Title:

What determines uptake of pertussis vaccine in pregnancy?

A cross sectional survey in an ethnically diverse population of pregnant women in London

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Keywords: pertussis vaccine, pregnancy, influenza vaccine, acceptancy, attitudes

Word count: 3754

ABSTRACT

Introduction

Following the major outbreak of pertussis and 14 infant deaths across England in 2012, the Department of Health (DH) introduced the UK's first maternal pertussis vaccination programme. Data published by Public Health England (PHE) suggest uptake of the vaccine varies considerably across the country. The reasons for this heterogeneity need to be addressed to optimise the impact of the program.

Objective

To assess uptake of antenatal pertussis and influenza vaccine in a leading NHS Trust in London and to explore awareness and attitudes of pregnant women towards the pertussis vaccination programme.

Design

A cross sectional survey was conducted in an ethnically diverse group of 200 pregnant women accessing antenatal care at Imperial Healthcare NHS Trust. Quantitative data was tabulated and content analysis was carried out on the free text. Qualitative data was divided into themes for accepting or declining the vaccine.

Results

Awareness of the program was 63% (126/200) with actual uptake of the vaccine only 26.0% (52/200). Women had received information from multiple sources, primarily General Practitioners (GP) and midwives. 34.0% (68/200) of women were offered the vaccine at their GP practice, but only 24% reported a meaningful discussion with their GP about it. Uptake differed by up to 15.0% between ethnicities. Qualitative data showed that uptake could be significantly enhanced if vaccination was recommended by a familiar healthcare professional. Feeling uninformed, lack of professional encouragement and uncertainties of risk and benefit of the vaccine were the greatest barriers to uptake.

Conclusion

Vaccine uptake in this cohort of pregnant women was poor. Understanding the target audience and engaging with key groups who influence women's decision-making is essential. Knowledgeable health care professionals need to recommend the vaccine and provide accurate and timely information to increase success of this important program.

1. INTRODUCTION

Pertussis (whooping cough) is a highly contagious, acute bacterial infection of the respiratory tract caused by *Bordetella pertussis.* This exclusively human pathogen can affect people of all ages. Whilst adolescents and adults often display relatively mild symptoms, in unimmunised newborn infants the disease may run a severe course resulting in a high rate of complications and death, [1,2]. Pertussis persists as an infection of significant global public health importance leading to 126,000 deaths worldwide in children up to the age of 5 years in 2013,[3].

Fortunately, wide-scale childhood vaccination programmes have been influential in reducing the morbidity and mortality associated with pertussis,[4, 5, 6, 7]. However, despite high vaccine coverage, a sharp increase in cases has been observed over the past decade,[8,9,10,11] in several countries in Europe, North America and Australia, most likely due to waning immunity after the introduction of the acellular pertussis vaccine,[12]. In the UK, pertussis currently remains the most common cause of hospitalisation and deaths in infants from a vaccine-preventable disease,[5,13].

In late 2011 the UK witnessed a remarkable resurgence of confirmed pertussis cases to a level not seen for almost 20 years. By 2012, infected cases had risen tenfold and the outbreak was extending to infants too young to be protected through routine vaccination. Sadly, a total of 14 infant deaths were reported in England in that year. Consequently, an urgent review by the UK Joint Committee on Vaccination and Immunisation (JCVI) recommended to the Department of Health (DH) that pregnant women should be offered routine vaccination with a five component acellular-pertussis containing vaccine, and this program was initiated in October 2012, and was offered to all pregnant women between 28 and 38 weeks of pregnancy within the UK National Health Service (NHS)[14]

A subsequent Public Health communications campaign to inform women about the need for vaccination and to stimulate uptake ran for approximately 5 months, including publication of a range of printed materials, available on order. Communication with healthcare professionals used DH and NHS channels and relied upon Heads of Profession to convey key messages and clinical information about pertussis. The Primary Care Trusts (PCTs) were asked to establish vaccination services quickly using local GP Practices,[15]. Vaccine stocks were delivered to GP practices and the hospital pharmacy held only a limited stock of vaccine for women who were long-term antenatal inpatients.
The intervention aims to minimise morbidity and prevent further infant deaths by boosting pre-existing maternal immunity and protect newborns indirectly via transplacentally transferred protective antibody, prior to receiving their own vaccines within the infant immunisation schedule,. During the summer of 2014 the upper gestation recommended

for receiving the vaccine was reduced to 32 weeks, in light of recent evidence, [16] to ensure sufficient antibody transfer from mother to baby prior to birth.

