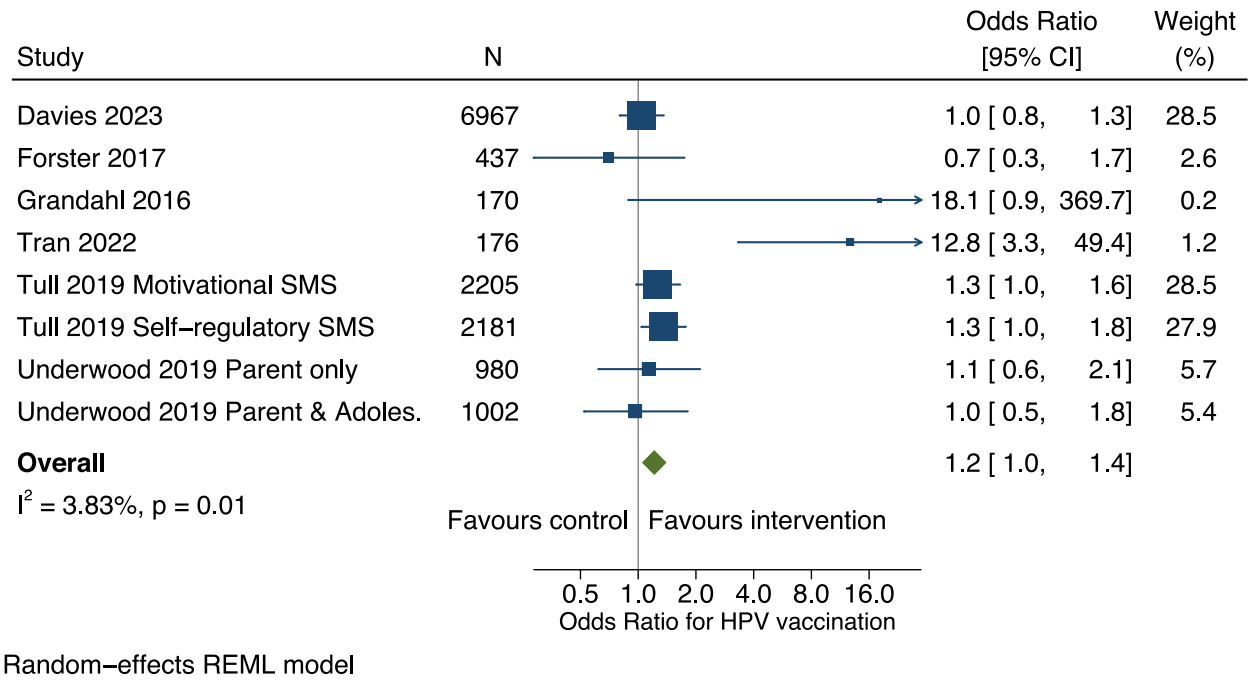

Fig. 3 Forest plot of all interventions, including all BCTs

Post-hoc analysis was performed of two interventions including 'Adding objects to the environment' (BCT 12.5), which also both implemented 'Instruction on how to perform the behaviour' (BCT 4.1) and 'Information about health consequences' (BCT 5.1). This BCT combination was associated with significantly increased HPV vaccine uptake compared to usual care in meta-analysis of two arms, with an odds ratio of 13.6 (3.9, 46.5) (Fig. 5).

Objective 3: determine whether targeting BCTs towards the adolescent, parent/carer(s), or both is associated with effectiveness in terms of increasing HPV vaccination

Targeting parent/carer(s)-only was associated with significantly increased HPV vaccine uptake compared to usual care in meta-analysis of three arms, with an odds ratio of 1.3 (1.1, 1.5) (Fig. 6). The intervention in Santa Maria et al. (2021) [26], although not meta-analysed, was targeted at parent/carer(s)-only and stated that there was a significant increase in HPV vaccine initiation after six months in the intervention arm compared to the usual care arm ($p = 0.02$). There was no association between adolescent-only targeted interventions and HPV vaccine uptake compared to usual care in meta-analysis of two arms, with an odds ratio of 2.6 (0.1, 57.8) (Fig. 6). Targeting parent/carer(s) and adolescents was not associated with increased HPV vaccine uptake compared to usual care in meta-analysis of three arms, with an odds ratio of 2.1 (0.4, 9.7) (Fig. 6). The intervention in Epstein et al. (2021) [21], although not meta-analysed, targeted parent/carer(s) and adolescents and reported no significant difference between usual care and intervention arms.

