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ARTICLE

Factors influencing vaccine hesitancy among United Kingdom adolescents in a senior high school environment and actions to address it

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ABSTRACT

We explored adolescent viewpoints on vaccines and hesitancy using an anonymized, validated, self-completed electronic questionnaire amongst state-school Year 12–13 adolescents in London, UK. As the response rate was low (Cohort 1; $n = 112/486$, 23.0%), we repeated the survey with incoming students (cohort 2, $n = 256/275$; 93%). A focus group ($n = 31$) evaluated international HPV campaign posters. Cohort 1 participants were 82.1% female, 13.4% male, and ethnically diverse (32.1% Asian/Asian British, 29.5% Black/Black British, 25.9% White, 7.1% Mixed); Cohort 2 were 80% female, 18% male, with participants identifying as 38% Black/Black British, 34% Asian/Asian British, 15% White, 12% Mixed/Others. Across both cohorts, participants believed childhood vaccinations were safe (Cohort 1 = 95.8%, Cohort 2 = 91%). COVID-19 vaccination uptake was higher in Cohort 1 than 2 (76.8% vs 67%), with fewer participants believing it was adequately tested (56.3% vs 47%). Support for mandatory COVID-19 vaccination for healthcare workers (HCW) was high (Cohort 1:77.8–79% "all" vs "patient-facing HCWs;" Cohort 2 = 62–64%). Similar patterns were observed for mandatory influenza vaccination (Cohort 1: 62.5–66.7%; Cohort 2: 62–63%). Vaccination decisions in Cohort 2 were primarily influenced by parents (96%), healthcare providers (48%), and school friends (36%) (Cohort 1 = 30.2%, 19.6%, and 12%, respectively). Recommendations by doctors, experts and parents (but not politicians) and school-based vaccine availability boosted vaccine confidence. Social media had minimal impact. Most participants received HPV vaccine (Cohort 1 = 83.1%, Cohort 2 = 77.2%). International HPV posters received strong but mixed support; direct design input from the target group is needed to ensure the success of visual vaccine promotions.

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Introduction

Vaccines play a vital role in the prevention of acute and chronic infectious diseases. Increasingly, they are of value in preventing antimicrobial resistant infections and cancer.[1] Vaccines are a crucial link between individual and societal-level actions to promote health as well as carrying economic benefits. A study predicted that in 94 modeled countries, vaccination would avert $1510.4 billion ($674.3–$2643.2 billion) (2018 USD) in costs due to illness in a vaccinated population compared with a scenario of no vaccination at all.[2] Despite the pandemic raising awareness about vaccines, it also served to polarize views about their value.[3] In 2012, the WHO defined vaccine hesitancy (VH) as a "complex behavioural phenomenon specific to vaccines, context, time, and place influenced by factors of complacency, convenience and confidence." VH is pragmatically highly variable depending on the vaccine, context, time and geographical location.[4] In 2019, the WHO described VH as one of the major threats to global health triggered by a significant global increase in a key vaccine-preventable disease, measles.[5]

While vaccinations for adolescents have typically had a lower priority than those given in early childhood, they are now becoming increasingly important.[6,7] Typically, data on hesitancy for childhood vaccination largely reflect parental opinions.[7] However, adolescence is a crucial period for administering certain primary vaccinations, such as the human papillomavirus (HPV) and for booster doses of early childhood vaccinations against diseases like diphtheria, polio and tetanus[8–10] and at this age, decisions to vaccinate are likely formed through a combination of parental and adolescent views.[11] VH has contributed to measles cases and outbreaks, in LMICs and high-income countries including the USA, Europe and UK[7,12,13] e.g. 128,000 children died of measles globally in 2021, yet measles vaccination rates have fallen. The UK has seen significant measles outbreaks against reduced MMR vaccination rates in the West Midlands and London.[14] Measles outbreaks have been reported in Austria, the Philippines, Romania and the USA.[15]

In the 2023–2024 academic year, HPV vaccine uptake decreased for Year 9 teens to 74.1% (females) and 68.5%

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(males) and Year 10 rates dropped to 76.7% (females) and 71.2% (males), remaining well below pre-pandemic levels of around 90%.[16] Similarly, Td/IPV coverage among Year 9 students ranged from 64.0% in London (the lowest) to 78.6% in the East of England (the highest) in 2023–24.[17]

In the UK, Canada, and Sweden, teenagers can legally override parental decisions if deemed mature enough to understand the consequences of vaccination (e.g. in the UK, "Gillick-competent"). In the UK, clinicians need to consider "Gillick competency" if a young person under the age of 16 wishes to receive treatment without their parents' or carers' consent or, in some cases, knowledge. If the person has informed their parents of the treatment they wish to receive but their parents do not agree with their decision, treatment can still proceed if the child has been assessed as Gillick competent i.e. mature enough to understand and make the decision. Despite this legal support for self-consent, written parental consent may still be required.

In the USA, self-consent laws for vaccination in minors vary by state: only Alabama, Alaska, Arizona, Arkansas, California, Delaware, Idaho, Illinois, Iowa, Louisiana, Minnesota, New York, North and South Carolina, Oregon, Pennsylvania, Rhode Island and Washington DC allow some form of consent rights by minors for vaccination. Within these states, vaccines such as HPV and hepatitis B (but not all other vaccines) can be given after self-consent by minors (usually under legislation or rights to reproductive health care and prevention of sexually transmitted diseases). Some states within this group allow choice if a medical professional deems the minor can understand benefits and risks without parental consent whilst others require explicit parental approval for COVID-19 vaccination.[18] Anecdotally in the UK, NHS health professionals may refuse to vaccinate adolescents without parental agreement. It remains uncertain whether allowing adolescents to consent independently would improve vaccination rates in this age group.[19]

A significant portion of the population remains hesitant against all or particular vaccines, with studies indicating that vaccine hesitancy affects approximately 20–40% of the population in some regions.[7] Additionally, surveys conducted in England revealed that only 36.8% of children and adolescents were willing to have a COVID-19 vaccination, highlighting the increasing importance of addressing vaccine hesitancy in this age group.[6] During the COVID pandemic, data from the 'Understanding Society' survey revealed a VH rate of 27% among individuals aged 16–24. Hesitancy was notably higher in young women (21.0% compared to 14.7% in men).[20]

The difference in uptake of vaccinations is governed by various factors including perception of the target disease and vaccines, sociodemographic characteristics, cultural context and parental/guardian influence and beliefs.[21] Understanding the perspectives of young adults is crucial, as they represent the bedrock of future familial and societal vaccine beliefs.

Therefore, it is important to understand the determinants that inhibit vaccine uptake and those that could promote it. Our study aims to identify the factors contributing to vaccine hesitancy in UK adolescents as part of developing and piloting future strategies and interventions tailored to promote vaccination in pre-adults.

