UK Health Security Agency

Risk assessment for measles resurgence in the UK

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Executive summary

Current situation

In the UK we have never met the WHO target of 95% coverage with 2 doses of MMR vaccine needed to achieve and maintain measles elimination.

Current MMR vaccine coverage in the routine childhood programme is the lowest it has been in a decade with about 10% of children not protected from measles by the time they are ready to start school.

Due to the COVID-19 pandemic, vaccine uptake rates for the routine childhood programme have fallen globally, worsening immunity gaps. Measles activity has also been slowly ramping up globally since 2022 with large outbreaks currently underway in multiple countries in South Asia and Africa leaving the UK at risk of importations.

Based on historic and current level of vaccine coverage, observed measles cases and using well established models, the risk of widespread transmission of measles, leading to a measles epidemic across the UK is considered low.

Levels of measles susceptibility are likely to exceed the threshold for optimal disease control in the teenage and young adult cohorts across the country, although it is more challenging to assess coverage in this age group as accuracy of vaccine records declines with age
With current levels of coverage, a measles outbreak of between 40,000 and 160,000 cases could occur in London. Hospitalisation rates vary by age but range from 20 to 40%. These estimates are subject to certain limitations, but most of the uncertainty relates to data inputs (ascertainment of coverage) rather than issues with the underlying model. Data in younger age groups (closer to the offer of vaccination) is more reliable and suggests coverage is well below the threshold needed for optimal disease control in London.

There is a high risk of imported cases leading to outbreaks in specific population groups (including migrant populations, traveller communities, and ultra-orthodox Jewish communities) and geographies (London and other inner-city areas) with some risk of limited spread to the wider community.

Recommendations

Using national vaccine registers to assess population susceptibility to measles in all birth cohorts would be highly beneficial for planning purposes.

Efforts to improve coverage in the routine childhood immunisation programme should continue to be prioritised with the aim of achieving 95% uptake with 2 doses of the MMR vaccine by the time children turn 5 years.

There is an urgent need to:

- catch-up children under the age of 5 years nationally
- catch-up children, teenagers and young people in London
- coordinate efforts to catch-up teenagers and young people nationally

Longer-term future

Accumulation of susceptibles in older age groups, even at very low numbers, will increase the risk of measles epidemics in the longer term.

System partners should work collaboratively to formalise opportunities for immunisation status check and offer for school aged children in order to avoid the need for large scale catch-up campaigns every few years.

As delivery of campaigns to older individuals is challenging, efforts to mainstream opportunistic vaccination of young people and adults in general practice and other suitable settings will improve resilience.

Risk assessment for measles resurgence in the UK

Measles transmission

Measles is highly infectious – the most infectious of all diseases transmitted through the respiratory route. In a population with no immunity to measles (a totally susceptible population) a single case of measles will infect between 10 and 20 others – this is known as the basic reproduction number (R0). Previous measles infection and vaccination with a measles-containing vaccine, however, induces long term immunity and thereby provides protection to that individual and reduces transmission to others. This 'herd immunity' is particularly important for diseases of high infectivity, like measles, and for this reason, measles is a regional target for elimination and ultimately for eradication.

Achieving measles elimination

In the pre-vaccine era, measles was endemic in the UK with most children being infected before the age of 5 years. When measles vaccination was introduced in the UK in 1968, most older children and adults were already immune from having been infected in childhood.

Because of pre-existing immunity in older people, when a high proportion of children are successfully vaccinated, the number of susceptibles in the population remains low and any cases that occur do not transmit to many others. Of note, however, is that in the absence of measles transmission, those who remain unvaccinated, or those who do not respond to vaccination, are not exposed to measles and so remain susceptible to an older age. If these individuals remain unvaccinated, the susceptible cohorts gradually accumulate to a level that will allow measles to re-circulate. To prevent the re-establishment of endemic transmission, therefore, the proportion of susceptibles has to remain at low levels in all age cohorts. Because measles is so infectious achieving and sustaining very high vaccine coverage (≥ 95%) with 2 doses of the MMR vaccine is necessary to interrupt virus transmission.