Discussion

We conducted a systematic review and behaviour change techniques analysis to understand which BCTs may be effective at increasing HPV vaccine uptake in 11–17 year-olds in schools. We included eight studies from five countries. We found that simply implementing any behaviour change intervention is associated with borderline increased HPV vaccine uptake in school children. Implementing the most commonly used combination of BCTs 'Instruction on how to perform the behaviour' (BCT 4.1) and 'Information about health consequences' (BCT 5.1) was not associated with increased HPV vaccine uptake in school children. The only BCT that the two interventions associated with increased HPV vaccine uptake both implemented was 'Instruction on how to perform the behaviour' (BCT 4.1). We cannot conclude from our analyses whether this BCT alone increases HPV vaccine uptake; a further review with this pre-stated aim may be warranted. We also found that implementing the BCTs 'Adding objects to the environment' (BCT 12.5), 'Instruction on how to perform the behaviour' (BCT 4.1) and 'Information about health consequences' (BCT 5.1) together increases HPV vaccine uptake significantly more than when only implementing the BCTs 'Instruction on how to perform the behaviour' (BCT 4.1) and 'Information about health consequences' (BCT 5.1). It is possible that objects, such as condoms, or a flipchart with pictures and information, serve as more salient, long-term reminders of the importance of HPV vaccination and of how to be vaccinated.

