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Keep calm and carry on vaccinating: Is anti-vaccination sentiment contributing to declining vaccine coverage in England?

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ABSTRACT

Background: In England, coverage for childhood vaccines have decreased since 2012/13 in the context of an increasingly visible anti-vaccination discourse. We determined whether anti-vaccination sentiment is the likely cause of this decline in coverage.

Methods: Descriptive study triangulating a range of data sources (vaccine coverage, cross-sectional survey of attitudes towards vaccination, UK-specific Twitter social media) and assessing them against the following Bradford Hill criteria: strength of association, consistency, specificity, temporality, biological gradient and coherence.

Results: Strength of association: compared with well-documented vaccine scares, the decline in childhood vaccination seen since 2012/13 is 4–20 times smaller; consistency: while coverage for completed courses of the hexavalent and meningococcal vaccines decreased by 0.5–1.2 percentage points (pp) between 2017 and 2019, coverage for the first dose of these vaccines increased 0.5–0.7 pp; specificity: Since 2012–13, coverage decreased for some vaccines (hexavalent, MMR, HPV, shingles) and increased for others (MenACWY, Td/IPV, antenatal pertussis, influenza in 2 years of children), with no age-specific patterns. Temporality and biological gradient: the decline in vaccine coverage was preceded by an increase in vaccine confidence and a decrease in the proportion of parents encountering anti-vaccination materials.

Coherence: attitudes towards vaccination expressed on Twitter in the UK became increasingly positive between 2017 and 2019 as vaccine coverage for childhood vaccines decreased.

Conclusions: In England, trends in vaccine coverage between 2012/13 and 2018/19 were not homogenous and varied in magnitude and direction according to vaccine, dose and region. In addition, confidence in vaccines increased during the same period. These findings are not compatible with anti-vaccination sentiment causing a decline in vaccine coverage In England.

1. Introduction

England offers a free, comprehensive, national immunisation programme throughout the life course and is regarded as an innovative and successful programme worldwide. It was the first country to implement a routine national programme for group C meningococcal (MenC) vaccine in 1999, a national antenatal pertussis immunisation programme in 2012 which rapidly achieved high vaccine uptake, and 4CMenB, a protein-based meningococcal group B (MenB) vaccine into the national infant immunisation programme in 2015 [1]. Vaccine coverage for most routine childhood programmes in England has been over 90% since the early 1990s [2]. Coverage for the measles, mumps and rubella (MMR) vaccine peaked 92.7% at 2013/14 following a decreasing to around 80% in the early 2000s as a result of a discredited alleged association between the vaccine and autism [3]. Coverage for the completed course of primary combined diphtheria, tetanus, pertussis, polio and *Haemophilus Influenzae* type b vaccine (DTaP/IPV/Hib) at two years, which had not been affected by the MMR concerns, peaked at 96.3% in 2012/13 [2]. Since then, coverage for childhood vaccines has been declining slowly but steadily. By 2018/19, coverage had declined for all childhood routine vaccinations in children under the age of 5 years, with DTaP/IPV/Hib coverage at 12 months

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declining by 2.6 percentage points (pp) since 2012/13 and MMR coverage measured at 24 months declining by 2.3 pp since 2013/14 [2].

Globally, since 2012/13, interest in vaccination and vaccine safety has increased [4] and confidence in vaccines, measured through perceived vaccine safety and effectiveness [5] has become increasingly reported in the media. Anti-vaccination is not new [6], and the modern vaccination era (since the 1970s) has seen several scares linked to specific vaccines. Examples include alleged links between pertussis vaccine and encephalopathy along with MMR and autism in the UK [3,7], Polio and infertility in Nigeria [8] and human papillomavirus (HPV) vaccine and complex regional pain syndrome in Japan [9]. Each of these was country-specific and vaccine-specific. In the current digital era, there are legitimate concerns that anti-vaccination sentiment is spreading online and will affect more vaccines in more countries [6].