Despite measures taken to promote pertussis vaccination, monthly figures published by Public Health England (PHE) since the start of the campaign have revealed varied vaccine uptake across England with London achieving 53.3% coverage at best in February 2013,[17].

In 2013 and 2014, a further 10 deaths in infants occurred with nine of these infants born to non-vaccinated mothers. In light of these data and the recent announcement that the vaccination programme will continue for a further five years, [18], evaluation of the current pertussis vaccination programme in pregnancy is, therefore, timely and essential to inform the long-term strategy for optimising pertussis control.

We undertook a cross sectional survey to evaluate women's awareness, attitudes towards and acceptance of the current pertussis vaccination programme in order to identify potential barriers that could be addressed in order to improve implementation.

2. MATERIALS AND METHODS

2.1 Study design

This study adopted qualitative and quantitative research techniques in the form of a cross-sectional questionnaire survey. Self–reported qualitative information on attitudes to vaccines and experiences was gained from the analysis of the free text.

2.2 Ethical considerations

Ethical approval was granted by the London-Hampstead Research Ethics Committee reference:13/LO/1712.

2.3 Theoretical framework and questionnaire development

A four part, anonymised questionnaire was developed based upon the Precaution Adoption Process Model and the Health Belief Model of health behavior [19,20,21]. Consideration was given to the potential for inaccuracy in self-reported vaccination status,[22,23,24] and questions were phrased in order to highlight any discrepancy and allow further questions to be asked.

A pilot survey was conducted with six pregnant women from the target population to optimise the questionnaire to ensure that the 'instrument' was logical and comprehensive for the domain that it was intended to measure. A convenience sampling strategy was adopted.

2.4 Study population

The questionnaire was administered to an ethnically diverse sample of pregnant women who were over 18 years old, at least 27 weeks pregnant and attending for routine pregnancy care over a one year period from May 2013 to June 2014.

When approached by the Research Midwife in the antenatal clinic waiting area,each woman was given a full explanation of the survey, supported by an information leaflet and sufficient time to ask questions before making an informed decision to participate. All questionnaires were returned to the Research Midwife in a sealed envelope prior to leaving the clinic.

2.5 Data analysis

Questionnaires were collated and data was entered into an Access database, double-checked for accuracy and subsequently exported into Microsoft Excel. Descriptive statistics such as percentages and means were calculated. Content analysis was applied to the free text and used to summarise recurring patterns across respondents. Quotes from the questionnaires were tabulated and repeated words and phrases were highlighted according to categories. Themes were derived from these to discern factors influencing women's decisions to accept or decline vaccine, [25].

3. RESULTS

205 questionnaires were distributed to eligible women. Five questionnaires were excluded due to insufficient response to multiple questions. 200 were completed and analysed (97.0% response rate).

3.1 Respondent characteristics

The average age of the respondents was 31.4 years (median, 31: range 18 – 34), the average gestation was 32 weeks (range 27 – 41weeks) and 46.0% (93) of the respondents were nulliparous. The respondents were of diverse ethnicities. Demographic details are summarised in Table 1.

To assess cohort representativeness, the demographic data of the respondents was compared with key data extracted from the Ciconia Maternity Information System (CMIS) of all women booking for routine care at the same NHS antenatal clinic. This comparison showed no significant differences between the groups and was representative of the pregnant population attending the hospital Trust.

Table 1. Characteristics of pregnant women participating in survey

Characteristic	Survey participants N=200	CMIS data comparison N=5877
Average age (years)	31.4years	31.57years
Range:	18-43years	16-52years
Parity (P)		
0	93(46.5%)	
≥1	107(53.5%)	
Parity range:	P0 – P8	
Average gestation	32 weeks	
Range:	27- 41weeks	
Ethnicity		
Asian (British, Bangladeshi, Indian, Pakistani including Chinese)	40 (20.0%)	14%
Black (British, African, Caribbean)	37 (18.5%)	18%
White (British, various other nationalities)	88 (44.0%)	48.5%
Mixed	9 (4.5%)	3.3%
Other ethnicities	19 (9.5%)	15.4%
Did not want to say or not stated	7 (3.5%)	
London postcodes		
NW2	26 (13%)	458 (7.8%)
W2	22 (11%)	602 (10.2%)
NW6	21 (10.5%)	520 (8.8%)
NW10	19 (9.5%)	822 (13.9%)

3.2 Uptake of pertussis vaccine

Of the 200 respondents, 26.0% (52/200) had been vaccinated during their current pregnancy. 72.0% (144/200) had not received the vaccine and four women (2.0%) could not remember. Of the 144 women who had not been vaccinated, 79 (54.8%) stated that they were undecided about accepting the vaccine during this pregnancy but may consider it in the future (Fig.1).