Measles susceptibility targets

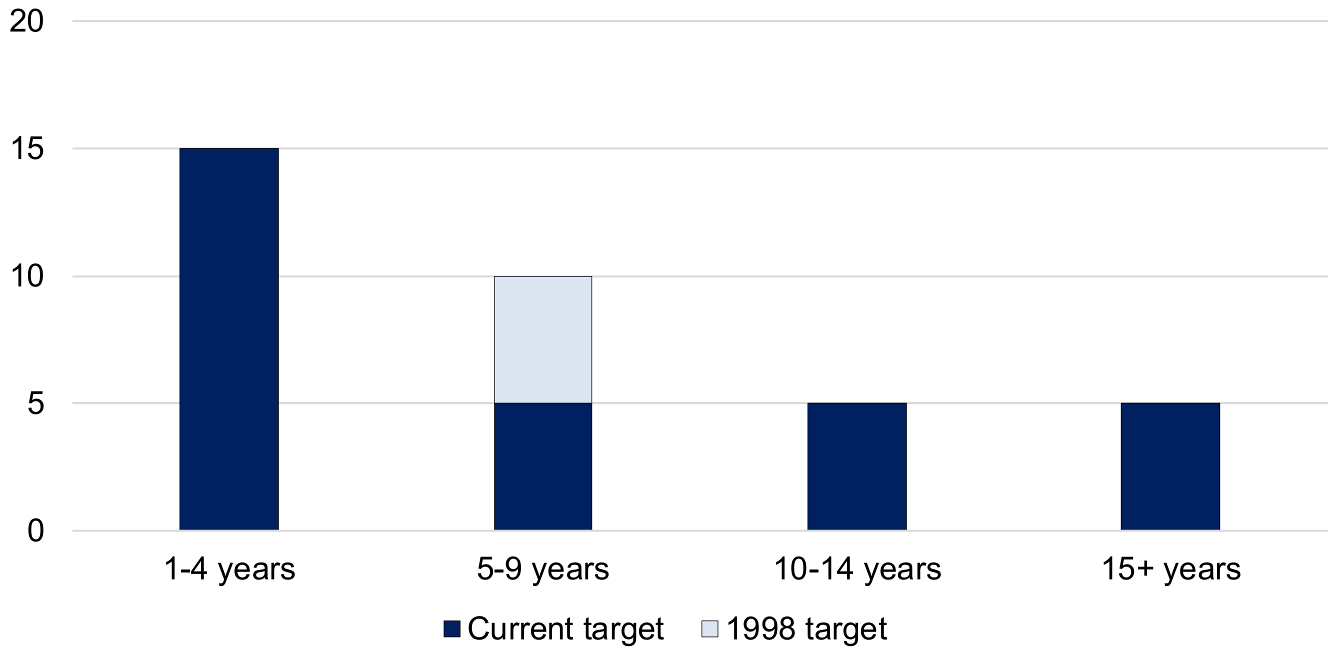
The levels of immunity required to achieve and sustain elimination have been established using mathematical modelling in the UK and formed the basis of targets set for the WHO European Region in 1998 (1). In a real population, the average number of secondary cases infected from each case of measles is called the effective reproduction number (R) – R is derived from the basic reproduction number R0 (~15) multiplied by the proportion of the population who are susceptible to measles (x).

$$R_e = R0x$$

When R is below 1, each case of measles will produce less than one secondary case and ultimately the number of cases will decline. Nevertheless, relatively large outbreaks with 100s of cases can still occur when R is below 1, due to variations in susceptibility and mixing patterns and high risk of importations. To allow for this heterogeneity, WHO susceptibility targets to achieve elimination were set to maintain R below 0.7. The vaccination strategy, therefore, aims to keep the proportion of the population that are susceptible (x) very low. The level of susceptibility required to prevent measles transmission depends upon the contact patterns in the population and therefore vary by age. Once children start school they have much higher levels of contact with others in their age cohort, therefore the proportion of susceptibles in the population must be lower than in pre-school children.

Models developed by the Public Health Laboratory Service in the early 1990s were used to develop susceptibility targets. These were recently updated at the London School of Hygiene and Tropical Medicine (LSHTM) and were used to underpin the 2019 UK strategy for measles and rubella elimination (Figure 1) (2, 3).

Figure 1. Target levels of measles susceptibility in the UK



Achieving these targets requires very high coverage by primary school age, bearing in mind that around 95% of children respond to the first dose, whereas around 99% will be protected after 2 doses. It is therefore vital that every opportunity is used to maximise coverage before children leave full time education in order to ensure that susceptibility in adults is very low. There is also no routine offer of vaccination to healthy young adults and therefore access to that population is limited and relies on opportunistic vaccination check and offer.