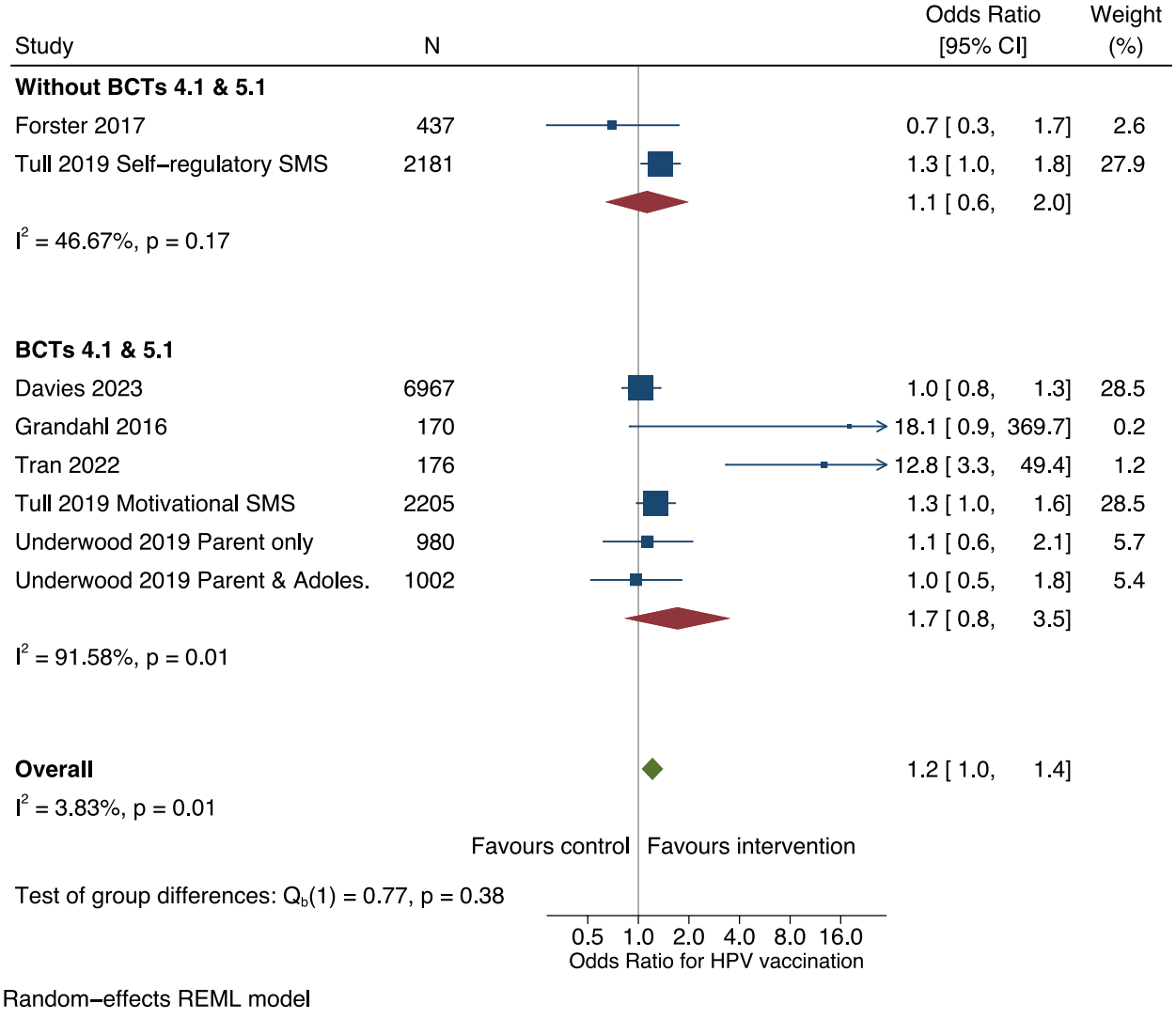

Fig. 4 Forest plot of interventions including 'Instruction on how to perform the behaviour' (BCT 4.1) and 'Information about health consequences' (BCT 5.1) versus those not using this combination of BCTs

Our findings that provision of a salient object in addition to instruction and information significantly increases HPV uptake more than provision of instruction and information alone aligns with a 2021 systematic review of interventions to mitigate vaccine hesitancy, which showed that providing educational messages increased knowledge but was not consistently associated with behaviour change [30].

Our findings regarding the optimal intervention target population to increase HPV vaccination require further investigation. Subgroup analyses show that there was no evidence of an association between adolescent-only, nor adolescent and parent/carer(s) targeted interventions and increased HPV vaccine uptake. There was evidence for a significant increase in HPV vaccine uptake compared to usual care with parent/carer(s)-only targeted interventions, suggesting that these interventions hold most promise. However, as this effect size is modest and confidence intervals are close to 1, this is suggestive but not conclusive of a relationship between a parent/carer-only target population and increased HPV vaccine uptake. It cannot be concluded from this systematic review that targeting parent/carer(s) only is a better intervention strategy than targeting adolescents only or parents and adolescents. Many other vaccines are administered to the adolescent age group, which are affected by the complex interplay between consenting parent/carer(s) and adolescent vaccinees. We recommend that a further systematic review is warranted to determine the optimal intervention target population for adolescent vaccines more generally, which would benefit from a broader search criteria, no doubt allowing more studies to be included, which would, likely, narrow confidence intervals and provide a more robust evidence base.