Uptake differed by ethnicity with the highest uptake amongst 'White women' with 29.5% (26/88) vaccinated. Within this group the highest uptake was in the "White – Other" ethnic group (predominantly Polish) with 36.0% (18/50) vaccinated. The lowest uptake of 18.9% (7/37) was in the "Black/Black British group with the poorest uptake being 7.1% (1/14) in Black Caribbean women. Women who did not state their ethnicity had an uptake of 14.3% (1/7).

3.3 Reasons for accepting pertussis vaccine

Vaccinated women were asked to describe their reasons for accepting the pertussis vaccination with four themes emerging.

3.3.1 The importance of encouragement and understanding

The predominant reason given by 78.8% (41/52) of women for accepting the vaccine was encouragement or recommendation by a healthcare professional known to them.

When asked about their knowledge and understanding of the pertussis vaccine only 16 of the 52 vaccinated women could name the vaccine they had received or provide any detail in their response. This suggested that while women had opted to take the vaccine perhaps the information given was difficult to interpret or the discussion around this process had been limited.

3.3.2 Keeping me and my baby safe

Women believed that by receiving the vaccine they were acting in the best interests of their unborn baby by protecting themselves and reducing the risk of their baby developing pertussis in the early weeks following birth.

3.3.3 Risk avoidance and precaution

Other reasons given for accepting the vaccine included preventing the disease and preventing any damage caused to the baby as a result of pertussis infection.

3.3.4 How experience influenced decision-making

Identifying with the disease by knowing someone who had experienced pertussis, influenced women's decisions to accept the vaccine. Personal experience of vaccine–preventable illness also had a positive influence on decision-making.

3.4 Impact of complications in pregnancy on decision making

Forty three of the 200 respondents (21.5%) reported complications in their current pregnancy with 13 (6.5%) reporting gestational diabetes and 7 (3.5%) with pre-eclampsia. Of these women, 30.2% had received the pertussis vaccine. In contrast, only 22.9% of the 157 women with uncomplicated pregnancies had been vaccinated.

3.5 Attitudes to vaccination in future pregnancies

47.5% (95/200) of all the respondents expressed a willingness to accept the pertussis vaccine in their next pregnancy. Over one third (38.5%) were undecided, but only 8.0% stated they would not wish to take up the vaccine and 6% did not answer this question.

3.6 Reasons for declining pertussis vaccine

Unvaccinated women were asked to describe their reasons for declining the pertussis vaccination during pregnancy and gave a number of different reasons for declining the pertussis vaccine, as summarised in Table 2. Five women gave more than one reason.

253 **Table 2. Reasons for declining vaccine**

Question: If you have decided not to have the whooping cough vaccination, why did you take this decision?	N=144
Not aware and never informed about the vaccine	51.3% (74)
Insufficient information about the vaccine	32.6% (47)
Safety concerns as we need more research evidence to show efficacy/safety	12.5% (18)
Trust in natural immunity and lifestyle	4.1% (6)
Breastfeeding gives baby enough immunity	0.6% (1)
Had whooping cough as a child so have enough immunity	0.6% (1)
Religious reasons	0.6% (1)
Other reason	0.6% (1)

254

255 Content analysis was applied to the free text and was used to summarise recurring
256 patterns across respondents in four emerging themes.

257 ***3.6.1 Lack of information, awareness and professional encouragement***

258 The main reasons for declining the vaccine were the lack of information and awareness
259 of the vaccine combined with a lack of encouragement from familiar healthcare
260 professionals. The vast majority (91.0% (182/200)) of women believed that their
261 healthcare professional should provide them with more information about the
262 recommended vaccinations during pregnancy. They requested that this information
263 should be given in a timely manner supported by a meaningful discussion in order to
264 make an informed decision about accepting or declining the vaccine within the optimal
265 timeframe. Women who were undecided about accepting the vaccine also considered
266 that it was important to be fully informed and that information should be more accessible.
267 It was also apparent that women who sought advice wanted detailed information about
268 the causes, symptoms, side-effects and significance of the disease in order to support
269 their decision-making.

