

COMMENTARY



Are we speaking the same language? an argument for the consistent use of terminology and definitions for childhood vaccination indicators

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ABSTRACT

Vaccination indicators are used to measure the health status of individuals or populations and to evaluate the effectiveness of vaccination programs or policies. Ensuring that vaccination indicators are clearly and consistently defined is important for effective communication of outcomes, accurate program evaluation, and comparison between different populations, times, and contexts. The purpose of this commentary is to describe commonly used vaccination indicators and to highlight inconsistencies in how childhood vaccine researchers use and define these terms. The indicators we describe are vaccine coverage, uptake, and rate; vaccination status, initiation, and completion; and up-to-date, timely, partial, and incomplete vaccination. We conclude that many vaccination indicators are not explicitly defined within published research studies and/or are used quite differently across studies. We also note that the choice of indicator in a given study is often driven by program or vaccine specific factors, may be constrained by data availability, and should be chosen to best reflect the outcome of interest. We conclude that the use of consistent language and definitions would promote more effective communication of research findings. We also propose some standardized definitions for common indicators, with the goal of provoking discussion and debate on the issue.

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Effective communication is contingent on a shared use and understanding of language. This is no less true in the communication of research findings. In this commentary, we identify commonly used vaccination indicators and highlight inconsistencies in how childhood vaccine researchers use and define these terms. We propose the use of more standardized language to promote effective communication of research findings. For the purpose of this commentary, we define ‘vaccination’ as the administration of a vaccine to an individual, recognizing that vaccination and immunization are often used interchangeably in the literature.

What are vaccination indicators?

A ‘health indicator’ is a variable that can be directly measured to reflect the state of health of persons or a community and helps quantify the achievement of a result.^{1,2} Establishing and monitoring health indicators enables effective surveillance of health states and program success, detection of public health risks, and identification of the need for policy or program improvements. Health indicators related to vaccination (e.g. vaccine coverage, up-to-date vaccination) are critical public health indicators that permit ascertainment of individual and

population protection from disease and monitor the effectiveness of vaccination programs. Vaccination researchers, as well as public health practitioners and policy-makers, commonly use vaccination indicators to measure and report vaccination targets and outcomes. Using clear and consistently defined terminology is essential to ensure that indicators can be compared between different time points, settings, and populations.

Commonly used vaccination indicators

The most frequently used vaccination indicators in the research literature include: vaccine coverage, uptake, and rate; vaccination status, initiation, and completion; and up-to-date, timely, partial, and incomplete vaccination. How these terms are used and defined varies throughout the research literature.

Vaccine coverage

The most common vaccination indicator is *vaccine coverage*. In the research literature, this term is typically used to report a proportion, specifically the proportion of a defined population that received a specific number of doses of a particular vaccine(s).^{3–7} The Centers for Disease Control and Prevention

(CDC) in the USA defines childhood vaccine coverage as the percentage of those children in the target population who received a dose of a recommended vaccine.⁸

The *numerator* in the coverage calculation differs across studies. In most, it is (as the CDC defines it) the number of children in the target age group who received a dose of a recommended vaccine^{9–13}, while in others it is the number of vaccine doses prescribed or dispensed,^{14,15} with the assumption that every vaccine dose prescribed/dispensed equates to one person vaccinated. The numerator may report on (a) a specific number of doses of a vaccine, such as one dose of varicella vaccine¹⁶ or the third dose of HPV vaccine¹³; or (b) a range of doses, such as children receiving ≥ 1 dose of HPV or influenza vaccine^{9,17}; or (c) the number of children completing the vaccine series.^{12,18}

The target population in the coverage *denominator* typically includes persons who are eligible for a specific vaccination program because they are considered at risk for disease, perhaps due to age, gender, or a pre-existing health condition, and are either residing in the jurisdiction of interest or are affiliated with a particular health centre/health insurance plan.^{19,20} In some studies, the denominator is defined quite broadly, without consideration for whether the child is truly at risk for disease. For example, in annual coverage assessments of early childhood vaccines conducted by the CDC, the target population is defined as children aged 19–36 months²¹; and in a study by Jeannot, Sudre et al.,¹⁹ the target population to be vaccinated with HPV vaccine was defined as 11–19 year-old girls living in Geneva. Here, the assumption is made that all children in the denominator are actually eligible to receive the vaccine and/or at risk from the disease. Other studies explicitly limit the denominator to children who are susceptible to the disease. For instance, in studies by Giammanco et al. 2009²⁰ and Streng 2010,¹⁶ the denominator only includes children susceptible to varicella (i.e. without history of having had varicella disease).