The perceived prominence of the anti-vaccination movement has prompted increasing focus on vaccine hesitancy and resulted in a number of high-level reports, including those by the World Health Organization [10] and the European Commission [5]. These reports, however, still show a mixed, country specific picture. The European Commission report on the state of vaccine confidence showed that, between 2015 and 2018, overall confidence in vaccines had decreased in Poland and the Czech Republic, but had increased in Greece, Italy and the UK [5]. Yet, in the UK, the recent decrease in coverage for some vaccines has been interpreted as a programme-wide decline and largely attributed to increasing anti-vaccination sentiment [11,12,13]. This perceived association has also become part of the prevalent discourse among public health professionals [14]. The aim of this study is to challenge this perception. In order to determine whether anti-vaccination is the likely cause of the decline in vaccine coverage in England, we examined and triangulated various vaccination-related data against the relevant Bradford Hill Criteria [15], namely strength of association, consistency, specificity, temporality, biological gradient and coherence.

2. Methods

We used vaccine coverage data from The Coverage of Vaccination Evaluated Rapidly (COVER) and ImmForm, the two routine vaccine coverage surveillance systems used by Public Health England (PHE) [16,17]. These systems measure vaccine coverage at 6 months, 12 months, 2 years and 5 years of age and the data is publicly available online through a series of reports. Vaccine coverage data for years that precede the introduction of the COVER surveillance systems were retrieved from the publicly available Health Protection Agency archive. Coverage for vaccines delivered in the first year of life but measured later (at 2 or 5 years) reflect past performance. We also used data on attitudes to vaccine collected as part of the PHE longitudinal attitudinal survey [18], and UK-specific vaccine related tweets posted on Twitter, extracted and analysed using the Crowdbreaks platform. In brief, Crowdbreaks generates country-specific trends of vaccine sentiment in real-time. The platform collects tweets containing certain keywords and uses Natural Language Processing to predict a label of −1 (anti-vaccine), 0 (neutral) or +1 (pro-vaccine) based solely on the text field. The vaccine sentiment index *s* is calculated as the mean of all labels predicted within a certain time window [19]. Furthermore, tweets were only included if they contained geo coordinates, a place, or a user location which could be mapped to the UK. For this process, the Geonames database (geonames.org) was used. To make the data used in this paper easily accessible, we have listed all the data sources and where to access them in Appendix 1. For each of the Bradford Hill Criteria employed, we identified whether the data collected fulfilled the criteria employed.

2.1. Criterion 1: Strength of association

This criterion explains that the larger an association between exposure and disease, the more likely it is to be causal. In order to test this, we compared the magnitude of the decrease in vaccine coverage for DTaP/IPV/Hib and MMR1 measured at 2 years of age in England since 2012/13 with the decreases that occurred during well-documented vaccine scares, namely the MMR and pertussis vaccines in England in the 1990s/2000 s and 1970s respectively.

2.2. Criterion 2: Consistency

The consistency criterion is upheld when multiple epidemiological studies using a variety of locations, populations, and methods show a consistent association between two variables with respect to the null hypothesis [15]. If a generic anti-vaccination sentiment was the main cause of the decrease in vaccine coverage, it should impact all regions equally and all doses of vaccines: for example, a scare about the DTaP/IPV/Hib vaccine should cause a decrease in coverage for the first dose as well as the third dose. To test this criterion, we described vaccine coverage across different regions of England and for different doses of the same vaccine.

2.3. Criterion 3: Specificity

This criterion suggests that associations are more likely to be causal when the exposure causes only one specific disease. While this criterion is considered to be one of the weakest from an epidemiological perspective [15], in this context it generates an interesting hypothesis: either a specific scare leads to a decline in coverage of a specific vaccine, or a generic change in sentiment towards vaccination causes a decline in coverage of all vaccines. Another, less likely, but nevertheless plausible hypothesis would be that the scare only affects a specific age group (young children, for example). There is no simple way to explain how attitudes towards vaccination would lead to a decrease in coverage for some, but not all, vaccines across different age groups. In order to test this, we conducted and compared three analyses: (i) coverage for the measles- and DTP-containing vaccines at 2 years of age in England over the MMR scare period (late 1990s/early 2000s); (ii) coverage for the polio- and pertussis-containing vaccines at 2 years of age in England over the pertussis scare period (1970s); and (iii) coverage for DTaP/IPV/Hib (at 12 months), HPV (in school year 9), MenACWY (in school year 10), MMR1 (at 2 years), MMR2 (at 5 years) seasonal influenza (at 2 years), Td/IPV booster (in school year 10), antenatal pertussis (targeting pregnant women) and shingles (among 70 year-olds) vaccines over the period of reported increasing anti-vaccination sentiment between 2012/13 and 2017/18, the most recent year with data available for all vaccines.