270 Other important sources of information included discussions with relatives and friends,
271 utilising media sources such as printed material and radio and actively seeking
272 information on the internet. Just 3.0% (6/200) of women indicated the public health
273 campaign as their primary source of information. Of these, only one woman had received
274 the vaccine.

275

276 ***3.6.2 Natural is better***

Women thought that over-medication could be a hazard during pregnancy and that 'natural was better'. There was a firm belief that 'nature would take care of things'.

3.6.3 Perceived risks and safety concerns

Some women worried about the side-effects of the vaccine on their unborn baby and to themselves. Others felt that there was insufficient evidence to support the use of the vaccine at this present time. Women's perceptions of risk about vaccination both for themselves and their unborn baby influenced how they felt about accepting any vaccines during pregnancy.

3.6.4 Not needed as low perceived susceptibility

The vaccine was also considered unnecessary by some women who did not perceive that they were at sufficient risk of contracting the disease. Women were associating their healthy lifestyle with being at 'low risk' of getting the disease. Furthermore, some women believed that breastfeeding provided all the immunity their baby would need to prevent them from developing the infection.

3.7 Awareness of recommendations for vaccines in pregnancy in general

In order to assess whether the attitude towards pertussis vaccine might also influence the uptake of other vaccines recommended in pregnancy, we included questions that related to both pertussis and influenza vaccine. Overall, 63.0% (126/200) of respondents were aware that the pertussis vaccine is recommended in pregnancy compared with 69.5% (139/200) aware of the maternal influenza vaccine programme (Fig.2)

While 34.0% (68/200) of the respondents had been offered pertussis vaccination at their GP practice, only 24.0% (48/200) reported that they had discussed the issue with their GP. Some women had approached their GP and asked for the pertussis vaccine or for further information, nevertheless, 61.5% were not offered the vaccine and 4.5% could not remember. Of the 126 women who had been informed of the pertussis vaccination programme by their healthcare professional, 38.8% (49/126), nevertheless declined to take the pertussis vaccine.

In contrast, 48% (96/200) of the respondents had been offered the influenza vaccine at their GP practice. Of the 139 women who were informed of the influenza vaccination programme by their healthcare professional, 50.3% (70/139) were vaccinated during pregnancy.

3.8 Preferred sources of information

When women were asked to report all known sources of information about the pertussis programme available to them, 16.6% (21/126) indicated the GP and midwife as the

primary sources. Other sources of information included friends and the internet. Seventy four women(37.0%) were not aware of the vaccination programme.

When asked about receiving information about vaccination programmes in the future, 91.0% (182/200) of women said that it would be helpful to receive more information in a timely manner accompanied by a meaningful discussion and the opportunity to ask questions. Table 3 summarises the sources accessed and preferred sources of information for all future communications about vaccination in pregnancy.

Table 3. Sources of information accessed by respondents

Question: How were you informed about the whooping cough vaccination program?	**N=126**
Source of information:	
GP	24.0% (48)
Midwife	13.0% (26)
Antenatal clinic	10.0% (20)
Other source (internet etc.)	9.0% (18)
Media (newspaper, radio)	4.0% (8)
Public health campaign	2.5% (5)
Obstetrician	0.5% (1)
Question: How would you like to receive information about maternal vaccination in the future? (more than 1 answer allowed)	
Antenatal clinic	60.0% (120)
GP	59.0% (118)
Midwife	35.0% (70)
Personal letter sent out in post	22.0% (44)
Online website	20.5% (41)
Leaflet or poster in clinic or surgery	19.0% (38)
Text or email	15.0% (30)
Maternity helpline	1.0% (2)
Other	1.0% (2)
Would prefer not to have any additional information	5.0% (10)
Did not respond to question	4.0% (8)

4. DISCUSSION

Despite an ongoing public health campaign to promote pertussis vaccination during pregnancy in the UK and new cases in infants in the community, uptake has varied considerably across the country and has remained comparatively low in London.

We assessed the awareness and attitudes to pertussis vaccination in pregnancy using both quantitative and qualitative tools. Only 26.0% of women in our cohort had received the vaccine, considerably less than the 62.3% national coverage recently reported by PHE,[17] and fell short of the reported London coverage which ranged from 33.5% at worst to 53.3% in February 2013, [26]. PHE have suggested that the published coverage data should be interpreted with caution due to inherent problems identified in data capture and reporting,[17]. Nonetheless, our findings are a source of concern since they indicate a generally lower than average uptake of pertussis vaccination by pregnant women attending our busy, acute NHS Trust.