We are focusing on adolescents as this is a neglected group with most studies focusing on parental attitudes or other adults toward vaccination. Nevertheless, our study builds on earlier work. In a longitudinal study of vaccine hesitancy attitudes relating to COVID-19 vaccine uptake in the USA, Latkin et al.[22] showed that vaccine hesitancy was independently associated with family and friends discouraging vaccination, uncertainty around information sources on vaccine safety and vaccine testing, as well as gender, politics and income. In a cross-sectional web-based survey conducted in June 2023 among female college students in four cities in Guangdong Province, vaccine hesitancy to HPV was linked to factors such as trust in vaccine efficacy, perception of HPV infection risk, price considerations, and constraints like distance or time.[23] Several studies have looked at the potential for social media misinformation to affect vaccine hesitancy to a specific vaccine or to affect the uptake of other vaccines, e.g. hesitancy to HPV or Hepatitis B vaccination and COVID-19 vaccination.[24] Similarly, misinformation due to the COVID-19 pandemic may still affect HPV vaccination. For example, in a national survey of attitudes to HPV vaccination post-COVID amongst ($n = 3968$) U.S. mothers with children aged 9–17 y, 11.5% had changed to a negative attitude to HPV vaccination. The authors argued that targeted strategies were needed to address erosion in confidence in the HPV vaccine and other vaccines resulting from disinformation associated with the COVID-19 pandemic.[25] In a survey of 1745 parents in the USA, at the height of the COVID-19 pandemic, less than half of the parents said that they were likely to have their child vaccinated against COVID-19.[26]

Understanding and addressing adolescent vaccine hesitancy will have a major public health impact if vaccine uptake is improved individually and vaccine hesitancy reduced generally within the population. School-based education and behavioral campaigns with novel extra-curricular approaches can help to address misinformation by encouraging more to challenge mis- or disinformation relating to vaccines.

The findings of this study will enable the development and implementation of targeted interventions tailored to address the determinants of vaccine hesitancy in adolescents, leading to greater support for vaccination in general and improved vaccination rates overall.

Methods

Review of literature on adolescent vaccine hesitancy

We reviewed articles examining vaccine hesitancy in teenagers or adolescents related to HPV, COVID-19, and flu vaccinations. The specific search strategy involved using PubMed, and Google Scholar to identify research articles focusing on adolescent perspectives on HPV, flu and COVID-19 vaccination. Search terms included combinations of keywords such as *"adolescents"*, *"teens"*, *"young adults,"* *"HPV vaccine"*, *"COVID-19 vaccination"*, *"flu vaccine,"* *"vaccine hesitancy"* and *"vaccine uptake"*. Boolean operators like *"AND"* and *"OR"* were used to refine the results. Filters were applied to include only English language articles and studies published from 2005 to 2023, ensuring relevance and timeliness.

Participants

As part of our study, year 12 and 13 (final school years) students of a London, mixed gender and socially and ethnically diverse, state school were invited to participate (October to November 2023). This age group was chosen as individuals over 16 could both accept vaccinations and participate in surveys without the requirement for parental permission. We wanted to obtain the independent viewpoint of pre-adult students without capturing parental influences or opinions and prior to viewpoints being influenced at work and university which we have explored previously.[27]

We repeated the identical anonymized survey 1 y later (October–November 2024) for the new incoming Year 12 students ($n = 275$ students) (Cohort 2). As the response rate in the first cohort was relatively low, in order to boost the response rate, whilst preserving the anonymous nature of the survey we offered a small reward to the whole year group (a donut for all) if the response rate overall exceeded 70%.

The high school leadership approved the study and the school's participation. The Imperial College London Research Ethics Committee approved the study. The corresponding author will "preserve the confidentiality of participants taking part in the study and fulfill transparency requirements under GDPR for health and care research" (data is anonymized at the source so confidentiality is preserved). Data will be stored for 10 y after completion of the study.

Measures

Results are reported here for demographic characteristics (e.g. age, gender, ethnicity, intention to receive a COVID-19 vaccine, influenza, HPV and meningitis vaccine if offered, and the reason for this decision). We also sought to understand awareness of childhood vaccines, and by contrast the HPV vaccine, including its role in preventing cervical cancer, and meningococcal vaccine as examples of vaccines taken at the point at which parental and individual decision-making are arguably most balanced.

Self-administered questionnaire

The draft questionnaire was based on our previously validated questionnaire (Drobniewski et al.)[27] supplemented by the Vaccine Hesitancy Scale (VHS), part of another validated questionnaire developed by Larson et al.[28] and Shapiro et al.[29] The latter is a 5-point scale with participants scoring after an initial prompt of "*How much do you agree with the each of the following statements on vaccinations?*" The scoring corresponded to 5 (strongly disagree), 4 (disagree), 3 (neither agree or disagree), 2 (agree), 1 (strongly agree) with the statement. We retained the VHS questions, even when they overlapped with others, but modified them slightly to create a personal adolescent-focused rather than parent-focused scale which could be used in future to create longitudinal assessments as well as help us understand the degree of VH amongst the students currently.

The Vax Hesitancy Questions from Larson et al.[28] and modifications:

Original VHS Questions (Larson et al.)[28]	Modified and used for this study
Getting vaccines is a good way to protect my child/children from disease	Childhood vaccines are important for my health
Childhood vaccines are effective	Childhood vaccines are effective
Having my child vaccinated is important for the health of others in my community.	Having myself vaccinated is important for the health of others in my community
All childhood vaccines offered by the government program in my community are beneficial.	All childhood vaccines offered by the government program in my community are beneficial
The information I receive about vaccines from the vaccine program is reliable and trustworthy	The information I receive about vaccines from the vaccine program is reliable and trustworthy
Generally, I do what my doctor or healthcare provider recommends about vaccines for my child/ children.	Generally, I do what my doctor or healthcare provider recommends about vaccines
New vaccines carry more risks than older vaccines	New vaccines carry more risks than older vaccines
I am concerned about serious adverse effects of vaccines (question removed as found unreliable and 9 item survey was adopted instead of 10 items (Shapiro et al. 2018)	I am concerned about serious adverse effects of vaccines
My child/children does or do not need vaccines for diseases that are not common anymore.	I do not need vaccines for diseases that are not common anymore

To pretest the questionnaire, we organized a focus group of 13 students, coordinated by two other students amongst the authors (MB, AG), who were studying sociology A levels in Year 13 selected by a teacher-author and school year leader (AM). Pre-testing the questionnaire allowed revision to remove ambiguity and to ensure consistent understanding of questions, and appropriate phrasing.

The authors (FD, MA, MB, and RA) redrafted the questions based on the student feedback and input. This revised and finalized survey questionnaire was then uploaded to the Qualtrics survey tool. Questionnaires, with a response link or QR code to click on, were emailed to students via the school communication system. Individuals were informed in writing that completion of the questionnaire was completely voluntary and would constitute acceptance to participate anonymously. The self-administered, anonymous (at source) questionnaire covered basic demographics, knowledge of COVID-19, influenza, HPV, and meningitis vaccines and their willingness to receive these vaccines. We also questioned whether they believed that healthcare workers (including students) should receive vaccinations compulsorily. Additionally, we inquired about the factors that would motivate them to get vaccinated. We employed a 5-point Likert scale to obtain a more nuanced response for some questions.