Measles control in the UK

When measles vaccination was first introduced in the UK in 1968, coverage was sub-optimal and measles continued to circulate. This situation lasted until the late 1980s when combined measles-mumps-rubella vaccine (MMR) was introduced. Coverage increased and exceeded 90% for the first time.

In the early 1990s, surveillance indicated that levels of susceptibility to measles remained high in older children, many of whom had not been vaccinated in the 1970s and 1980s, and modelling predicted an outbreak of between 100,000 and 200,000 cases (4). This prompted the need for a school-based Measles-Rubella campaign in 1994, where approximately 9 million school age children were offered vaccination and an uptake of 92% was achieved. Following this, in 1996, a second routine dose of MMR was introduced at pre-school age.

In the late 1990s and early 2000s, however, coverage of MMR in younger children started to decline, following the media interest in the Wakefield study falsely linking MMR vaccination to autism. MMR coverage dropped to about 80% nationally and took many years to recover. Modelling was used to inform the need for a primary school MMR capital catch-up in 2005 in London, and for a national catch-up programme for all under 18s in 2008 (5).

From 2008, coverage of MMR in younger children had started to improve and then reached the highest levels ever recorded in 2012 to 2013. However due to relatively modest coverage in previous catch-up campaigns, a large national measles outbreak started in 2012 mainly affecting teenagers leading to a national catch-up campaign targeting 10- to 17-year-olds in 2013.

By 2014 the UK had interrupted endemic transmission of measles and in 2017 the WHO declared that the UK had eliminated measle. In England, vaccine coverage of the first MMR dose evaluated in 5-year-olds also reached the WHO 95% target for the first time in 2016 to 2017. Annual vaccine coverage estimates for MMR1 at age 2 has never reached the WHO target of 95% in England and has been decreasing since 2013 to 2014.

Achieving measles elimination does not mean that measles has been wiped out. Measles remains endemic in many countries around the world and since 2016 there have been large measles outbreaks across Europe. Multiple importations to the UK led to a number of outbreaks with some limited spread in the population, particularly young people and adults and under vaccinated communities such as travellers, migrant populations and the Anthroposophic (Steiner) community.

By 2018 measles virus transmission had re-established in the UK, at a time when the whole of Europe was experiencing large epidemics. In 2019, there were 1,085 lab confirmed measles cases in the UK and 79 cases were confirmed in early 2020 prior to the first COVID-19 lockdown in March. Due to the travel and social restrictions in place during the COVID-19 pandemic the incidence of measles in England was dramatically reduced. There were only 2 cases of measles in the UK in 2021 and 54 in 2022. Since 2022, measles activity has been slowly gathering pace globally with large outbreaks currently underway in multiple countries in South Asia and Africa. In February 2023, WHO Europe called for urgent action in all countries to implement catch-up of children and adults who missed MMR vaccine doses in order to prevent a resurgence of measles.

Current levels of measles susceptibility

Due to the COVID-19 pandemic, vaccine uptake rates for the routine childhood programme have fallen globally, worsening immunity gaps and leaving more children susceptible. Coverage for the MMR vaccination programme in England has also fallen to the lowest level in a decade. Uptake for the first dose of the MMR vaccine in 2-year-olds in England is 89.5%, and uptake of 2 MMR doses at age 5 years is 85.6%. London remains the most vulnerable region with immunity targets not achieved for many birth cohorts (82.5% MMR1 at 2 years and 74.1% for both doses at 5 years of age). There are also inequalities in vaccine uptake by ethnicity, deprivation and geography and the burden of measles falls disproportionately on under vaccinated communities such as the Charedi Orthodox Jewish community, the traveller community, Steiner (anthroposophic) community and recent migrants.

UKHSA (formerly PHE) has estimated susceptibility rates in England for different birth cohorts based on coverage rates of routine MMR vaccination, catch up vaccination campaigns and the effectiveness of the MMR vaccine (Appendix 1). Reported coverage rates tend to underestimate true vaccine coverage, and so susceptibility estimates have been corrected for under-ascertainment based on best evidence available (3). Initial analysis conducted in 2019 for the UK Chief Medical Officer, suggested that if routine vaccine coverage continued to fall and in the absence of substantial catch-up there would be an increasing risk of large measles outbreaks. These analyses suggested that routine vaccine coverage has been sufficiently high to meet susceptibility targets in the youngest age cohorts, however, teenagers and young adults appear to remain under-vaccinated, even if we assume that 50% of those recorded as unvaccinated are in fact fully vaccinated.