It would appear that making decisions about accepting vaccine during pregnancy is a complex process and women will utilise their own beliefs, attitudes and values about vaccination in general when balancing perceived risks and benefits to themselves and their baby,[27]. However, consistent with similar studies our findings also highlight the importance of encouragement and recommendation by a familiar healthcare professional in this process,[27,28,29, 30].

Despite recommendation from the UK Department of Health, awareness of the need for maternal vaccination was comparatively low at 63.0%, which, in itself represents a barrier to uptake. Lack of awareness combined with a lack of encouragement by professionals were the main reasons given for not accepting the vaccine. Being informed was important, also noted in previous studies, [31,32] and being aware of the disease increases women's probability of accepting the vaccine,[33]. Many women were sceptical of vaccine safety and efficacy despite published evidence,[34] and 91% wanted more information about vaccines in general.

The main sources of information for pregnant women were GPs and midwives and yet women displayed misconceptions about the vaccine. This suggests that the information received was limited and difficult to interpret and only 24% of the women questioned reported a meaningful discussion with their GP. A study examining postpartum vaccine acceptance in a diverse sample of 815 Australian women also noted that access to information was significantly associated with uptake,[35].
From the contrasting comments in this study -see supplementary document- it was obvious that women's needs around obtaining and retaining information are very diverse. The experience reported here was one of disempowerment which ultimately impacted decision-making and maternal choice.

Uptake varied across ethnic groups with only 7.1% of Black Caribbean women being vaccinated. This finding is consistent with prior studies on racial disparity in vaccination

practice which showed that black women are more likely to reject vaccination because they doubted the effectiveness, distrusted the healthcare system and feared they may become ill from the vaccine [36, 37, 38, 39]. This was an important finding given the significant number of women with Black/Black British ethnicity booking for care at this Trust (18%). Understanding the target audience and engaging with key groups who influence women and parents in vaccination decision-making is important and might be influenced by ethnicity and possible disparities in access to PH materials or use of GP's. Our questionnaire did not capture such details, but our subsequent focus group activities will be able to explore these issues in more depth.

The latest enquiry into maternal deaths, *Saving Lives, Improving Mothers' Care* [40] reports that between 2009-2012, 357 women died during pregnancy or within six weeks of the end of their pregnancy. One in 11 of these women died from influenza and more than half of the influenza deaths could have been prevented by a flu vaccination. Compared with pertussis, reported uptake of Influenza vaccine in our study was 9% higher. This difference may be attributed to greater awareness of the influenza vaccine during pregnancy and better availability at their GP practice.

Women were dissatisfied with the extent of information they received and resorted to researching information online as an alternative. There is little doubt that the development of new media such as the Internet and facilities such as NHS Direct have created easier access to 'medical' knowledge about pregnancy and childbirth, but, without professional help to explain the importance and relevance, misconstrued information may have caused women to reject the vaccination. This may be helped by emphasising the importance of maternal vaccination early in pregnancy at the first antenatal appointment then following this up at each subsequent clinic attendance and support this discussion with the inclusion of the DH leaflets in the 'booking pack'. Ideally, maternal vaccination should form part of the recommended information provided in the routine schedule of antenatal care and should be included in the National Institute for Health and Care Excellence (NICE) Antenatal Care Guidelines.

A number of women expressed concerns about the safety and efficacy of the vaccine. Previous studies have shown that perception of harm to the baby or pregnant woman is directly related to vaccine refusal,[35,36,41,42,43]. An observational study of over 20000 pregnant women who participated in the maternal vaccination programme in the UK, concluded that there were no safety concerns,[34]. The data also show that maternal immunisation with an acellular-pertussis-containing vaccine can provide 90% protection against infant disease,[16].

Our results underline the critical role of healthcare professionals in advising and informing women in pregnancy. Only 24% of the women had engaged in a discussion with their GP about the vaccine. Other studies conducted during the H1N1 epidemic reported similar findings [31].

In recognition of the need for accurate information which targets misconceptions we have recently developed a vaccination information telephone APP, and we are using a mobile vaccination information 'hub' which is 'rolled out' and displayed in the antenatal clinic area and manned by the research midwives. This allows women and professionals direct access to current information, is interactive and achieves better visibility than leaflets.