Sample size

To calculate the required sample size based on a 95% confidence level, a margin of error of 10% a population proportion of 50%, and a population size of 486, the required sample size was approximately 97. This was the estimated sample size needed to achieve statistically significant results with the desired level of precision.

For the study, data was collected in two rounds:

Round 1: In the first round, 112 out of 486 participants responded, yielding a response rate of approximately 23%. Although the response rate was lower than expected, the sample size of 112 was sufficient to achieve adequate statistical power. However, due to the low response rate, we confirmed our findings by:

Round 2: repeating the survey with a new cohort of Year 12 students ($n = 275$). This round achieved a higher response rate of 93%, with 256 students completing the survey. The final sample size after both rounds combined was 368 participants (112 from Round 1 and 256 from Round 2).

Behavioural change

To pilot the evaluation of different public health and Non-Governmental Organization HPV campaign posters aimed at promoting the uptake of HPV vaccination in adolescents, we conducted focus groups amongst year 12 students ($n = 31$).

Volunteer sampling was used; the opportunity to participate was advertised on the school digital Hubs (Google Classroom) for all Year 12 students studying psychology and sociology, with a link to register their interest. They were told that the activity would occur on a single day for between 2 and 3.5 h and comprise a brief presentation regarding the vaccine hesitancy results from the previous phase and to provide feedback and input on different HPV posters as to how effective they would be in terms of messaging.

The intent was to random sample volunteers if the number was too large, but the number of volunteers made it viable to recruit all of them. No remuneration or incentives were offered as a reward for participation, other than noting that it is a good opportunity to get involved in academic research (e.g. getting first-hand experience of how research is conducted), particularly for students interested in scientific or social sciences research.

Posters with text were limited to English. Images were HPV promotional posters produced by the UK Health Security Agency (UK HSA), USA Centers for Disease Control and Prevention (CDC), George Washington School of Medicine and CDC, Public Health England, American College Health Foundation, The National Institute for Public Health and the Environment (RIVM), Nederlands and The New Zealand HPV project.

The focus group centered on the public health HPV images and was mediated by FD, CH and MA with a self-selected group of student volunteers from Cohort 1 ($n = 31$). One of the 12 public health posters was projected onto a screen for 30 s (to mimic view time of someone walking past the poster). Students were invited to score each image for personal impact regarding HPV vaccination and whether it would encourage them to be HPV vaccinated (regardless of whether they had actually been vaccinated) from 1 (least likely) to 10 (most likely) using a paper-based form completed anonymously. Participants could also add further free text if they wish to explain their score/impact on them. Visual images (Figure 1) were ranked according to the mean scores for each poster (by calculating the mean score across all participants) ($n = 31$). An additional thematic table has been included to present findings based on free-text comments (Supplementary Table S1).

Each image was given an aggregate score. Following this, an open discussion was conducted with the group in response to questions on "what images had made the most positive impact (and the most negative impact)" in persuading an individual to be HPV vaccinated.

Analysis

Paper forms were transcribed into an Excel database, and Qualtrics questionnaires were analyzed using descriptive statistics methodology using Qualtrics and Excel.

To measure the relationship between independent variables, such as gender and ethnicity, and dependent variables, including attitudes toward vaccines, we used Chi-Squared and logistic regression analysis. Chi-Square was performed to test whether the distribution of responses differs significantly across gender or ethnicity groups. Logistic regression showed the direction and strength of associations between variables, while using p-values to determine statistical significance, with $p < .05$ indicating a significant relationship.

Results

Literature review

This process identified 27/87 English-language articles that provided insights into vaccine hesitancy and uptake among adolescents. However, our review revealed a significant research gap regarding nuanced adolescent perspectives on vaccine hesitancy.

Survey participant demographics

A total of 112 students (Cohort 1) completed the questionnaire at a response rate of 112/486 or 23.0%, with 82.1% identifying as female, 13.4% as male, and 4.5% preferring not to specify their gender. The participants were aged between 16 and 18 y. Ethnically, the group was diverse: 32.1% were Asian/Asian British, 29.5% were Black/Black British, 25.9% were White, 7.1% were of mixed or multiple ethnic backgrounds, 3.6% belonged to other backgrounds, and 1.8% preferred not to disclose their ethnicity.

Cohort 2 consisted of 256 responding students (response rate of 256/275 or 93%) were 80% female, 18% male, with participants identifying as 38% Black/Black British, 34% Asian/Asian British, 15% White, 12% Mixed/Others.

Figure 1. Images supporting HPV vaccination from national public health sources and NGOs. Sources: a, b: UK Health Security Agency (https://assets.publishing.service.gov.uk/media/5d15d59840f0b609c9210135/PHE_HPV_A3_poster.pdf.; https://assets.publishing.service.gov.uk/media/6495affb831311000c2962b7/UKHSA_12609_HPV_A3_Poster_02_WEB.pdf); c, d, e, f: USA Centers for Disease Control (CDC) (https://www.cdc.gov/vaccines/partners/teens/posters.html); g: George Washington School of Medicine and CDC (https://cancercontroltap.smhs.gwu.edu/news/hpv-awareness-campaign.); h: Public Health England (https://x.com/petersasieni/status/1026869294288789504.); i: American College Health Foundation(https://www.acha.org/ACHA/Foundation/Partner_Supported_Resources/Utilizing_Social_Media_to_Increase_HPV_Vaccination.aspx.); j: National Institute for Public Health and the Environment, *Ministry of Health, Welfare and Sport*, RIVM Committed to health and sustainability, Nederlands (https://www.rivm.nl/en/news/drop-in-and-get-vaccinated-without-appointment-on-hpv-awareness-day); k: https://www.bestshot.co.nz/#hpv, New Zealand (https://www.stief.org.nz/application/files/1115/8260/4575/HPV_Vaccine_Student_Health_Posters.pdf).

Trust in vaccines

Regarding overall trust in vaccines, 94.8% (91/96) of the Cohort 1 participants believed that vaccines can prevent diseases. However, 12.5% (12/96) thought vaccines could cause diseases, and 21.8% (21/96) were unsure about vaccines causing disease. A significant portion, 76.8% (73/95), reported having received the COVID-19 vaccine. A high proportion, 95.8% (91/95), believed that childhood vaccinations were safe.

Cohort 2 results (Table 1) showed that most responses were not significantly different between the cohorts.

COVID vaccine safety and efficacy

Seventy-five percent (60/80) were confident that the vaccine available to them was safe, but 26.6% (21/79) were concerned about the immediate or short-term side effects of the COVID-19 vaccine. Only 56.3% (45/80) thought that the COVID-19 vaccine had been adequately tested (Table 1).