Susceptibility targets have also not been met in a large number of age cohorts in London, where reported coverage is lower than the rest of the country, (Appendix 2) suggesting a potential risk of outbreaks in the capital.

Current risk of a measles epidemic

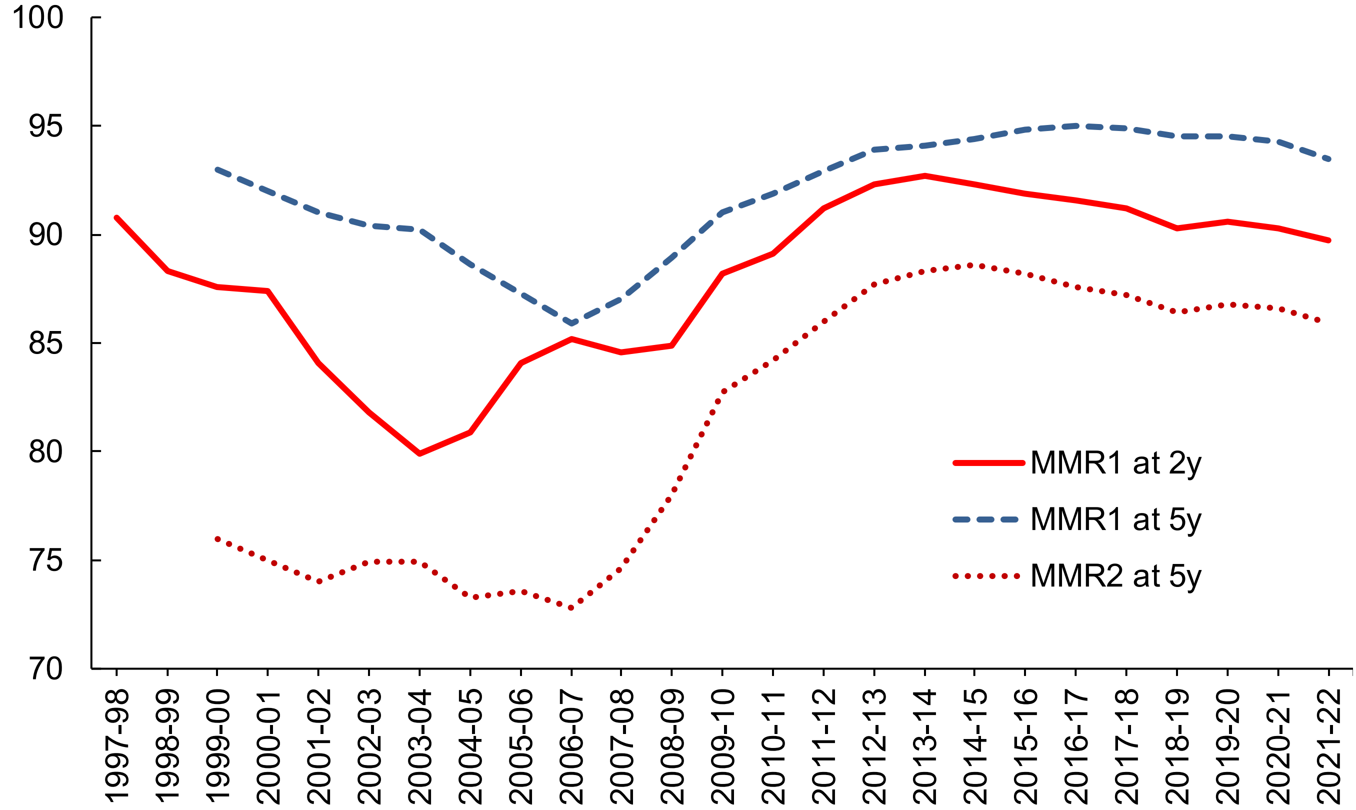
Despite the failure to meet the susceptibility targets across all ages, modelling suggests the level of R in England remains below 1 (Appendix 3). The level of R can be estimated in 2 different ways.