With a growing body of evidence supporting the safety of the vaccine, weekly/monthly email shouts to healthcare professionals to update and increase awareness of current pertussis activity in the community would ensure staff are equipped to deal with queries efficiently.This type of information can be provided via text message and adapted for pregnant women and healthcare professionals alike, utilising the existing NHS text messaging service.

Our study acknowledges some limitations. This was a cross-sectional study of only 200 women at a single large NHS TRUST in London. However the sample was representative of the diverse population of women attending this Trust and our findings are likely to be applicable to many other settings caring for a similar population of women.

We relied upon self-reported vaccine status and while this is recognised as a suitable alternative to medical record audit for determining vaccine uptake in adults, [44], there is potential for some reporting bias in our estimates of vaccine uptake.

It could be argued that surveying women at 27 weeks gestation might have been too early. However, since the vaccine can be administered from 28 weeks onwards, women should ideally be made aware of the vaccine at least one week in advance and the average gestation in our study was 32 weeks.

At the start of the DH pertussis campaign, pertussis-containing vaccine stocks were supplied to GP practices. With hindsight vaccine stocks may have been better placed in antenatal clinics where women could be informed about the vaccination programme and receive the vaccine without an additional visit to their GP practice. Both information and vaccines should be available at any point of contact with health services during pregnancy, with knowledgeable staff promoting their use. Comparative studies might be warranted to analyse where vaccination of pregnant women could be delivered with the highest success rates, and the opinion of pregnant women should be sought as part of

this process. Some GP practices are likely to have much higher rates of uptake and pathways to success could be shared.

In this campaign, communication of information used a top-down approach which, in this particular care setting was ineffective in delivering the key messages to staff in direct contact with pregnant women. In any future campaign it will be essential that PHE and DH engage directly with the staff delivering the care. In addition, although appropriate resources were developed to inform professionals and pregnant women, these are only provided on demand and not issued routinely to areas such as antenatal clinics.

In summary, the main barriers to uptake of the maternal immunisation program were lack of awareness and the lack of accessible information about safety and rationale for the program. Healthcare professionals with GP's and midwives in particular need to be more engaged in delivering these important messages to women in their care in an accessible and timely fashion. Practically, a four-pronged approach should be employed, which delivers education for expecting parents, support for healthcare professionals with up to date knowledge, enhanced media coverage promoting the benefits of vaccination and increased understanding of the consequences of poor vaccine uptake for individuals and society.

Acknowledgements

We acknowledge the Midwives and Obstetricians in the antenatal clinics who facilitated recruitment and thank all of the pregnant women who filled in the questionnaires.

Author's contributions

The study was conceived by BK, BD and LR. The questionnaires were developed and implemented by BD and PJ with critical input from BH, LR and BK. The database was designed by BK and BL. The data entry and analysis of results was conducted by BD, PJ and BK. The first draft of the manuscript was developed by BD and BK and subsequent versions had input from all authors. The final submission has been approved by all authors. We affirm that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and

that any discrepancies from the study as planned have been explained. BK is the guarantor of the paper.

Competing interest statement

All authors declare that no support from any organisation for the submitted work has been received. There is no financial relationships with any organisations that might have an interest in the submitted work, and no other relationships or activities that could appear to have influenced the submitted work.

Funding

This study was funded by a grant from the Imperial College Biomedical Research Centre to BK. BK is also supported by a program grant from the MRC MC_UP_A900/1122). The research was conducted independently from its funders.

References

1.Health Protection Scotland. Increased levels of pertussis circulating in Scotland. *eWeekly Report* 25 April 2012.
http://www.documents.hps.scot.nhs.uk/ewr/pdf2012/1217.pdf [Accessed 7 May 2015]

2.Public Health England. Whooping cough (pertussis).
http://www.hpa.org.uk/topics/InfectiousDiseases/InfectionsAZ/Whoopingcough. [Accessed 8 May 2015]

3.Liu L, Oza S, Hogan D, et al. Global, regional and national causes of child mortality in 2000-13, with projections to inform post-2015 priorities: an updated systematic analysis. *The Lancet* 2015;385: 430-440.

4.Roush SW, Murphy TV, and the Vaccine-Preventable Disease Table Working Group. Historical Comparisons of Morbidity and Mortality for Vaccine-Preventable Disease in the United States. *JAMA* 2007; 298(18): 2155-2163.

5.Campbell H, Amirthalingam G, Andrews N, et al. Accelerating the control of pertussis in England and Wales. *Emer Infect Dis* 2012;18: 38-47.