The choice of denominator and the ability to restrict it to children truly at risk is often driven by the availability and completeness of data sources. Thus, in practice, the target population is actually limited to the *accessible population*, which has implications for accuracy and bias in coverage calculations. For instance, a national/state population registry or census data can provide a fairly complete and unbiased denominator,^{19,20,22,23} whereas a mail or phone survey of a sample of parents may be less so.^{16,24}

While many studies explicitly define “coverage”, including the numerator and denominator, in other cases, the definition is only implied. Most commonly, this is seen when the authors report coverage as a percentage without clearly articulating the numerator and/or denominator.^{6,24–27} While in some cases, it is possible for the reader to deduce what is intended, the lack of definition leaves open the potential for misinterpretation of findings and makes comparison between studies/settings challenging.

Vaccine uptake

In contrast to the term vaccine coverage, *vaccine uptake* is most commonly defined as the absolute number of people

who received a specified vaccine dose(s), i.e. the numerator in the vaccine coverage calculation. For example, vaccine uptake of influenza vaccine has been reported as the number of recipients of ≥ 1 dose of the vaccine during the influenza season,^{4,28} whereas influenza vaccination coverage for that influenza season would be the proportion of the target population who had received the vaccine.^{4,29,30} As with coverage, uptake may also refer to the number of *doses administered*, rather than number of people vaccinated. For instance, some studies report on the total number of doses administered to the targeted population,^{9,13} or even the number of vaccine doses dispensed or sold, rather than administered.^{19,31–33}

Although less common, some studies report vaccine uptake as a proportion, and use/define it similarly to how the term “coverage” is defined in other papers.^{23,34–37} This is sometimes done implicitly, for instance “pandemic influenza vaccine uptake was low at 11.1%,”²⁴ and “vaccine uptake was higher in children (32%).”²⁶ In other cases it was explicitly defined as such. For instance, “uptake was defined as the proportion of girls who had received each dose at the end of the study period out of the total number of girls, who were still part of the study population at the end of the study period”²³; and “vaccine uptake was expressed as the number of individuals receiving at least one dose of an influenza A/H1N1 vaccine over the number of individuals invited, according to the vaccination database”.³³

Some studies even use the terms “uptake” and “coverage” interchangeably within the same paper.^{33,35,38,39} For example, one study stated “uptake was higher in younger women (25–44 years) compared to younger men (8.2% and 5.9% respectively, $p < 0.001$), and conversely older men (aged 45 + years) had better coverage than older women (8.2% and 6% respectively, $p < 0.001$)”³³ (italics added). Another stated that “the programme achieved overall coverage of 71.5%... (and) a study ...in Manchester, UK found a similar vaccine uptake ... to our study, of 70.6%”³⁸ (italics added).

Interestingly, we are aware of one national body that uses the indicators coverage and uptake to both mean proportions but defines them different. Uptake is the “initiation but not completion of the vaccine series”, while coverage is defined as “completion of the vaccine series by the recommended age”.⁴⁰

Although rare, we did note some studies that explicitly differentiate between coverage and uptake.^{9,13} In their study of the HPV vaccine, Schmidt and colleagues⁹ defined vaccine uptake as the absolute number of vaccine doses given to eligible participants, while they defined single-dose vaccine coverage as the proportion of eligible participants who had ever received ≥ 1 vaccine doses. In Limia & Pachon,¹³ they define uptake as “the total number of administered doses (reported by health care professionals) in the targeted female population” and defined coverage as “the proportion of the targeted population that received the first and the third doses of any HPV vaccine”. However, even in this paper that explicitly defined uptake as an absolute number and coverage as a proportion, the terms were sometimes used contrary to these definitions, for instance, “a high level of vaccine uptake (80.1%) was achieved”.¹³

Finally, it is noteworthy that while the term “uptake” is commonly used as an indicator, it is also often used as a *verb*, referring to the behavior of receiving a vaccine. For example,

“uptake of seasonal influenza vaccine has been shown to be a strong predictor of vaccination intention”²⁴; “uptake of these vaccines may differ by age and race”⁴¹; and “a steady uptake of the programme was observed”.²⁰