2.4. Criteria 4 and 5: Biological gradient and temporality

These two criteria suggest that for an association to be causative, the exposure has to precede the outcome, and that the magnitude of the outcome increases with the magnitude of the exposure, (acknowledging that the relationship does may not be linear). In order to test these criteria, we described trends in the proportion of parents who automatically vaccinated their 2 year-old children when their vaccines were due, obtained from an ongoing national longitudinal survey of attitudes to vaccines [18], and compared them with trends in DTaP/IPV/Hib coverage among children in this age group.

2.5. Criterion 6: Coherence

Coherence suggests that the cause and effect mechanism should make sense with all knowledge available to the researcher. In other words, coherence should be used to demonstrate a comprehensible story regarding the causal pathway between exposure and outcome [15]. When this concept is applied to the causes of decreasing vaccination coverage, anti-vaccination sentiment should be increasing as vaccine coverage decreases in order to generate a coherent causal pathway. In order to measure attitudes towards vaccination in generic terms, we measured the trends in vaccine sentiment as expressed by activity on Twitter about vaccination in the UK between 2017 and 2019, using the Crowdbreaks platform [19].

This study was based on secondary use of previously collected aggregated data and did not require ethics approval.

3. Results

3.1. Strength of association

Vaccine scares have historically led to rapid, large declines in vaccine coverage. Between 1997/98 and 2003/04, coverage for MMR1 at 2 years dropped 11 pp to 80% (Fig. 1a). Similarly,