6.Edmunds WJ, Brisson M, Melegaro A, et al. The potential cost-effectiveness of acelluar pertussis booster vaccination in England and Wales. *Vaccine* 2002;20: 1316-30.

7.Joint Committee on Vaccination and Immunisation. Minutes of the meeting held on Monday 9 October 2000. London: Department of Health; 2000.
http://webarchive.nationalarchives.gov.uk/20130107105354/http://www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/@dh/@ab/documents/digitalasset/dh_117402.pdf [Accessed 8 May 2015]

8.Güri D, Strebel PM, Bardenheier B, et al. Changing epidemiology of pertussis in the United States: increasing reported incidence among adolescents and adults, 1990-1996. *Clin Infec Dis* 1999;28: 1230-1237.

9.Yih WK, Lett SM, des Vignes FN, et al. The increasing incidence of pertussis in Massachusetts adolescents and adults, 1989-1998. *J Infect Dis* 2000;182: 1409-1416.

10.Celetano LP, Massari M, Paramatti D, et al. Resurgence of pertussis in Europe. *Pediatr Infect Dis J* 2005;24: 761-765.

11.Quinn HE, McIntyre PB. Pertussis epidemiology in Australia over the decade 1995-2005 – trends by region and age group. *Commun Dis Intell* 2007;31: 205-215.

12.Koepke R, Eickhoff JC, Ayele RA, et al. Estimating the effectiveness of tetanus-diphtheria-acellular pertussis vaccine (Tdap) for preventing pertussis: evidence of rapidly

waning immunity and difference in effectiveness by Tdap brand. *J Infect Dis* 2014; 210:942-53.

13.Amirthalingam G. Strategies to control pertussis in infants. *Arch Dis Child* 2013;98: 552-555.

14.Department of Health. Pregnant women to be offered whooping cough vaccination. http://www.dh.gov.uk/health/2012/09/whooping-cough/ [Accessed 7 May 2015]

15.Department of Health. CMO letter dated 27 September 2012 (PL/CMO/2012/2). https://www.gov.uk/government/publications/whooping-cough-vaccination-programme-for-pregnant-women

16.Amirthalingam G, et al. Effectiveness of maternal pertussis vaccination in England: an observational study. *The Lancet* 2014;384(9953): 1521-1528.

17.Public Health England. Pertussis Vaccination Programme for Pregnant Women : vaccine coverage estimates in England, September to December 2014. *Health Protection Report* 2015;9(7)-27 February 2015 [Accessed 7 May 2015]

18.Department of Health. *Joint Committee on Vaccination and Immunisation minutes of meeting 4 June 2014.* https://www.gov.uk/government/groups/joint-committee-on-vaccination-and-immunisation#minutes. [Accessed 7 May 2015]

19.Weinstein ND, Sandman PM, Blalock SJ. The precaution adoption process model. In, Glanz K, Rimer BK, Viswanath K, (eds) *Health Behavior and Health Education. Theory, Research and Practice.* San Francisco: CA Jossey Bass.2002; 123-145.

20.Weinstein ND. The Precaution Adoption Process. *Health Psychology* 1988; 7(4): 355 - 386.

21.Janz NK, Becker MH.The Health Belief Model: A Decade Later. *Health Education Quarterly* 1984;11(1): 1-47.

22.Rolnick SJ, Parker ED, Nordin JD, et al. Self-report compared to electronic medical record across eight adult vaccines: Do results vary by demographic factors? *Vaccine* 2013;31: 3928-3935.

23.Lu AB, Halim AA, Dendle C, et al. Influenza vaccine uptake amongst pregnant women and maternal care providers is suboptimal. *Vaccine* 2012;30:4055-9

24.Cheng P-J, Huang S-Y, Shaw S-W, et al. Factors influencing women's decisions regarding pertussis vaccine. A decision-making study in the Postpartum Pertussis Immunization Programme of a teaching hospital in Taiwan. *Vaccine* 2010;28: 5641-7

25.Silverman D. *Interpreting Qualitative Data.* (5th Edition) London: Sage Publications 2015:116-118.

26.Public Health England. Pertussis vaccination programme for pregnant women 2012-2014: monthly data by area team (England). https://www.gov.uk/government/statistics/pertussis-vaccine-uptake-in-pregnant-women-october-2012-to-march-2014 [Accessed 7 May 2015]

27.Collins J, Alona I, Tooher R, et al. Increased awareness and health care provider endorsement is required to encourage pregnant women to be vaccinated.*Human Vaccines & Immunotherapeutics*2014;10(10):2922-2929.

