Critical immunity thresholds for measles elimination

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Outline

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1. Background
Background

- When the number of secondary infections generated by each infective person is less than 1, transmission will stop.

- To achieve this for measles, the population immune needs to be 93-95%, the herd immunity threshold.

- This is based on two assumptions:
  1. homogeneous mixing among individuals
  2. stationary, uniform immunity (through vaccination)
Basic Reproduction number $R$

**Measles**

$R_0 = 12-18$

Herd-immunity threshold:

Vaccinate at least so many that $R = 1$

Measles: 93-95% (randomly mixing population)

Limitations:

Population immunity reflects vaccination and case history

Mixing (person-to-person contact) is age-dependent
Measles immunity profile (e.g., UK)

Question:

Which levels of immunity are required for elimination?
Vaccination vs immunity targets

Vaccination target

Vaccinate (e.g. 95%) in each birth cohort.

Immunity target

Aim for age-specific levels of immunity, including past birth cohorts.
Target immunity levels for measles

WHO European Region

Ramsay, 1997

The age specific transmission rates used in the model are derived from age stratified notifications of measles in England and Wales before vaccination was introduced. Similar estimates can be

Question:
Are these appropriate? If yes, in which settings?
Age-specific differences in contacts

Mossong et al., 2008
Calculate R from mixing pattern and given immunity levels
Contact data used in this study
2. Results
Results: homogeneous vs age-specific mixing

Plot shows effective reproduction number R if countries had immunity levels according to current target levels.
Results: scenarios

Plot shows effective reproduction number $R$ if countries had immunity levels as shown at the top.
Finding gaps in immunity: serology

Andrews et al. (2008)
Results: homogeneous vs age-specific mixing

Estimated reproduction numbers (R) from serological studies conducted around 2000 vs cases incidence in the 10 years following.
Serological data from the around 2000 vs cases incidence in the 10 years following.
3. Conclusions and recommendations
Lessons from the United States

Measles eliminated in 2000

- Pre-elimination outbreaks in vaccinated school-aged populations (>90% uptake)
  
  => high vaccination levels needed to prevent outbreaks in schools.

- Lower coverage at 2\textsuperscript{nd} birthday may be sufficient to prevent outbreaks IF population immunity is high among school-age children (except if there are high contact rates among preschool children, e.g., childcare)
Conclusions

- Old immunity targets are not sufficient for measles elimination.

- For elimination in all scenarios, need higher immunity levels in 5-9 year olds compared to previous targets.

- Besides, it is important to maintain high levels of immunity in older age groups.

- Serological studies can help identify gaps in immunity in key age groups.
Limitations

- National targets don’t take into account heterogeneity and clustering of susceptibles.

- Targets don’t take into account waning immunity.

- Results depend on reported contact rates.

- Range of 11-18 for $R_0$ may not apply to all settings.
Programmatic implications

- Achievements towards elimination usually expressed via coverage levels, but they only tell part of the story.

- School-entry checks could be a method to identify and correct missing immunity in 5 year olds.

- Serological studies could be needed to identify immunity gaps in older age groups.
1. Achieving at least 95% immunity across all age groups, geographical regions and population subgroups through coverage of at least 95% of each birth cohort with 2 doses of MCV remains the primary goal for measles elimination.

2. To achieve this, countries ideally should assess age-group specific immunity levels to identify age-groups with levels of immunity below predefined thresholds to be targeted for vaccination.
3. Neglecting immunity gaps in children older than five years of age, adolescents and adults could make it more difficult and costly to achieve measles elimination.

4. Immunity gaps in school-aged children are important and could increase the disease burden and mortality among infants younger than 1 year of age as school-aged children are likely sources of measles virus infection within families (as siblings in school or in the future as parents). Therefore, the MR SAGE WG recommends that:

   - Countries conducting follow-up MCV vaccination campaigns should target school-age children 5-9 years of age whenever MCV coverage among this epidemiologically important age group is assessed to be significantly lower than 95%.

   - Countries should put into place school entry checks for vaccination as they are an important tool to help identify and address immunity gaps in school-age children.