Vaccination rate

The indicator *vaccination rate* is often used interchangeably with vaccine coverage in the research literature, but is rarely explicitly defined.^{9,20,26–28,32,38,41–44} It is usually synonymous with coverage, e.g. “the vaccination rates are calculated from the numbers of vaccinated persons over the respective populations”⁷ or in a paper by Ernst et al.,⁴⁵ where they state that changes in vaccination coverage by region are reported as vaccination rate per 100,000 children. Rarely, vaccination rate is used in the technically correct sense, i.e. “a measure of the frequency with which an event occurs in a defined population in a defined time”.⁴⁶ For instance Tennis⁴⁷ stated, the “vaccination rate was calculated by dividing the number of children vaccinated in a cohort by the total child-days of follow-up within a cohort”; or Lin¹¹ stated “to calculate vaccination coverage rate, we divided the total number of children who were ... vaccinated by the latest Census population estimates in the area for the corresponding year”.

Vaccination status

The term *vaccination status* is not usually explicitly defined in the literature but is generally used as an overarching term that encompasses various categories of vaccine receipt, including vaccine initiation, vaccine completion, up-to-date vaccination, timely vaccination, partial and incomplete vaccination, and non-vaccination, as described below. At the population-level, vaccination status appears to refer to the proportion of the population with a given status.²⁵

Vaccine initiation

The term *vaccine initiation* necessarily only applies to a multi-dose vaccine series,^{31,48,49} referring to receipt of the first dose in a given vaccine series.^{50–54} A number of studies assess vaccine initiation as receipt of ≥ 1 dose of a vaccine,^{50–54} such as “HPV vaccine initiation (receipt of at least one dose based on healthcare provider records)”³⁷; and “vaccine initiation (receiving ≥ 1 dose of HPV vaccine)”.⁵⁵

Vaccine completion

Vaccine completion was defined in various ways in the literature. In some studies, it referred to receipt of all recommended doses for a particular vaccine series divided by the vaccine eligible population.^{37,44,54,55} In others, it was defined as completion of the vaccine series among those who initiated the series (i.e. the denominator only included initiators, not the entire eligible population).^{9,56} For example, Pathela et al.⁵⁶ defined completion as “the proportion of adolescents who received ≥ 3 doses among those who had ≥ 1 HPV vaccine dose”. In both cases, the indicator could be more accurately referred to as *vaccine series completion*, but the choice of

denominator should be clearly stated. In other studies, completion referred to the receipt of the requisite number of doses of *all vaccines in the recommended schedule*,^{42,57} and was sometimes referred to as being *fully vaccinated*.^{43,58} For example, Hull et al.⁵⁸ define fully vaccinated as the number of children who were completely vaccinated with the vaccines of interest by the designated age divided by the total number of children in the age cohort. When referring to “recommended doses” or “recommended schedule”, it is important for researchers to identify the recommending body and the recommended series/schedule, as these recommendations vary between jurisdictions and over time. For instance, in February 2015, Canada’s National Advisory Committee on Immunization changed their recommendation from 3 to 2 doses of HPV vaccine for immunocompetent individuals 9–14 years of age, but implementation of this change is not occurring simultaneously in the various jurisdictions across the country.⁵⁹ Thus, “series completion” may mean 2 doses in one jurisdiction, but 3 doses in another.

Up-to-date vaccination

The indicator *up-to-date vaccination* is generally used to describe individuals that have received recommended vaccines by a certain age or age range, or by a specific point in time, such as school-entry.^{60–65} For example, “those (children) who received all 16 doses by 19 months of age”;⁶⁵ and “received all of the vaccine doses required for school entry”.⁶⁶ As noted in regard to vaccine series completion, the type, dose number, and timing of recommended/required vaccines are determined based on jurisdiction/country-specific vaccination guidelines and thus should be specified in the report. An example of such reporting is from Dummer’s study,⁴² in which they present the Nova Scotia immunization schedule for children under two years of age at the time of the study and then specify that “a dose was up-to-date if it was administered according to the schedule, defined as within 1 month at ages 2, 4, 6, 12 or 18 months”.