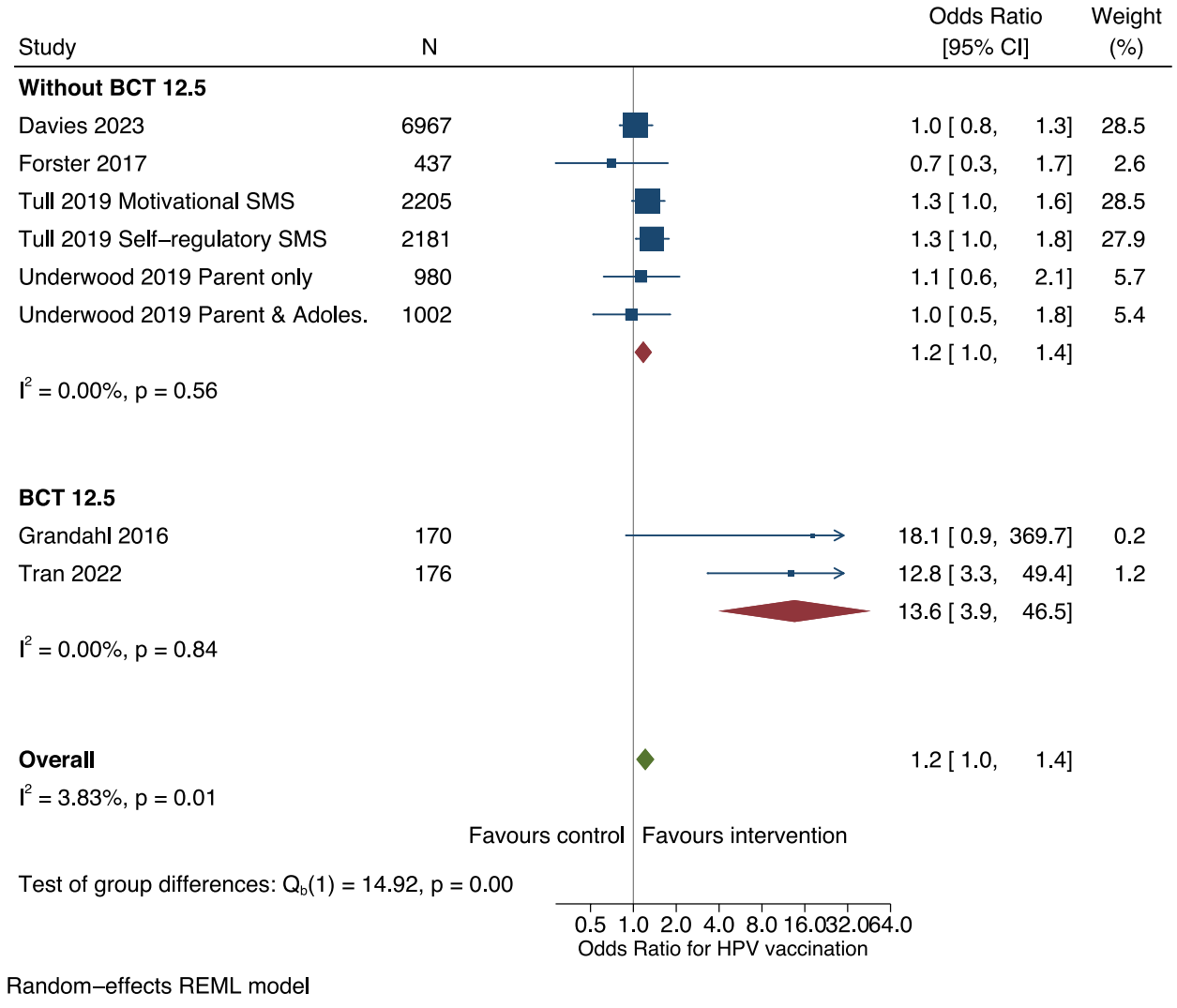

Fig. 5 Forest plot of interventions including 'Adding objects to the environment' (BCT 12.5) versus those not using this BCT

Previous studies assessing the efficacy of behaviour change interventions to increase HPV vaccine uptake have yielded mixed results and many fail to account for the heterogeneity of interventions because they neglect standardised taxonomies to categorise interventions [5, 6]. Our research builds on this extant evidence by categorising interventions according to the BCTs they implement. This study is the first, to our knowledge, to do this. However, it is possible that the heterogeneity between the studies included in this review could be accounted for by variables other than BCTs implemented or intervention target population, such as distinct public health infrastructure and HPV vaccination programs in different countries, different requirements for consent from parent/carer(s) and/or adolescents, differences in school experience (such as class size), or differences between the components of 'usual care' in relation to HPV vaccination. Our measures of heterogeneity using the I^2 statistic should also be interpreted with caution due to the low number of studies included. Further, Cochran's Q test *p* values (see Figs. 3–6) suggest significant heterogeneity may remain.