One method uses current susceptibility levels applied to mathematical models. Models can be developed and validated in different ways. The UKHSA model, which has been used to plan previous campaigns in the UK was validated using measles epidemiology from the pre-vaccine era. A more recent model by the London School of Hygiene and Tropical Medicine (LSHTM) has incorporated contact patterns derived from surveys. The second approach uses real data on the distribution of outbreak size, which can be estimated where surveillance is complete and epidemiological links between cases can be established and confirmed or refuted by measles genotyping (3).

Using the UKHSA model and observed outbreak size it is estimated that R for measles has ranged between 0.45 and 0.90 across England. This suggests that the UK has not been at risk of a national measles epidemic. In all scenarios (assuming 10%, 25% and 50% of those recorded as unvaccinated are in fact vaccinated), using the UKHSA model, the reproduction number in London is now close to or above 1 (R=1.6, R=1.4, R=0.91) and could therefore result in an outbreak of between 40,000 and 160,000 cases. Based on preliminary modelling by LSHTM, R is also likely to have exceeded 1 in London, even with 25% under-ascertainment, emphasising the importance of accurate estimates of susceptibility.

The burden of the public health and clinical management of measles cases and their contacts on Health Protection Teams and the NHS is significant. Most cases will seek medical attention, attending general practice or Accident and Emergency Services with hospitalisation rates ranging from 20 to 40% – with infants under the age of 1 and adults over the age of 25 years having higher rates of admission.

Figure 2. MMR annual vaccine coverage, England 1997/1998 to 2021/2022



Source: Childhood Vaccination Coverage Statistics 2020 to 2021 Annual National Official Statistics, NHS Digital, UKHSA.

Conclusions

Based on historic and current level of coverage, observed measles and rubella cases, and using well established models, the risk of widespread measles epidemics in England is considered low. Despite this, levels of measles susceptibility do exceed target levels in older age groups nationally. This suggests that outbreaks may be observed in young adults. The impact of these may be particularly marked in specific settings such as health care and universities.

In addition, low levels of coverage, different mixing patterns and high risk of imported cases makes relatively large outbreaks (~10s to 100s) in specific population groups, such as migrant and travelling communities likely, with limited spread to the wider population.

At current vaccine coverage, the risk of a large measles epidemic outside of London is considered low but models suggest that an outbreak of between 40,000 and 160,000 cases could now occur in London.

Accumulation of susceptibles in older age groups over time will increase the risk of epidemics in the longer term. This emphasises the importance of efforts to improve coverage in the routine childhood immunisation programme and the need for partners to work collaboratively to formalise opportunities for immunisation status check and offer for school aged children in order to avoid the need for large scale catch-up campaigns every few years.

These estimates are subject to certain limitations, although most of the uncertainty relates to data inputs (estimates of vaccine coverage) rather than issues with the underlying model.

Appendix 1. Reported vaccine coverage (COVER) and susceptibility to measles by birth cohort, England, 1985 to 2016