Cohort 2 results (Table 1) showed that most responses were not significantly different between the cohorts. However, one difference was observed in that a higher percentage in Cohort 2 agreed that "the risk of the COVID-19 vaccine outweighs the risk of COVID-19 itself ($p = .013$). Table 2 presents the

Table 1. Student responses to COVID-19 vaccine questions from both cohorts.

n = 112 cohort 1 n = 256 cohort 2	Cohort 1	%	%	Cohort 2	%	%	X^2	*p*-value	Significant at $p < .05$
Question	No	Not sure	Yes	No	Not sure	Yes			
Confident that the COVID-19 vaccine available to me is safe	3.8	21.3	75.0	6.2	32.0	61.8	4.6051	.100005	NOT significant
Concerned about the immediate/short terms side effects of the COVID-19 vaccine	59.5	13.9	26.6	49.4	18.6	32.0	2.5	.286506	NOT significant
Risk of having the COVID-19 vaccine is greater than the risk of COVID-19	83.8	11.2	5.0	66.7	20.0	13.3	8.7511	.012581	YES **
COVID-19 vaccine has been adequately tested	8.8	35.0	56.3	14.6	37.9	47.5	2.6173	.270179	NOT significant
COVID-19 vaccines are effective	8.8	23.8	67.5	11.2	32.8	56.0	3.2907	.192943	NOT significant
I can develop my own immunity through having COVID-19	16.5	40.5	43.0	20.0	35.6	44.4	0.774	.679079	NOT significant

X^2 test determines whether the distribution of responses is significantly different between the two round cohort population groups.
**Percentage supporting statement "Risk of having the COVID-19 vaccine is greater than the risk of COVID-19 higher than cohort 1.

Table 2. General views and beliefs regarding vaccination from cohort 1 (based on VHS questionnaire Larson et al.[28] and Shapiro et al.[29]).

Question	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Significant difference between 2 cohorts ~
Childhood vaccines are important for my health	2.1%	1.1%	3.2%	21.1%	72.6%	NOT significant $p = .167657$
Childhood vaccines are effective	2.1%	0.0%	5.3%	35.8%	56.8%	NOT significant $p = .2479$
Having myself vaccinated is important for the health of others in my community	2.1%	0.0%	4.2%	22.1%	71.6%	YES $p = .01197$**
All childhood vaccines offered by the government program in my community are beneficial	2.1%	0.0%	16.8%	36.8%	44.2%	NOT significant $p = .05837$
New vaccines carry more risks than older vaccines	7.4%	24.2%	39.0%	24.2%	5.3%	NOT significant $p = .44045$
The information I receive about vaccines from the vaccine program is reliable and trustworthy	0.0%	7.4%	22.1%	49.5%	21.1%	YES $p = .0167$**
Getting vaccines is a good way to protect myself from disease	1.0%	0.0%	6.3%	39.0%	53.7%	NOT significant $p = .1878$
Generally I do what my doctor or healthcare provider recommends about vaccines	1.1%	0.0%	11.6%	37.9%	49.5%	NOT significant $p = .3951$
I am concerned about serious adverse effects of vaccines	10.5%	32.6%	28.4%	21.1%	7.4%	NOT significant $p = .86029$
I do not need vaccines for diseases that are not common anymore	23.2%	44.2%	26.3%	6.3%	0.0%	NOT significant $p = .595$

~ X^2 or Fishers' exact test to test the null hypothesis of no significant difference between responses to statement within cohort 1 and cohort 2.
**cohort 2 showed lower percent agreement with statement "Having myself vaccinated is important for the health of others in my community" and "The information I receive about vaccines from the vaccine program is reliable and trustworthy."

responses of Cohort 1 ($n = 112$) to general vaccine-related beliefs and attitudes. It includes statements assessing the importance of vaccines for personal and community health, vaccine effectiveness, and trust in vaccine-related information. Statistical tests (Chi-square or Fisher's exact) were applied to identify significant differences in agreement levels. Most statements in Table 2 did not show significant differences, between the two cohorts, indicating stable general beliefs about vaccines among the questionnaire respondents.

However, two statements were significantly different between the two cohorts: (1) agreement with "Having myself vaccinated is important for the health of others in my community" was significantly lower in Cohort 2 ($p = .012$). (2) Agreement with "The information I receive about vaccines from the vaccine program is reliable and trustworthy" was also significantly lower in Cohort 2 ($p = .017$). These findings suggest that most vaccine attitudes were broadly similar across cohorts but with some differences in perceived vaccine risks and value in community health impact, in Cohort 2.

Further, to examine attitudes toward vaccine hesitancy and determine whether independent variables were

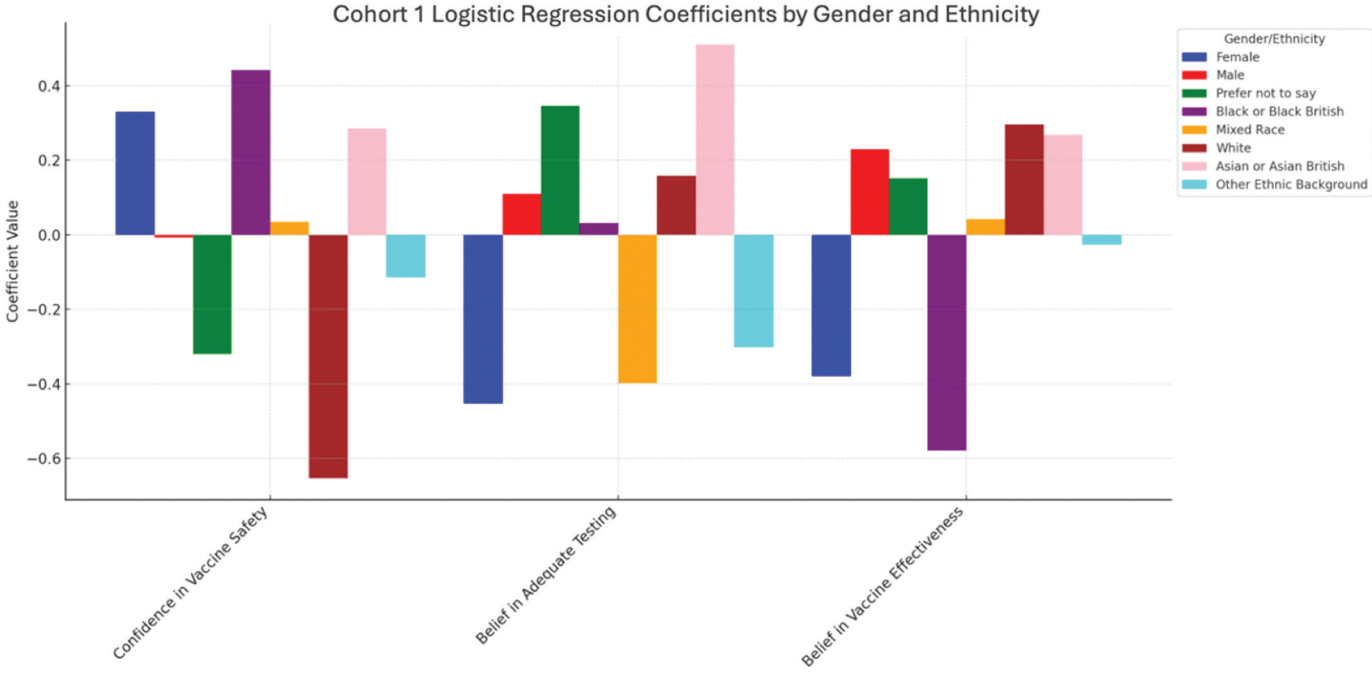

Figure 2. Logistic regression coefficients by gender and ethnicity (cohort 1).