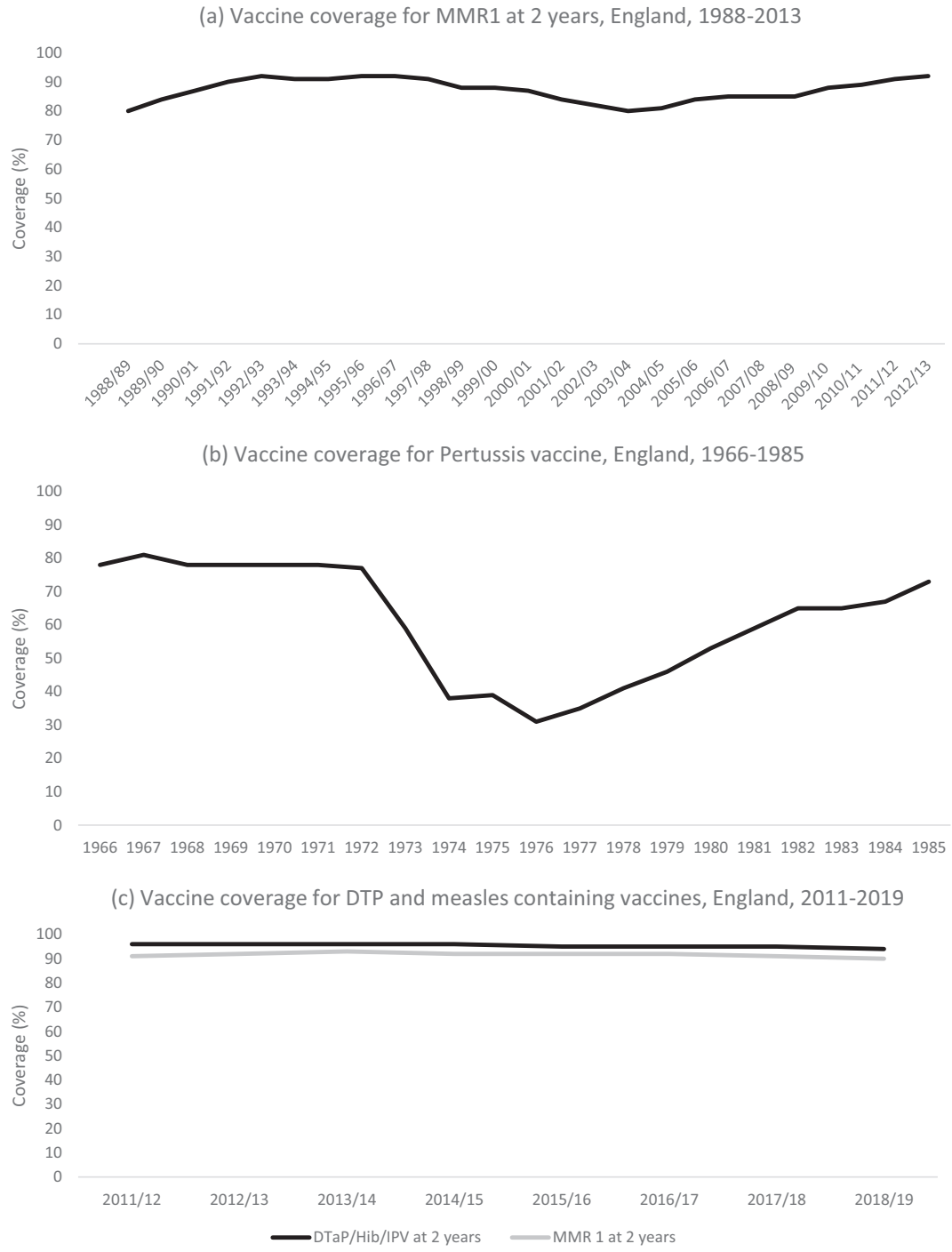

Fig 1. Vaccine coverage for selected vaccines during periods of change towards vaccine sentiment.

coverage in pertussis vaccination decreased 47 pp to 31% between 1971 and 1976 (Fig. 1b). By contrast, in England, coverage for all primary immunisations measured at 1 or 2 years of age have consistently remained over 90% since 2012/13, with the exception of rotavirus (89.7% in 2018/19), which traditionally achieves lower coverage because of the strict criteria for timing of both the first and second dose of vaccine and because catch up is not recommended after the age of 6 months of age. Between 2012/13 and 2018/19, coverage for DTaP/IPV/Hib measured at 12 months and for MMR measured at 24 months lost 2.6 and 2.3 pp, respectively (Fig. 1c).

3.2. Consistency

Between 2012/13 and 2018/19, vaccine coverage decreased in all English regions for both MMR1 and DTaP/IPV/Hib measured at 2 years of age. However, compared with London, the decline was almost 3 times smaller for DTaP/IPV/Hib in the North East, and more than 10 times smaller for MMR1 in the South East (Table 1).

Between July 2017 and April 2019, while coverage for the completed primary course of the MenB vaccine (2 doses, measured at 12 months) decreased by 0.5 pp to 92.2%, 1 dose coverage measured at 6 months increased by 0.7 pp to 95.9% (Table 2). Similarly, between July 2017 and April 2019, while coverage for the completed primary course of pentavalent/hexavalent vaccine (3 doses, measured at 12 months) decreased by 1.2 pp to 92%, 1 dose coverage measured at 6 months increased by 0.5 pp to 96.2% (Table 2).

Table 1
Change in coverage percentage points among selected vaccinations, England.

England Region	Change in DTaP/IPV/Hib coverage at 2 years, 2012/13 to 2018/19 (%)	Change in MMR1 coverage at 2 years, 2013/14 to 2018/19 (%)
North East	−1.1	−1.0
North West	−2.9	−2.4
Yorkshire and the Humber	−2.0	−1.8
East Midlands	−2.1	−2.9
West Midlands	−2.0	−2.9
East of England	−1.9	−2.4
London	−2.9	−4.5
South East	−1.5	−0.4
South West	−1.4	−1.2
England Total	−2.1	−2.3

3.3. Specificity

During the vaccine scares around MMR in the 1990 s/2000 s and pertussis in the 1970 s, vaccine coverage for MMR (Fig. 2a) and pertussis (Fig. 2b) in England fell for those specific vaccines only, but coverage for other vaccines remained relatively stable. While MMR coverage lost 11 pp between 1997/98 and 2003/04, DTaP/IPV/Hib coverage only lost 2 pp. Similarly, between 1971 and 1976, at the height of the pertussis scare, pertussis coverage decreased by 47 pp while polio coverage decreased by 2 pp only.