Birth year	MMR1 coverage (%)	MMR2 coverage (%)	Catch-up campaign	Catch-up coverage (%)	Catch-up campaign	Catch-up coverage (%)	Under-ascertainment scenario	Adjusted MMR1 coverage (%)	Adjusted MMR2 coverage (%)	% susceptible
2015 to 2016	91.2						50%	95.6		9.2
2014 to 2015	91.6						50%	95.8		9.0
2013 to 2014	91.4						50%	95.7		9.1
2012 to 2013	94.9	87.2					50%	97.5	93.6	2.9
2011 to 2012	95	87.6					50%	97.5	93.8	2.9
2010 to 2011	94.9	87.6					50%	97.4	93.8	3
2009 to 2010	94.6	88.4					50%	97.3	94.2	3.1
2008 to 2009	94.4	88.4					50%	97.2	94.2	3.2
2007 to 2008	94.2	88.3			MMR catch-up 2008	n/a	50%	97.1	94.1	3.3
2006 to 2007	93.5	87				n/a	50%	96.8	93.5	3.6
2005 to 2006	92.4	84.6				n/a	50%	96.2	92.3	4.2
2004 to 2005	91.5	83				n/a	50%	95.7	91.5	4.7
2003 to 2004	89.9	80.1				n/a	50%	94.9	90.1	5.5
2002 to 2003	87.3	74.7	MMR (2013)	10.8		n/a	50%	93.6	87.3	6.2
2001 to 2002	86.8	73.2		10.8		n/a	50%	93.4	86.6	6.4
2000 to 2001	86	73		10.8		n/a	50%	93	86.5	6.8
1999 to 2000	88.6	74		10.8		n/a	50%	94.3	87	5.7
1998 to 1999	89.6	74.6		10.8		n/a	50%	94.8	87.3	5.2
1997 to 1998	90.5	74.6		10.8		n/a	50%	95.3	87.3	4.8
1996 to 1997	90.8	74		10.8		n/a	50%	95.4	87	4.7
1995 to 1996	91.7	74.2				n/a	50%	95.9	87.1	4.8
1994 to 1995	92.6	74.7				n/a	50%	96.3	87.3	4.3
1993 to 1994	93.5	76.4				n/a	50%	96.8	88.2	3.9
1992 to 1993	94.1	74.4				n/a	50%	97	87.2	3.7
1991 to 1992	92.4		MMR 2 catch-up 1996	60		n/a	50%	96.2		5.9
1990 to 1991	92.7			60		n/a	50%	96.4		5.7
1989 to 1990	92			60			50%	96		6.1
1988 to 1989	89.8		Measles-rubella (1994)	92			50%	94.9		1.2
1987 to 1988	87.2			92			50%	93.6		1.4
1986 to 1987	90.8			92			50%	95.4		1.2
1985 to 1986	77.9			92			50%	88.9		2

Green indicates cohorts where susceptibility targets have been met, red indicates cohorts where susceptibility targets have not been met. Adjusted MMR coverage rates and susceptibility estimates are based on a 50% under-ascertainment scenario as reported in validation studies of COVER data.

Appendix 2. Reported vaccine coverage (COVER) and susceptibility to measles by birth cohort, London, 1985 to 2016

Birth year	MMR1 coverage (%)	MMR2 coverage (%)	Catch-up campaign	Catch-up coverage (%)	Catch-up campaign	Catch-up coverage (%)	Catch-up campaign	Catch-up coverage (%)	Under-ascertainment scenario	Adjusted MMR1 coverage (%)	Adjusted MMR2 coverage (%)	% susceptible
2015 to 2016	85.1								50%	92.55		12.1
2014 to 2015	85.1								50%	92.55		12.1
2013 to 2014	86.4								50%	93.2		11.5
2012 to 2013	91.4	77.8							50%	95.7	88.9	4.9
2011 to 2012	91.1	79.5							50%	95.55	89.75	5.0
2010 to 2011	90.9	79.3							50%	95.5	89.7	5.1
2009 to 2010	91.1	80.5							50%	95.6	90.2	4.9
2008 to 2009	90.9	80.2							50%	95.4	90.1	5.1
2007 to 2008	91.3	80.6			MMR catch-up 2008	n/a			50%	95.6	90.3	4.9
2006 to 2007	90.4	80.4				n/a			50%	95.2	90.2	5.3
2005 to 2006	88.4	76.3				n/a			50%	94.2	88.2	6.3
2004 to 2005	86.7	72.7				n/a			50%	93.3	86.4	7.2
2003 to 2004	82.7	66.9				n/a	Capital catch-up (2004)	24	50%	91.3	83.4	7.2
2002 to 2003	76.9	54.4	MMR (2013)	10.8		n/a		24	50%	88.4	77.2	8.6
2001 to 2002	75.6	52		10.8		n/a		24	50%	87.8	76	9
2000 to 2001	75.8	53.9		10.8		n/a		24	50%	87.9	77	8.9
1999 to 2000	79	57.3		10.8		n/a		24	50%	89.5	78.6	7.9
1998 to 1999	80	57.2		10.8		n/a		24	50%	90	78.6	7.5
1997 to 1998	80.2	56.9		10.8		n/a		24	50%	90.1	78.5	7.5
1996 to 1997	83.5	57.7		10.8		n/a		24	50%	91.8	78.8	6.3
1995 to 1996	84.7	58.9				n/a		24	50%	92.3	79.5	6.6
1994 to 1995	85	61.5				n/a		24	50%	92.5	80.8	6.4
1993 to 1994	87.7	58.1				n/a		24	50%	93.9	79	5.5
1992 to 1993	88.1	55.7				n/a		24	50%	94.1	77.9	5.4
1991 to 1992	87.6		MMR 2 catch-up 1996	60		n/a		24	50%	93.8		6.4
1990 to 1991	87.7			60		n/a		24	50%	93.9		6.3
1989 to 1990	86.8			60				24	50%	93.4		6.7
1988 to 1989	81.1		Measles-rubella (1994)	92				24	50%	90.5		1.4
1987 to 1988	77.3			92				24	50%	88.7		1.6
1986 to 1987	80			92				24	50%	90		1.5
1985 to 1986	67.1			92				24	50%	83.6		2