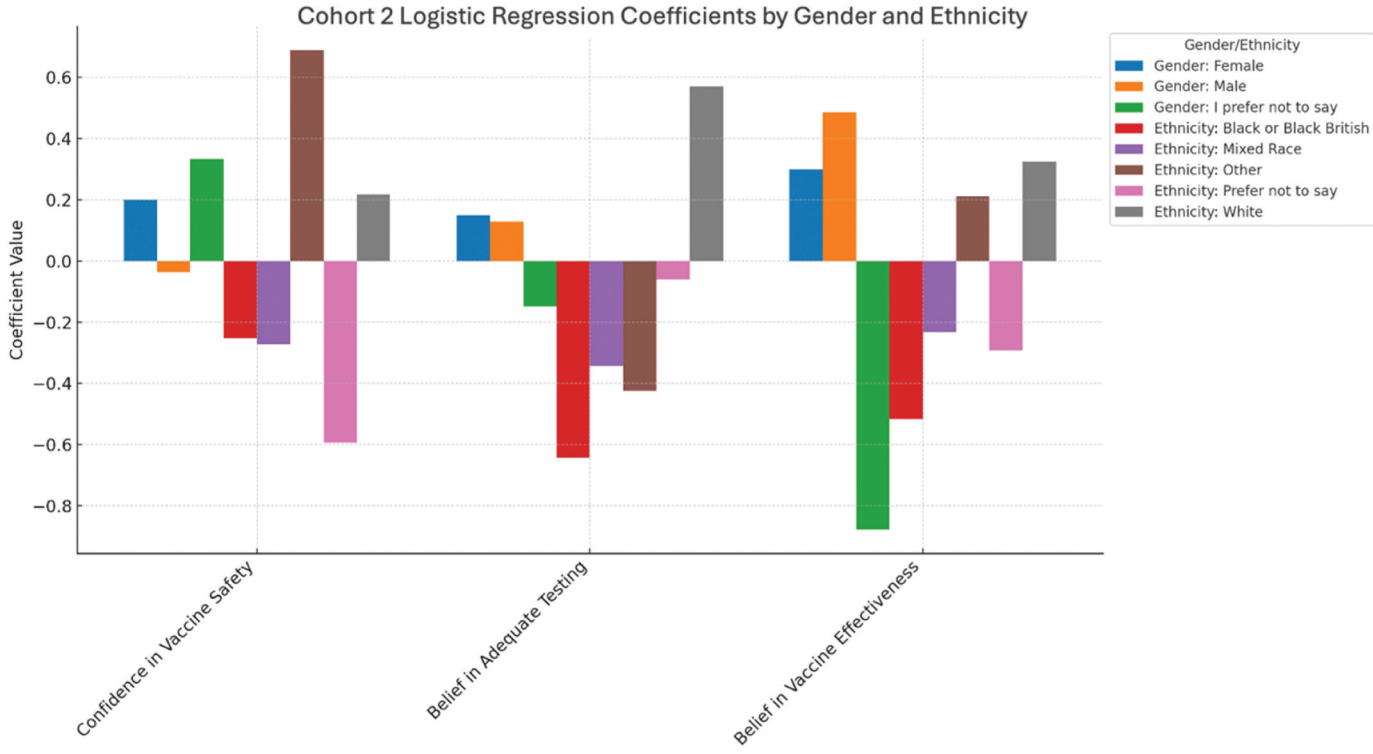

Figure 3. Logistic regression coefficients by gender and ethnicity (cohort 2).

associated with positive or negative attitudes across two cohorts, a logistic regression analysis was conducted. Three specific questions from the questionnaire were analyzed: (1) "I am confident that the COVID-19 vaccine available to me is safe," (2) "I think the COVID-19 vaccine has been adequately tested," and (3) "I believe the COVID-19 vaccine is effective." The analysis was carried out for both "Gender" and "Ethnicity" to explore potential relationships between these variables and responses to the three questions (Figures 2 and 3).

Female respondents showed a consistently positive association with confidence in vaccine safety and belief in vaccine effectiveness, whereas male respondents exhibited mixed associations, with lower confidence in adequate testing. Ethnicity-based results reveal that Black or Black British respondents had a stronger positive association with confidence in vaccine safety but a negative association with vaccine effectiveness. Conversely, White respondents show lower confidence in vaccine safety but a positive association with vaccine effectiveness and belief in adequate testing. Asian or Asian British respondents demonstrated positive associations across all attitudes, suggesting higher vaccine confidence overall. These findings emphasize the need for tailored communication strategies to address specific concerns within different demographic groups and build trust in vaccination programs (Figure 2).

Gender does not show strong differences in influencing vaccine hesitancy; the differences between categories are relatively small. A small "I prefer not to say" group might reflect those with a group with distinct hesitancy patterns or other influencing factors beyond gender (Figure 3).

Belief in mandatory COVID-19 vaccination

When considering the safety and efficacy of vaccines, particularly the belief in mandatory COVID-19 vaccination, 77.8% (63/81) of Cohort 1 participants thought it should be compulsory for all staff working in healthcare to be vaccinated against COVID-19. Additionally, 79.0% (64/81) believed that vaccination should be mandatory for all patient-facing healthcare staff, unless medically exempt, and 75.3% (61/81) felt it should be compulsory for all medical, nursing, and midwifery students.

Belief in mandatory influenza vaccination

Additionally, 62.5% (45/72) of Cohort 1 participants believed that influenza vaccination should be mandatory for all staff in healthcare. Furthermore, 63.9% (46/72) agreed it should be compulsory for all patient-facing healthcare staff, and 66.7% (48/72) felt it should be compulsory for all medical, nursing and midwifery students to be vaccinated against influenza.

Regarding influenza vaccination, 20.6% had received vaccine, 57.5% (42/73) would accept it if offered, 20.6% (15/73) had already received it, 9.6% (7/73) declined, and 12.3% (9/73) were unsure.