In the recent period, the magnitude and direction of trends varied from one vaccine to another. Fig. 3c highlights that coverage decreased for vaccines that delivered in primary care, including DTaP/IPV/Hib and MMR1 at 12 and 24 months respectively (−1.6 and −1.1 pp respectively), together with shingles delivered to elderly individuals (−17.4 pp) and HPV delivered to teenage girls in schools (−1.7 pp). In the same time period, vaccine coverage increased for the school-based MenACWY and Td/IPV programmes (+2.1 and +2 pp, respectively), antenatal pertussis delivered to pregnant women mainly in primary care (+15.4 pp) and primary care-based seasonal flu programme for 2 year-old children (+0.2 pp). These differences in magnitude and direction of trends cannot be easily explained by a generic change in attitudes to vaccination, nor by a specific one. Trends were also not specific to particular age group. Among young children, coverage for some vaccines declined (DTaP/IPV/Hib and MMR) while coverage for others increased (influenza). Similarly, among teenagers, coverage for HPV decreased slightly whereas MenACWY and Td/IPV coverage increased and, among adults, antenatal pertussis coverage increased whereas shingles coverage decreased.

3.4. Criteria 4 and 5: Biological gradient and temporality

Trends in vaccine confidence based on the PHE attitudinal survey and vaccine coverage during the same time period suggest that the decline in vaccine coverage was preceded by an *increase* in vaccine confidence and a *decrease* in the proportion of parents encountering anti-vaccination materials (Fig. 3). Compared with 2005/06, an additional 23% of parents declared automatically vaccinating their 0–2 year-old child when a vaccine was due in 2018/19, yet DTaP/IPV/Hib coverage at 2 years was exactly the same in both years (Table 3). In 2018/19, the proportion of parents automatically vaccinating their 0–2 year olds was at its highest in 14 years (91%), and the proportion of parents encountering material that might persuade them not to immunise was at its lowest in 14 years (8%), and yet DTaP/IPV/Hib coverage at 2 years was it its lowest (94%, Table 3).

Table 2
Vaccine coverage for first dose and completed courses for selected vaccines, England.

Time period	Hexavalent vaccine		MenB vaccine	
	1st dose coverage at 6 months (%)*	Completed course at 12 months (%)**	1st dose coverage at 6 months (%)*	Completed course at 12 months (%)*
Jul-17	95.7	93.2	95.2	92.7
Oct-17	95.6	93.1	95.9	93
Jan-18	95.4	92.6	95.8	92.5
Apr-18	95.3		95.9	
Jul-18	94.8	91.6	95.7	91.9
Oct-18	96	92.1	95.8	92.3
Jan-19	96.1	91.9	95.8	92
Apr-19	96.2	92	95.9	92.2
Change over time period	**+0.5 pp**	**−1.2 pp**	**+0.7 pp**	**−0.5 pp**

* ImmForm data.
** COVER data.