Our findings should be interpreted in the face of the limitations of this review. Only eight original studies are included, two of which failed to report necessary data for inclusion in the meta-analysis. Additionally, four of the studies included were rated 'some concerns' or 'high' risk of bias. More well-reported, high-powered RCTs with 'low' risk of bias ratings are needed. Further, some studies failed to clearly describe the components of interventions, making BCT coding challenging. Future randomised controlled trials should be pre-registered, high-powered and clearly reported. It would be beneficial for the BCTs in intervention and usual care arms in these primary studies to be reported according to the BCT taxonomy (v1), in combination with its use as a standardised taxonomy in reviews. This would provide continuity from

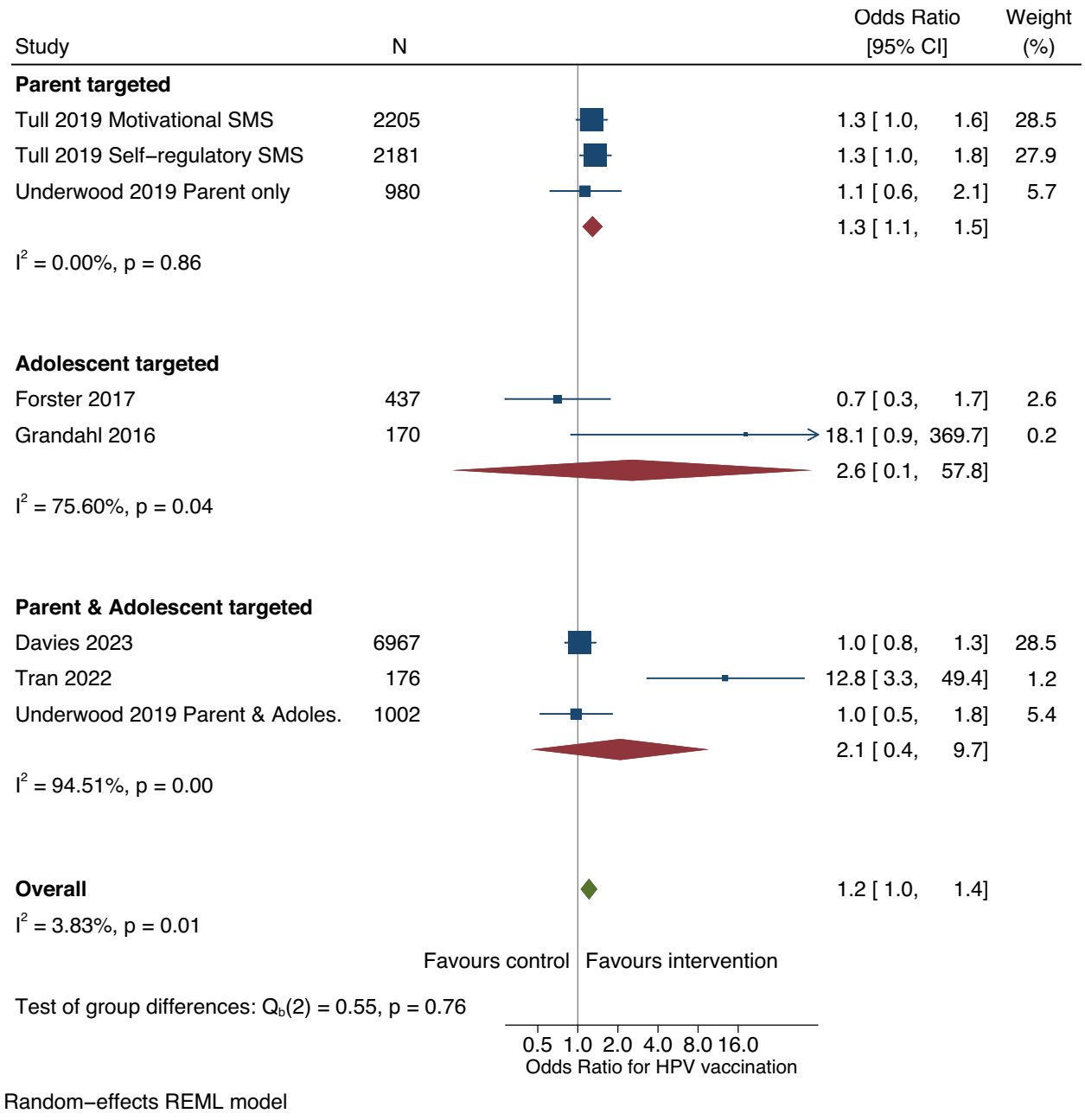

Fig. 6 Forest plot of adolescent-only targeted interventions versus parent/carer(s)-only targeted interventions versus parent/carer(s) and adolescent targeted interventions

primary to secondary literature and allow usual care arms to also be coded in reviews, in addition to intervention arms. The subgroup analysis of studies including 'Adding objects to the environment' (BCT 12.5) was post-hoc, and only includes two intervention arms. This still provides valuable insight, however a review with the primary aim of assessing the efficacy of this BCT to increase HPV vaccine uptake is warranted. Additionally, because we did not have the resources for the translation and screening of non-English texts, we restricted our inclusion criteria to studies published in the English language, however it is possible that this resulted in the exclusion of potentially valuable studies from non-English speaking high-income countries. We also excluded low- and middle-income countries from this systematic review due to significant differences in their public health infrastructure compared to high-income countries, which would have unacceptably increased the heterogeneity between the interventions implemented, making the conclusions drawn less reliable. However, these countries, which may lack cervical screening programmes, are high-priority for HPV vaccination. A further review assessing the efficacy

of interventions to increase HPV vaccine uptake in low- and middle-income countries is also warranted.

Conclusions