Timeliness/timely vaccination

Timely vaccination, also referred to as *age-appropriate vaccination*, is sometimes used interchangeably with up-to-date vaccination, to mean receipt of specified vaccines by a certain age or date.^{57,67,68} For example, in Hug et al.,⁵⁷ timely vaccination is defined as “administration of ≥ 1 dose of MMR before 24 months (≥ 730 days) of age”, while in Smith et al.⁶⁷ they define timely vaccination as “receipt of at least the recommended number of doses of each vaccine by age 19 months”. However, it is most commonly used to refer to receipt of specified vaccines within a very limited and specified time period following the age at which the vaccines are due.^{42,58,63,65,69} Common measure of timeliness are within 30 days,⁵⁸ 31 days,^{65,69} 4 weeks,¹² or a month^{42,63} of the recommended age. If children received a recommended childhood vaccine within the specified timeframe then they were considered to have received that vaccine in a timely manner.^{67,68} Vaccination before that age is considered *early vaccination* and those given after the specified interval are *late*

vaccination.^{12,42} It should be noted that the cut-points for determining timeliness have an impact on the calculation of coverage rates. While there may be circumstances that dictate that only timely vaccines will be counted, there are other instances in which exclusion of doses administered after a very short lag (e.g. 1 month) will artificially lower the coverage. Thus, in some instances, calculation of timely vaccination should be accompanied by a calculation of coverage with a more lenient lag time.

Partial vaccination and incomplete vaccination

Partial vaccination and *incomplete vaccination* are two indicators that appear to have the same meaning, with some authors seemingly having a preference for one versus the other. Some authors use the term *partial vaccination* to refer to vaccination status that was not complete.^{70–73} For instance, in Pabst et al.,⁷⁰ partial vaccination was defined as having received only one influenza vaccine dose when the child was recommended to receive two doses that season; and Moran et al.⁷² considered children under the age of 9 years who only received 1 lifetime dose of influenza vaccine as partially vaccinated, compared to the required 2 lifetime doses to be considered completely vaccinated. Alternatively, other researchers^{43,44,66,74} used the term *incomplete vaccination* to refer to people who were not completely vaccinated (i.e. they had not received all required vaccine doses for a vaccine series). The only study that we are aware of that distinguished between the two terms was Bell et al.,⁷⁵ who defined *partial vaccination* as receiving less than the recommended doses for at least one vaccine in the vaccine schedule, but having received some doses for any vaccine. Partial vaccination was then subdivided into *selective vaccination* (having received no doses of ≥ 1 vaccine while completing other vaccine series) and *incomplete vaccination* (having received ≥ 1 dose(s) of a multi-dose vaccine, but did not complete the series). While the definitions present a somewhat nuanced distinction, it was a useful method of operationalizing the categories of vaccine status in their study. The choice of term, partial versus incomplete, is not as important as ensuring that researchers define what is meant by the term chosen.

Non-vaccination

Non-vaccination is typically used to indicate no receipt of specified vaccine(s). The indicator is rarely defined explicitly, but has been used to mean failure to receive any doses of a given vaccine^{16,27,42} or of all the vaccines in the recommended schedule^{42,75} by a specified point in time. The assumption is often made that non-vaccination equates to unwarranted refusal of the vaccine. There is typically little mention of the fact that there are situations when vaccination is not recommended, e.g. due to a medical contraindication. Inclusion of these individuals in the denominator for calculation of coverage is warranted if the goal is to determine herd immunity, but not recommended if the goal is measurement of program performance. Since the number of non-vaccinators is typically small, this may not have implications at a population level for large geographic areas, but may result in meaningful difference in results for small populations, such as neighbourhoods or schools.

Population versus individual indicators

Many of the indicators used in the literature can be used to refer to both individuals and populations. For instance, vaccine completion and up-to-date vaccination status were used in the literature to refer to both individuals and populations. At the individual level, the terms indicated that a person had completed the vaccine series (or had received the specified number of vaccine doses by a certain age), while at the population-level the term referred to the proportion of the target population that had done so.^{3,34,54} Other terms, such as vaccine coverage or vaccine rate are exclusively used to refer to populations.

Summary and recommendations

Many vaccination indicators are not explicitly defined within published research studies and/or are used quite differently across studies. Although the term *coverage* is most commonly used to refer to a proportion, not all authors clearly state the numerator and denominator that contribute to the calculation. It is also not uncommon for the terms *vaccination rate* and *vaccine uptake* to be used interchangeably with *coverage*, although *uptake* is more commonly used to mean the numerator in the coverage proportion. Other indicators that are often used interchangeably are *timely* and *up-to-date* vaccination.

The choice of indicator in a given study is typically predicated by program or vaccine specific factors, such as the local vaccination program schedule, the type of vaccine, and/or the necessary number of vaccine doses (i.e. single versus multi-dose vaccines). For instance, vaccine series completion or dose-specific uptake and coverage would only be relevant for reports on multi-dose vaccines, e.g. HPV vaccine.