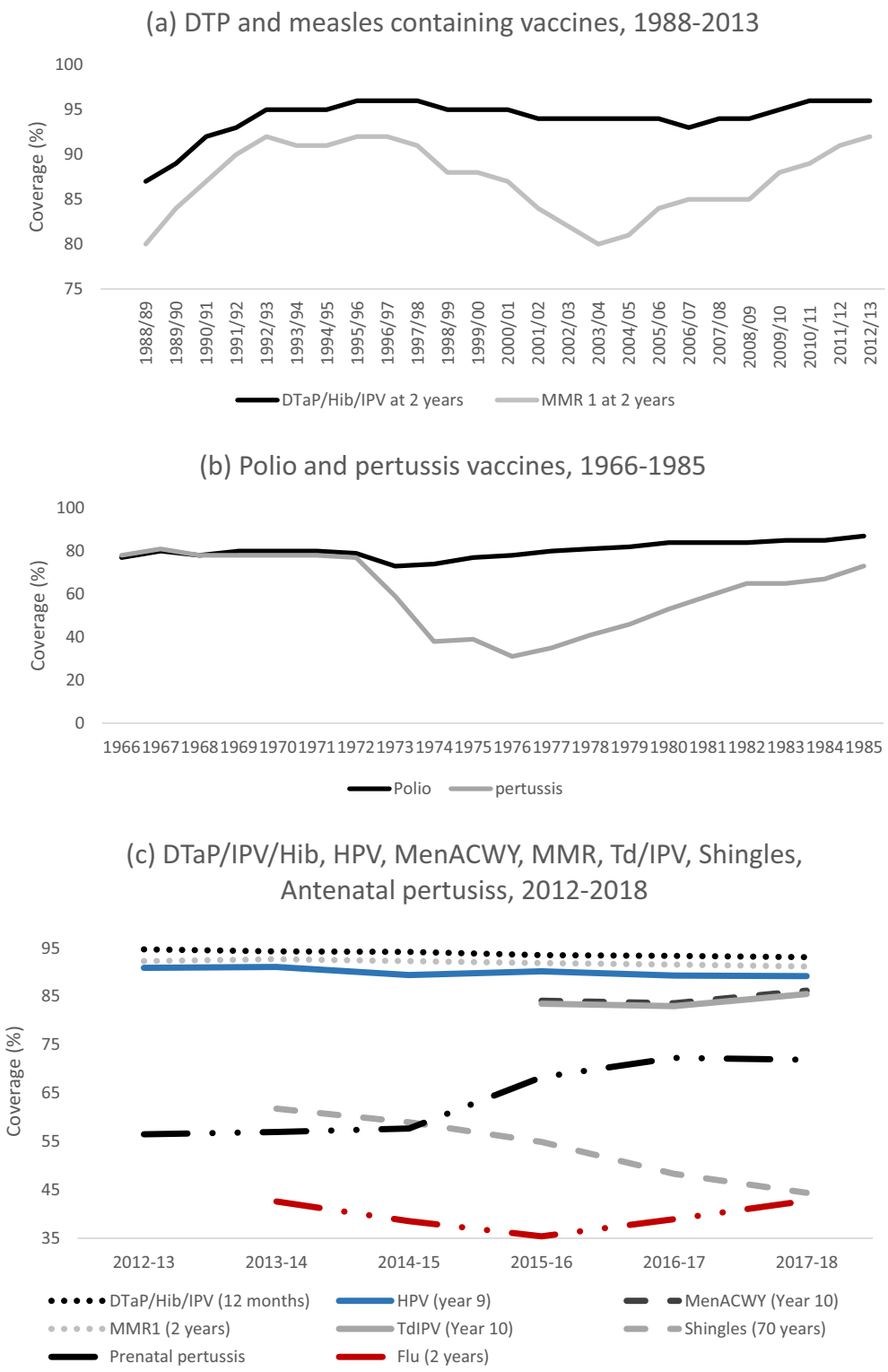

Fig 2. Vaccine coverage for selected vaccines and selected time periods, England.

3.5. Criterion 6: Coherence

Between 2017 and 2019, there were 187,182 UK-specific tweets about vaccination posted. The sentiment index (calculated as the mean of predicted labels) during this time period was constantly above 0, meaning that the volume of tweets positive towards vaccination was always larger than the volume of tweets conveying a negative sentiment (Fig. 3). During the study period, as the volume of tweets increased, attitudes towards vaccination became increasingly positive with the sentiment index increasing from 0.3 in July 2017 to 0.6 in October 2019. These trends, which are consistent with PHE's attitudinal survey [18] and the findings from the EC report on vaccine confidence [5], do not provide a coherent story to support the hypothesis that the recent decline in vaccine coverage is due to increasing anti-vaccination sentiment.

