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### **Understanding the impact of vaccination strategy: HPV as a case study**

Vaccination against the human papillomavirus (HPV) is a recent development in the UK, implemented as part of a prophylactic treatment regime to reduce incidence of cervical cancer – HPV is detectable in more than 99% of cervical cancer cases.

Whilst HPV is an infection for which there is no long-lasting induced immunity post-infection, a single exposure to the virus is sufficient to initiate the cascade of events which eventually lead to cervical cancer. HPV is thought to infect around 80% of the sexually active female population at some point during their lives. Of these, 10-20% have a persistent infection, lasting more than 6 months; such infections increase the likelihood of developing precancerous lesions which may then develop further into cancer. To date, whilst the male population is also susceptible to HPV infections, no links have been made between these infections and male cancers. Transmission of the virus takes place as a result of intimate contact, such as results from sexual interactions, between an infected and susceptible individual. Therefore we consider HPV as a sexually transmitted infection.

In order to benefit from the protection afforded by the HPV vaccine, individuals must be vaccinated prior to exposure to HPV. In the UK this is achieved by developing a vaccination strategy aimed at girls aged 12-13 and implemented through a school vaccination programme. This age choice means that the majority of individuals have not been exposed to HPV; moreover, given that the vaccination efficacy may wane over time, it provides the 'maximum' length of protection once exposure to HPV occurs (the rate of onset of sexual activity is greatest for young people aged 15-17 years in the UK). Currently the vaccination is thought to have an efficacy in excess of 6 years. Additional, 'catch-up' vaccination is also being used for girls aged around 17 years in the initial phase of the programme.

We use mathematical modelling, based on a compartmental model to describe the infection dynamics and extended to explore optimal control scenarios, to address the following questions:

- How does a vaccination programme with a fixed target coverage impact the prevalence of infection?
- How does waning immunity and time to sexual debut following vaccination impact the efficacy of the vaccination programme?
- What is the optimal vaccination strategy if cost of infection must be balanced by cost of vaccination programme?
- What impact would male vaccination have on the predictions from a female only vaccination programme?