This systematic review showed that interventions aiming to increase HPV vaccination of adolescents in schools may be more effective if they implement use of salient objects combined with information about how to receive the HPV vaccine, and the health consequences of HPV infection. Evidence is suggestive but not conclusive that interventions targeting only parent/carer(s) may be associated with increased HPV vaccine uptake. Recognising these active components of behaviour change interventions is important for supporting implementation and uptake in school-based vaccination programmes.

Abbreviations

HPV	Human papillomavirus
BCT	Behaviour change technique
RCT	Randomised controlled trial

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12885-025-15210-9.

Supplementary Material 1.

Supplementary Material 2.

Supplementary Material 3.

Supplementary Material 4.

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Not applicable.

Authors' contributions

H.B. was the lead author and is the corresponding author. H.B., C.A., J.L., and N.R. developed the research question, H.B. and N.R. performed systematic searching, H.B., J.C., C.A. and J.L. performed screening and data extraction, H.B., J.H. and C.A. performed behaviour change techniques coding, J.L. performed data analysis, H.B. and T.A. performed a risk of bias assessment, H.B., C.A. and J.L. wrote the main manuscript text and all authors reviewed the manuscript.

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Data availability

The dataset supporting the conclusions of this article is included within Additional File C.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

Charlotte Albury has worked as an independent consultant for the Behavioural Insights team, Wildfowl Wetlands Trust, Adelphi Real World, Oxford Health BRC, and Linney Create for which she was paid personally. She was an academic advisor for NESTA, and did not receive personal payment. Joseph Jonathan Lee has received grants, unrelated to this project, from the NIHR.

Author details

[1]Jesus College, University of Oxford, Oxford, UK
[2]Nuffield Department of Primary Care Health Sciences, University of Oxford, Oxford, UK
[3]Nuffield Department of Orthopaedics, Rheumatology and Musculoskeletal Sciences, University of Oxford, Oxford, UK
[4]University of Oxford, Oxford, UK
[5]Bodleian Health Care Libraries, Oxford, UK

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