Factors encouraging vaccination

Factors encouraging vaccination included availability at school, recommendations by doctors, and accessibility at local clinics. In Cohort 1, participants' decisions about vaccination were influenced by parents (30.2%), healthcare providers (19.6%), and school friends (12.0%). Moreover, 75% (72/96) of the students mentioned that they would encourage their

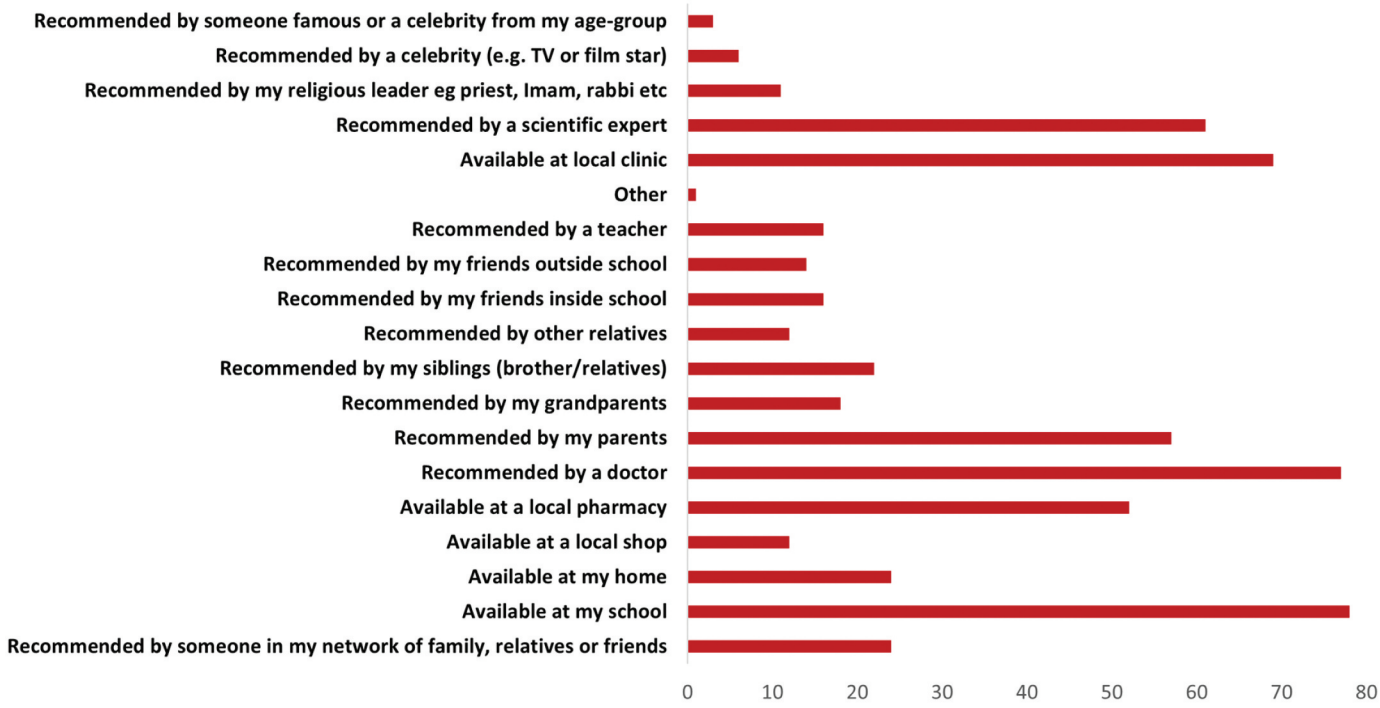

Figure 4. Factors associated with increased vaccine uptake (multiple answers possible by each student).

friends to get vaccinated Figure 4 shows the main groups that a vaccine decision would be discussed with by a student.

Response to meningitis and HPV vaccines

About 90.3% of Cohort 1 participants believed that meningitis is dangerous. When asked about the meningitis vaccine, 90.3% (65/72) of participants would accept it if offered, while 6.9% (5/72) were unsure. An overwhelming majority, 91.6% (65/71) had heard of HPV, and 83.1% (59/71) had received the vaccine. Availability at school (18.0%), recommendations by doctors (13.2%), and encouragement from parents (11.8%) were key factors that would help in deciding to get the HPV vaccine. Table 2 gives further insights into general views on vaccination from both Cohorts.

Focus groups regarding visual images

Most of the posters aroused strong but mixed feelings with even those scoring highly for an impact on HPV vaccination receiving very low as well as high scores. Figure 1 shows the images used. Key individual comments from participants are quoted in Table 3. A breakdown of content thematically is given in the Supplementary Table S1.

The posters scored a mean of 3.8 to 7.6. Two of the 12 posters were clear favorites: posters E (mean score of 6.8, range 5–9) and H (mean 7.6, range 3–10). Poster E was a CDC poster of carer and daughter demonstrating the important role of parents/carers in encouraging (or discouraging) vaccination. The CDC poster was framed in the context of vaccination being part of an ongoing caring relationship from parent to adolescent i.e. you have looked after her all her life and vaccination is just a part of this. Poster H was a graphic-style poster capturing a wide ethnic spectrum in animation format with a clear message emphasizing that HPV vaccination can prevent six cancers i.e. not solely focused on cervical cancer so a more global message that the vaccine would prevent anal and oral cancers that would affect both genders. The Gen Z image was also popular.

Two posters, C and K scored the worst; K used humor and a play on words which several in the group thought funny (more of males) but others found offensive.

The UK HSA posters were less well regarded although the newest poster (September 2023) scored slightly higher. The fact that there were two boys and one girl for a poster discussing the importance of vaccination to prevent cervical cancer was found ironic by many.

Discussion

Of the 87 articles originally identified and reviewed 27 articles provided a comprehensive understanding of vaccine hesitancy and uptake among adolescents. In summary, the reviewed articles highlighted that vaccine uptake among adolescents is shaped by a combination of individual, parental, social, and cultural factors. Parental support, healthcare provider recommendations, and culturally tailored education were crucial for addressing hesitancy and improving vaccination rates. The articles could be broadly grouped into factors determining vaccine hesitancy and those promoting vaccine uptake (in more detail below).

Factors determining vaccine hesitancy

Parental concerns about safety and efficacy significantly shape adolescent vaccine uptake with 30–40% of adolescents

Table 3. Student free-text responses to each poster.