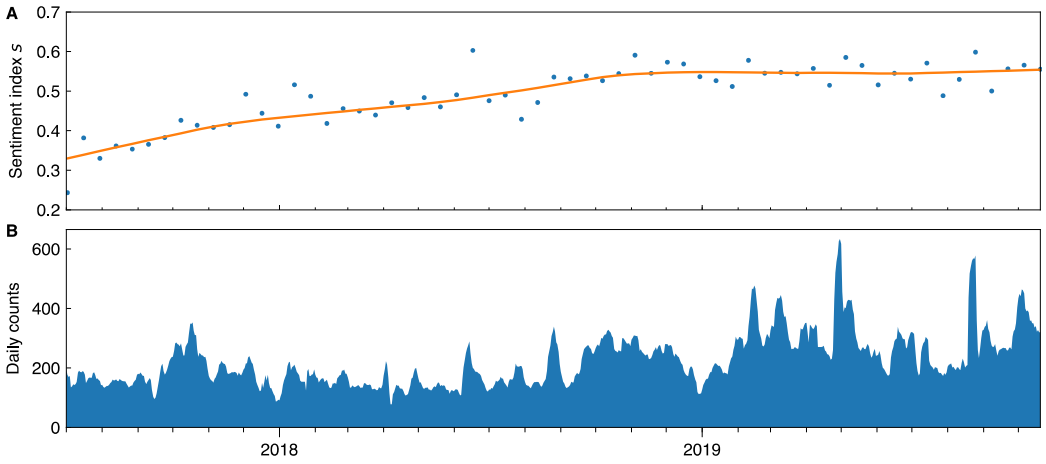

Fig 3. Vaccine Sentiment index between July 2017 and October 2019 of UK-specific Twitter data.

Table 3
Vaccine coverage and vaccination behaviour among parents, England 2004–2019.

Year	DTaP/Hib/IPV Vaccine coverage at 2 years (%)	Proportion of parents who automatically vaccinate their child when due (%)	Proportion of parents of 0–2 year olds who saw anything that might persuade them not to immunise (%)
2004/05	94	61	23
2005/06	94	68	20
2006/07	93	70	14
2007/08	94	73	17
2008/09	94	72	14
2009/10	95	75	17
2010/11	96		
2011/12	96		
2012/13	96		
2013/14	96		
2014/15	96	90	12
2015/16	95	84	8
2016/17	95	89	10
2017/18	95	87	9
2018/19	94	91	8
Change from 2012/13 to 2018/19	**−2pp**	**+1pp**	**−4pp**

4. Discussion

In England, coverage for most vaccines remains high and coverage for childhood vaccines, while not optimal, remains above 90%. Compared with other countries, England continues to achieve high coverage for vaccines delivered at an older age. For example, in 2018, the Netherlands and Sweden achieved 45% and 81% coverage, respectively, for HPV among 14 year-old females [20,21], compared with 83.8% in England (Fig. 2c). In 2016, the USA achieved 48.2% coverage for antenatal pertussis [22] compared with 72.3% in England (Fig. 2c). In 2016, the UK achieved 70.5% coverage for influenza in individuals aged 65 and over, higher than any other country in the EU [5]. Nevertheless, the decline in vaccine coverage in England is a concern, in particular in the context of a resurgence of measles in Europe and beyond [23].

Because of reported increases in anti-vaccination activity that have recently been highlighted in communication channels aimed at the general public and the public health community, and because of the temporal association with the small but steady decrease in vaccine coverage across England, it is tempting to link the two and attribute this decline to the rise in anti-vaccination sentiment. National-level evidence, however, as well as comparison with other industrialised countries across Europe and worldwide suggest that confidence in the vaccine programme in England has increased in recent years. Our systematic analysis of vaccine coverage data does not highlight a strong, consistent, specific, temporal or dose-specific association between reporting of anti-vaccination sentiment and vaccine coverage in England. While none of these analyses in isolation constitute high-grade evidence, when considered collectively, they make a compelling case. This implies that anti-vaccination sentiment is unlikely to be a major contributor to the small decline in coverage for some of the vaccines in England.

Because of the nature of social media, it is difficult for public health services to truly quantify the size and influence of online anti-vaccination movements. Evidence suggests that anti-vaccination messages are dwarfed in volume by pro-vaccination ones, that the volume of anti-vaccination messages has actually decreased since 2014 [24] and the anti-vaccination community is ideologically isolated [24,25], leading to an "echo chamber effect" whereby anti-vaccination information is only consumed within anti-vaccination groups [26]. This effect may very well be further amplified by increased content moderation on social media platforms in recent years. It is likely, therefore, that the attention the media give to anti-vaccination groups is disproportionately high compared to the actual impact they have, thereby artificially making the problem appear bigger than it is. This may be as a result of "false balance", a well-recognised issue in journalism where an equal platform is given to views that do not have an equal weight of evidence supporting them, simply for the sake of appearing balanced [27]. This phenomenon was well-documented during the UK MMR scare and contributed to the false impression that parents had about the vaccine [28,29].