The choice of indicator may also be constrained by the data sources available. For instance, if there is no way to confirm administration of vaccine doses, the numerator may necessarily be the number of vaccine doses dispensed. In jurisdictions that cannot determine accurate numbers for the target population (i.e. no denominator available), researchers would be limited to reporting vaccine uptake (i.e. only the numerator). The ability to assess timeliness of vaccination is commonly limited due to data that can only report vaccination by a given age or time point, for example school entry, rather than being able to identify the exact date of vaccine administration.

It is also important to choose the indicator that best reflects the outcome of interest. For instance, the performance of a vaccination delivery program is often evaluated based on the achievement of high vaccination coverage or vaccine series completion. Indicators like coverage also play an important role in assessing herd immunity within a population, which is critical to ascertain in a disease outbreak scenario. Other indicators, such as partial vaccination and non-vaccination, are useful for the assessment of the vaccine behaviours of a population (e.g. assessing the proportion of the population that starts but fails to complete the vaccine series versus those that refuse all vaccines). In contrast, indicators like timeliness of vaccination could be useful for assessment of individual protection or, conversely, period of time at risk from disease.

Table 1. Proposed standardized definitions of vaccination indicators.

Terminology	Definition	
	Referring to an individual	Referring to a population
Vaccine coverage	N/A	The proportion of the target (or accessible) population that received the specified number of vaccine doses. It is important for researchers to specify the nature of the target population, eg., all persons in a specific population who are in the age group, vs. only those persons in the age group who meet eligibility criteria according to the named and specific recommending body.
Vaccine uptake	The behavior of accepting a vaccine.	The number of people who received a specified vaccine dose(s).
Vaccination rate	N/A	The proportion of the target (or accessible) population that received the specified number of vaccine doses, within a specific timeframe.
Vaccination status	Receipt of vaccines categorized as non-vaccinated, vaccine series initiated, vaccine series completed, partially or incompletely vaccinated.	The proportion of the target population that have achieved the designated category.
Vaccine series initiation	Receipt of the first dose in a specified vaccine series. It is important to specify whether the denominator is all eligible individuals, or only those that initiated the series.	The proportion of the target population that have received the first dose in a specified vaccine series.
Vaccine series completion	Receipt of all recommended doses for a particular vaccine series (should specify who makes the recommendation and what the recommended series consists of).	The proportion of the target population that have received all recommended doses for a particular vaccine series.
Completely/Fully vaccinated	Receipt of all vaccines recommended by a certain age (should specify who makes the recommendation and what the recommended schedule consists of).	The proportion of the target population that have received all vaccines recommended by a certain age.
Up-to-date vaccination	Receipt of the recommended number of vaccine doses by a specified age, whether or not it was all doses required for series completion.	The proportion of the target population that have received the recommended number of vaccine doses by a specified age, whether or not it was all doses required for the series.
Timely vaccination	Receipt of specified vaccines within a time-limited period following the age at which it was due (most commonly, within 1 month of scheduled date). The age it is due and the lag time being applied should be specified.	The proportion of the target population that have received specified vaccines a time-limited period following the age at which it was due.
Partial vaccination or incomplete vaccination (there is no clear consensus on which term to use)	When referring to a multi-dose vaccine: Receipt of less than all required vaccine doses for a vaccine series. When referring to an entire vaccine schedule: Receipt of less than all required vaccine doses in the vaccine schedule.	The proportion of the target population that have received less than all required vaccine doses for a vaccine series or less than all required vaccine doses in the vaccine schedule.
Non-vaccination	No receipt of specified vaccine(s). If possible, researchers should specify if this includes individuals non-vaccinated for legitimate reasons, such as medical contraindication.	The proportion of the target population that have not received the specified vaccine(s).

It is important for researchers to thoughtfully consider the most appropriate vaccination indicator(s) to use in reporting their findings and to explicitly define those indicators. In Table 1, we list the most commonly used vaccination indicators, and propose some standardized definitions based on key reference sources (e.g. CDC, WHO) and common usage in the research literature.

Conclusion

Poorly defined and inconsistent use of indicator terminology in vaccination research limits the communication of study findings. It also decreases the ability to compare findings across settings and time periods, which is necessary when conducting comparative effectiveness research of vaccine programs and delivery systems. It is strongly recommended that researchers in this field consider adopting standardized terms and definitions. We have proposed such definitions here, but see this as an opportunity to open dialogue on this issue, rather than issuing an edict about the best choice. Regardless, we do emphatically encourage researchers to exercise transparency in reporting how vaccination indicators are defined, including the components, i.e. the numerator and denominator, of all indicators.

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