Poster A	Poster B	Poster C
Puts into perspective both parents and kids	Puts into perspective both parents and kids	Promotes healthy lifestyle by introducing vaccine
No colors, not eye-catching, quite forgettable	More colors, has a focus target	Text is too small, takes away message
Does emphasize choice, but can't relate, doesn't feel targeted	Don't like the background, it feels unnatural	This is about cancer not bikes
	Clear info provided with links	What exactly is this advertising
No detailed info about why I should have the vaccine	It's okay	It just has 2 guys in it not girls not encouraging
	Depends if I was in years 8–11 I would be very inclined to take vax	Not focused on HPV
Bit basic but not bad		Pic doesn't relate to HPV
Not entirely representative	Includes children, easy to read	Objective unclear
Includes children, easy to read, briefly explains HPV	The cancer part needs focus	Doesn't look like hpv poster, looks like a biking ad
	Seems a tad bit boring	Doesn't portray a lot about vaccine
Not eye-catching		Also boring don't see plus about vaccine
Seems a tad bit boring		Doesn't clearly say what it is for
Doesn't give reasons to take vaccine		Shows benefit later in life
Poster D	**Poster E**	**Poster F**
Rhetorical question	Emotional, shows mother-daughter relationship	Rhetorical question
Rhetorical question – draws attention	The protective, emotional aspects emphasized	It makes more unsure about why she wants the vaccine
Don't feel targeted to use, I'm not a parent	It still feels like vax is not my responsibility	It's okay, might look over it though
Not directed at me, directed at my parents	Quite compelling	Commentary persuasive
Catches the eye, colorful, persuasive	Emotions	Informative
Very nice poster	Mother with daughter keep safe	Not too much information
To parents, not to me	Pic shows mother and daughter, relatable	Simple
Young child, not HPV range	Only targeted parents	Don't know what she is looking for
Pic doesn't relate to HPV, off off-putting	More eye-catching and stands out	
The question makes you think	Seems emotional	
Clear message target audience	Emotional indicates agreement	
Poster G	**Poster H**	**Poster I**
I hate corporate minimalist posters	Info about when it is needed large	Includes effect of HPV which may encourage others to get it to remain healthy
Simple clear, no link to more info	Peer groups relatable	
Simple clear, not very compelling	Still don't like the corporate art style, but theme is cute	Catchy logo, nice color, message, lack of info
Not informative, not very compelling		No
Inclusive but lack of info	Clear, targeted at me, appealing, find in doctors	I don't think the main focus should have been Gen Z, it should be HPV
Lack of information/target audience	Too busy, not very clear	
Doesn't look informative	Very nice	catches your eye, informative
Inclusive but lack of information	Fun draws to children	Not lots of color, but nice idea
Simple and inclusive	Simple animated	I just don't like the color, it is too bleak, and not really eye-catching
Too unserious	Simple/clear	
Very diverse	Informative	It targets the generation
	Informative shows vaccine is well-received	Cringe
		A bit cringe
		Don't love the slogan, but simple ad, nice visually
		Informative
		Catchy phrase appropriate focus group
Poster J	**Poster K**	
We don't even know what they are talking what about	Doesn't make sense/childish	
	Yuck I don't trust this	
Plain-yet it does express the essence	Straight to the point, speaks to male audience	
Why there is so much negative space	I like it but not go down well with parents	
It would make me curious but no links to more info	Good idea but not for the target age group	
	Very eye-catching – if gets the point across well	
Like simple message but not specific enough	Thought it was poster for buying chicken	
Would be better to say what vaccine is	What does it mean	
Not at all informative	Silly	
Message is really good, not eye catching enough	Quite inappropriate	
	Not age appropriate	
Doesn't mention what vaccine	Weird, what about women	
Informative	Too much going on	
Plain, doesn't catch my eye	Too confusing would might walk past/ignore	
Bit plain, too much blue	Funny yet informative	
Straight forward		
Like that it includes statistics/clear message		
Makes me feel safer knowing that risk is lower		
Irrelevant		

reporting that their parents' opinions heavily influence their decisions.[30–32] Misinformation, often propagated through social media, exacerbates hesitancy. Brandt et al.[33] and Fazel et al.[6] highlight the role of misinformation in fostering skepticism about COVID-19 vaccines. Trust deficits in healthcare systems also hinder vaccine acceptance.[34,35] Additionally, cultural norms and limited healthcare access hinder vaccination in low- and middle-income countries, amongst poorer individuals in high-income countries and rural areas, as noted in studies like Ampofo et al.[36] in Ghana, Newcomer et al.[37] in the U.S., and Marlow et al.[38] who highlighted the influence of religion and ethnicity in the UK. Studies in China[39] and

Ethiopia[40] highlight low knowledge levels, while Garcia et al.[41] report similar findings in Mexican-American populations. Bowyer et al.[42] also noted disparities in HPV vaccine uptake linked to ethnicity, with Black and 'Other' ethnic backgrounds associated with lower uptake.

Factors promoting vaccine uptake

Trusted recommendations from doctors or GPs consistently boost acceptance. For instance, Tung et al.[43] found that 61% of unvaccinated individuals in Australia indicated a willingness to vaccinate if advised by a GP. Suryadevara et al.[44] highlight the strong link between provider recommendations and HPV vaccine completion rates. Studies emphasize the importance of tailored educational efforts. Zhang et al.[39] and Karafillakis et al.[34] recommend school-based programs and culturally specific messaging to address knowledge gaps and counteract misinformation. Studies show that parental involvement is critical for improving vaccine adherence among adolescents.[31,32,45] Adolescents are influenced by parental attitudes, peer opinions, healthcare provider trust, and accurate information, often preferring reliable sources over social media.[31,34] However, in some other studies, social media strongly shaped negative opinions about COVID-19 vaccines, spreading misinformation that increased hesitancy among adolescents in the U.S. and England, respectively.[6,33] Reinforcing the role of trusted scientific sources to counter misinformation on vaccines, in adolescents, coupled with social media-based approaches to change attitudes amongst parents would be logical strategies. This study enabled us to gain insights into the general degree of VH amongst pre-university school students (using a combination of two validated questionnaires), and specifically to COVID-19, influenza, HPV and childhood vaccines. This group has been neglected in comparison to vaccination in early childhood where the focus has been on parental viewpoint rather than on the child. We were successful in capturing the viewpoint of students rather than parents. Nevertheless, answers to our core questionnaire demonstrated that teens would discuss vaccination uptake with parents predominantly (i.e. a strong influence), but less commonly with siblings and other family members; input from friends inside and outside school as well as doctors and other healthcare providers would complete the core influencers. Focus on family viewpoints regarding vaccination would be critical in reducing VH. School staff including teachers would have a more limited role. Interestingly, social media would have a much smaller effect than adults, particularly parents, believe. Ideally, a virtuous circle could be created as 75% would definitely recommend vaccinations to their friends. They were also strong advocates of compulsory COVID-19 vaccination amongst healthcare workers with 77.8% believing vaccination should be compulsory for all staff, 79.0% believing that vaccination should be mandatory for all patient-facing healthcare staff, unless medically exempt, and 75.3% that it should be compulsory for all medical, nursing, and midwifery students. Rates for influenza vaccination were high but lower for the same groups.

Despite recent political viewpoints negating the value of scientific experts, vaccine promotion by scientific or medical experts has a positive effect. Politicians generally have a negative effect even in this age group. Encouragingly, only a small percentage (Cohort 1 = 4.5%) would discuss intention-to-vaccinate decisions via social media.

Similarly, to adult VH studies,[46–49] minimizing the practical 'friction' of obtaining a vaccination helps promote uptake, e.g. being available at school, local pharmacy, local clinic.

The VHS with its Likert scale choice[29] supported the earlier conclusions with students overall being quite positive about vaccination (i.e. "agree" or "strongly agree").

The greatest strength of our study was that participation was completely anonymous and independent of parental (or teacher) permission or influence. From our review of VH studies conducted earlier, understanding adolescent view independent of parental input is rare. For example, 10 studies explicitly mention parental involvement. These studies either surveyed parents alongside adolescents or included parental influence as a key factor in the research. For example, studies[30,50–53] directly mention the inclusion of parents.