Green indicates cohorts where susceptibility targets have been met, red indicates cohorts where susceptibility targets have not been met. Adjusted MMR coverage rates and susceptibility estimates are based on a 50% under-ascertainment scenario as reported in validation studies of COVER data.

Appendix 3. Estimation of the effective reproductive number (R) for measles

Two approaches have been used to estimate the effective reproductive number: (i) Susceptibility levels applied to measles transmission metrics have been used to model the effective reproductive number (R), (ii) R has been estimated based on the distribution of outbreak sizes, this is possible where surveillance is complete and endemic measles has been eliminated (6). Where R is estimated to exceed 1 an estimate of outbreak size has been undertaken.

Modelled R based on susceptibility levels and measles transmission

Susceptibility has been estimated using vaccine coverage data and measles vaccine effectiveness. Three under-ascertainment scenarios have been applied to vaccine coverage estimates, of a 10%, 25% or 50% misclassification of unvaccinated and under-vaccinated individuals. For historical vaccine coverage data, evidence suggests that approximately 50% of English 10- to 16 year-olds reported as unvaccinated had in fact received at least 1 dose of measles-containing vaccine (7), although this figure is likely to vary across region and birth cohorts. R remains below 1 in all scenarios outside of London and is just below 1 in the 50% misclassification scenario in London. However, it is predicted that under the 10% and 25% under ascertainment scenarios London could sustain an outbreak of anywhere between 40,000 to 160,000 cases.

Table 1. Percentage susceptible and effective reproduction number (R) in England

England Excluding London				London			
Age group	**Under-ascertainment scenario**			**Age group**	**Under-ascertainment scenario**		
	10%	**25%**	**50%**		**10%**	**25%**	**50%**
0-4	19.07%	18.13%	16.57%	**0-4**	25.98%	23.89%	20.41%
5-10	7.10%	5.96%	4.05%	**5-10**	14.10%	11.79%	7.94%
11-17	4.74%	3.99%	2.75%	**11-17**	8.79%	7.37%	4.99%
18-24	9.27%	7.76%	5.26%	**18-24**	18.26%	15.26%	10.26%
25+	1.09%	0.93%	0.67%	**25+**	2.19%	1.85%	1.28%
Total	3.61%	3.18%	2.46%	**Total**	6.37%	5.48%	3.99%
R	**0.8304**	**0.6984**	**0.4819**	**R**	**1.626**	**1.3605**	**0.9164**

Table 2. Age distribution and outbreak size in London (assuming 10% under-ascertainment scenario)

Under ascertainment	10%		25%	
Age group	**Cases required to reach R=1**	**Estimated total outbreak size**	**Cases required to reach R=1**	**Estimated total outbreak size**
0-4	6502	13004	4150	8301
5-10	6153	12306	3457	6914
11-17	4008	8016	2259	4517
18-24	57612	115224	31875	63750
25+	5582	11164	3135	6270
Total	79857	159714	44876	89752

Estimate of R based on outbreak size

The table below estimates R for different years, the data suggests an increase in R between 2002 and 2013, declining after the MMR catch-up in 2013. The level has been relatively stable since then.

Table 3. Estimated effective reproductive number based on outbreak sizes

Years	Clusters	Average outbreak size	Re
2017 to 2018	109	10.2	0.90
2014 to 2016	72	8.4	0.88
2010 to 2013	295	16.2	0.94
2006 to 2009	408	9.1	0.89
2002 to 2005	124	8.1	0.81

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About the UK Health Security Agency

UKHSA is responsible for protecting every member of every community from the impact of infectious diseases, chemical, biological, radiological and nuclear incidents and other health threats. We provide intellectual, scientific and operational leadership at national and local level, as well as on the global stage, to make the nation health secure.

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