28.Mak D, Regan AK, Joyce S, et al. Antenatal care provider's advice is the key determinant of influenza vaccination uptake in pregnant women.*Australian and New Zealand Journal of Obstetrics and Gynaecology.*2015;55(2):131-137

29.Bödeker B, Walter D, Reiter S, et al. Cross-sectional study on factors associated with influenza vaccine uptake and pertussis vaccination status among pregnant women in Germany. *Vaccine*2014,32: 4131-4139.

30.Fabry P. Gagneur A, Pasquier JC. Determinants of A(H1N1) vaccination: Cross-sectional study in a population of pregnant women in Quebec.*Vaccine*2011;29: 1824-1829

31.Moukarram H, Nargund A, Photiou A, Kiran TS. Awareness and acceptance of the pandemic influenza (H1N1v2009) vaccination among antenatal patients in a district general hospital.*Journal of Obstetrics and Gynaecology:the journal of the institute of Obstetrics and Gynaecology* 2012;32(6): 537-539.

32.Panda B, Stiller R, Panda A. Influenza vaccination during pregnancy and factors for lacking compliance with current CDC guidelines. *The Journal of Maternal-Fetal & Neonatal Medicine: The Official Journal of the European Association of Perinatal Medicine, the Federation of Asia and Oceania Perinatal Societies, the International Society of Perinatal Obstetricians* 2011;24(3): 402-406.

33.Varan AK, Esteves-Jaramillo A, Richardson V, et al. Intention to accept Bordetella pertussis booster vaccine during pregnancy in Mexico City.*Vaccine*2014;32(7): 785-793.

34.Donegan K, King B, Bryan P. Safety of pertussis vaccination in pregnant women in UK: observational study. *BMJ* 2014;349: g4219

574 35.Wiley KE, Massey PD, Cooper SC, et al. Pregnant women's intention to take up a
575 post-partum pertussis vaccine, and their willingness to take up the vaccine while
576 pregnant: A cross-sectional survey. *Vaccine* 2013;31: 3972-3978

577 36.Goldfarb IT, Little S, Brown J, et al. Use of the combined tetanus-diphtheria and
578 pertussis vaccine during pregnancy. *American Journal of Obstetrics and Gynecology*
579 2014;211(3): 299.e1-299.e5.

580 37.Wray RJ, Buskirk TD, Jupka K, et al. Influenza Vaccination Concerns Among Older
581 Blacks: A randomized controlled trial. *American Journal of Preventive Medicine* 2009;
582 36(5): 429-343.e6.

583 38.Wray RJ, Jupka K, Ross W, et al. How can you improve vaccination rates among older
584 African Americans? *Journal of Family Practice* 2007;56: 925-929.

585 39.Fisher BM, Scott J, Hart J, et al. Behaviors and perceptions regarding seasonal and
586 H1N1 influenza vaccination during pregnancy. *American Journal of Obstetrics and*
587 *Gynaecology* 2011;204(6Suppl1): S107-111.

588 40. Knight M, Kenyon S, Brocklehurst P, Neilson J, Shakespeare J, Kurinczuk JJ (eds) on
589 behalf of MBRRACE-UK. Saving Lives, Improving Mothers' Care – Lessons learned to
590 inform future maternity care from the UK and Ireland Confidential Enquiries into Maternal
591 Deaths and Morbidity 2009-12. Oxford: National Perinatal Epidemiology Unit, University
592 of Oxford 2014.

593 41.Wiley KE, Massey PD, Cooper SC, et al. Uptake of influenza vaccine by pregnant
594 women: a cross-sectional survey. *MJA* 2013;198(7): 373-375.

595 42.Sim JA, Ulanika AA, Katikireddi SV, et al. 'Out of two bad choices, I took the slightly
596 better one': vaccination dilemmas for Scottish and Polish migrant women during the H1N1
597 influenza pandemic. *Public Health* 2011;125(8): 505-511.

598 43.Kharbanda EO, Vargas CY, Castano PM, et al. Exploring pregnant women's views on
599 influenza vaccination and educational text messages. *Preventive Medicine* 2011;52(1):
600 75-77.

601 44.Mangtani P, Shah A, Roberts JA. Validation of influenza and pneumococcal vaccine
602 status in adults based on self-report. *Epidemiology and Infection* 2007;135(1): 139-143.
603

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