The NIS-Teen framework (National Immunization Survey-Teen), is a U.S.-based survey conducted by the Centres for Disease Control and Prevention. As it collects data on vaccination coverage among adolescents aged 13–17 y, as well as factors related to vaccine uptake, it has national coverage and in theory should give a nationally representative viewpoint of adolescent (aged 13–17 y) viewpoints.[54] However, data are collected from parents or guardians of the adolescents rather than the adolescents directly. In a large study in Zhejiang, China, study ostensibly involving 11,565 students, an online survey approach was used (i.e. similar to our approach) but theirs was distributed to parents of the students from these schools.[53] Of the 6/27 studies performed in the UK, over half had parental involvement. In the largest UK study, which recruited students aged 9–18 y from schools across four counties, vaccine-hesitant students had greater indicators of social deprivation and felt a "lack of community cohesion by not feeling a sense of belonging at their school." The overall size of the study (27,910 students from 180 schools) was a strength, but schools were recruited by local authorities inviting schools in their catchment area to participate, *following parental opt-out*, which might have introduced bias.[6] The response rate was estimated to be 25.7% for combined years 12 and 13, a similar response rate to our first cohort.

Other strengths were that the study included conclusions derived from two validated questionnaires used together (which were reviewed, amended and piloted by students at the same school); it considered conclusions from the general to the specific in terms of measures that would reduce VH; the study is post-COVID pandemic asking students whose schooling was affected by it; that it employed an electronic questionnaire permitting direct contact with the student anonymously (of the studies reviewed earlier, only 9/27 used electronic/online surveys); participants were educated at a state (i.e. non-fee paying school); the respondents were multi-ethnic and multicultural reflecting the local urban population of London (the student catchment area is typically within a 10 km radius); were studying subjects according to a national curriculum to a national examination standard.

The limitations of our study were that it was a single school and that the original response rate was low. The school was selective, in that in common with most UK schools, students needed to do reasonably well in the UK General Certificate School Education exams (performed at year 10, age 15–16) for entry. Educationally there is diversity even within the UK which may affect generalizability. You can then leave school at 16 but in England, (compared to the rest of the United Kingdom) you must then do one of the following until you are 18: stay in full-time education, for example, at the same school or at a college, start an apprenticeship or spend 20 h or more a week working or volunteering while in part-time education or training. The generalizability to other countries' education systems may be limited, therefore. The addition of a second cohort addressed the key potential weaknesses of a low response rate and demonstrated that responses to key questions on vaccine safety and efficacy were not statistically different with one exception that "the risk of the COVID-19 vaccine is greater than the risk of COVID-19" which showed significant differences between groups ($p = .012$). This probably (and reasonably) reflected the COVID-19 risks for teenagers from current COVID-19 variants such as Omicron currently circulating in the UK. Moreover, the social and cultural diversity of the respondents from a large urban metropolis suggests reasonable representativeness of teen students in this age group. Finally, there may be unknown residual biases due to self-reported data.

Our findings support the importance of the value of social norm interventions in addressing vaccine hesitancy attitudes and in developing vaccine uptake programs to benefit public health as described in countries such as the USA.[22] To address this concern, public health campaigns should prioritize improving communication around the vaccine approval process, emphasizing the extensive clinical trials and safety monitoring involved. Utilizing trusted health experts, sharing transparent data on vaccine efficacy and safety, and dispelling myths through accessible educational content can help alleviate doubts. However, as well as knowledge, bold imaginative behavioral-based approaches are needed to counter hesitancy and misinformation.

Based on focus group critiques, effective public health campaigns should tailor messaging to specific audience demographics, simplify information, and use trusted healthcare professionals to enhance credibility. Additionally, addressing misconceptions, making services accessible, and leveraging school-based educational platforms for engagement will increase the campaign's reach and impact.

Our findings also reveal that adolescents harbor significant mistrust in information from social media. While social media platforms such as Instagram and Snapchat are seen as effective tools to reach their generation, concerns about manipulation, and the commercial nature of sponsored ads diminish their credibility. This skepticism, likely shaped by growing up amid discussions of widespread misinformation, extends even to credible sources.[34] Supporting this, Argyris et al.[55] found that anti-vaccine social media posts are associated with increased vaccine hesitancy among mothers and lower HPV vaccination rates in their children, whereas pro-vaccine content has no significant impact. However, Moore et al.[56] reported that among university students in Ireland, vaccination decisions were unrelated to social media platforms or the time spent on them, underscoring the limited influence of social media on vaccine decision-making. These insights suggest that adolescents' mistrust of information across various channels might dilute the influence of social media compared to trusted figures like healthcare providers and parents.

As highlighted by a study in England,[57] parental awareness of adolescents' ability to self-consent was low, and adolescents often preferred deferring the decision to their parents. The study also found that health professionals were not always clear on the best approach to consent, with some lacking familiarity with self-consent processes.[57] Our findings support the concept that improving consent pathways and interventions in school-based immunization programs could enhance vaccine uptake. This, in turn, may encourage more positive vaccine choices as adolescents take on greater responsibility for their health.

The importance of asking the relevant target group about their concerns and potential measures for improving vaccination rates was evidenced through the viewpoints made on HPV poster images (many public health posters presumably designed with a lot of adult expert design input were heavily critiqued). Social media was not as dominant a force in this group as adults believe. Similarly, adult "trendy" assumptions, e.g. the value of peers such as boy or girl bands were not seen as very sensible.

The future direction of this study highlights the need for further investigation into adolescent vaccine attitudes, particularly through longitudinal studies that track changes in vaccine perceptions over time. Additionally, a more detailed examination of the influence of demographic factors such as ethnicity and gender is warranted, as well as the exploration of interventions targeting adolescents outside formal school environments. Given the significant influence of parents, healthcare providers, and peers on vaccination decisions, future public health campaigns should strategically engage these groups to enhance vaccine uptake. The findings also emphasize the importance of incorporating adolescent input into the design of visual vaccine promotions, especially for HPV, to ensure campaign effectiveness. Furthermore, addressing concerns regarding vaccine testing, particularly for COVID-19 and influenza, alongside examining the role of social media in shaping vaccine perceptions, will be crucial for improving vaccine acceptance and informing public health interventions.

However, as well as knowledge, bold imaginative behavioral-based approaches are needed to counter hesitancy and misinformation.

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Francis Drobniewski is a physician and Professor of Global Health at Imperial College, London, UK. He has interests in vaccine hesitancy and behavioural aspects of medical therapy, respiratory infections, molecular diagnostics and antimicrobial drug resistance.

Author contributions

All authors were involved in data collection, investigation, methodology and resources. FD, RA and MA conceptualized the study. FD, MA, AM, MB, AM, CH supervised and administered the project. MA, CH, FD, MB and AG curated and visualized the data. FD, RA and MA wrote the original draft. All authors reviewed and edited the manuscript.

Informed consent statement

Informed consent was provided by all participants.

Institutional review board statement

The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Imperial College, London (Ref: 21IC6546).

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