This study does not suggest that increasing anti-vaccination sentiment can be dismissed or ignored. In some countries, confidence in vaccination has clearly decreased either overall or for specific vaccines [5]. The association between anti-vaccination movement and broader "anti-expert" populist movements [30], illustrated by prominent anti-vaccination figures having direct access to politicians [31] is a concern for global public health. It is perhaps reassuring, therefore, that the impact of anti-vaccination movements is often specific to a particular geography or context, and our study suggests that, for the moment, England is relatively spared. In this context, it is important to avoid raising the profile of the anti-vaccination groups and messages, as drawing attention to myths, even to pre-emptively counteract them, has

been shown to increase concerns and reduce willingness to vaccinate [32,33].

While we have demonstrated the limited impact of anti-vaccination sentiment on vaccine coverage in England, the analyses performed in this study do not explain why coverage has declined. While it is tempting to focus on a single explanation for changes in vaccine coverage, the reality is likely to be more nuanced and changes in vaccine coverage are most likely to be the result of multiple interconnected factors. Evidence suggests that a large-scale re-organisation of public health services in 2012/13, when public health services were taken out of health services and integrated into local government, severely disrupted the national immunisation programme and led to confusion about respective roles and responsibilities for stakeholders involved in the delivery of the programme [34]. In addition, changing migration patterns, with a higher proportion of the population belonging to groups who face barriers to immunization [35], may also contribute to the decline in vaccine coverage. Changes in the provision of invitation (call/recall) systems, one of the most effective interventions to improve vaccine coverage [36], may have also had an impact. A 2018 survey of general practices in London highlighted that 15% of practices had no call/recall system in place [37]. Primary care capacity to provide a sufficient number of appointments for vaccination may also play a role: GPs with a higher number of appointments per eligible patient achieve higher vaccination rates [38], and GP list sizes have increased between 2015 and 2020 [39]. This is consistent with coverage in GP-delivered childhood vaccines declining whereas coverage for most school delivered programmes increasing. The National Audit Office reviewed the childhood vaccination programme in England in in 2019 and, consistent with our findings, concluded that health system barriers and data system accuracy, rather than anti-vaccination messages, were the underlying reason for the decline in vaccine coverage [40]. A coordinated approach with clear roles and responsibilities between all agencies responsible for the commissioning, implementation, delivery, monitoring and governance of the immunisation programme, is essential to identify and address the causes of declining vaccine coverage are identified and addressed. In July 2019 The Department of Health announced a national Vaccination strategy [41] that will bring together Public Health England, NHS England and other stakeholders to collectively address system level barriers to reach 95% uptake for childhood vaccinations.

5. Conclusion

The immunisation programme in England is facing some serious challenges. For now, the anti-vaccination movement isn't the main one, and giving too much public coverage to the anti-vaccination views of a small minority can be harmful. It is essential that we, the public health community, do not contribute to making the problem appear bigger than it actually is. The best way to ensure this is by continuing to monitor and understand parental views and needs, and to ensure that health care professionals are well equipped to address parental concerns. Alongside this, the main focus should address the known system issues affecting the delivery of our immunisation programme in order to make it easy to get vaccinated and maximise protection against vaccine-preventable diseases.

Data Sharing

This study relies primarily on publicly available vaccine coverage data and the sources of data used are listed in Appendix 1, together with the relevant URLs. One of the vaccine coverage data sources (DTaP/IPV/Hib +/- HepB Dose 1measured at 6 months is not publicly available) but can be provided on request. Data from the attitudinal survey from 2016 onwards is being used for a manuscript currently in preparation and will become available through the publication of that manuscript. The raw Twitter data is available from a Github data repository and the URL is available in Appendix 1.

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Contributions

ME, MR and SL have planned the study. ME conducted the analyses based on vaccine coverage data. JY conducted the analyses based on attitudinal data. MM and MS conducted the analysis on social media data. ME drafted the manuscript and all authors edited it to produce the final draft. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.vaccine.2020.05.082.

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