Vaccine 36 (2018) 1353–1360

Contents lists available at ScienceDirect

Vaccine

journal homepage: www.elsevier.com/locate/vaccine

Vaccination timeliness and co-administration among Kenyan children

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ARTICLE INFO

Article history:
Received 1 November 2017
Received in revised form 31 January 2018
Accepted 1 February 2018

Keywords:
Vaccination timeliness
Co-administration
Late vaccination
Kenya
Expanded Program on Immunization

ABSTRACT

Background: Timely administration of recommended vaccines requires children to have multiple vaccines co-administered in the first year of life. The objectives of this study were to estimate the proportion of timely vaccinations and the proportion of co-administered vaccines, and to assess the relationship between vaccine co-administration and vaccine timeliness in Kenyan children.
Methods: Using the 2014 Kenyan Demographic and Health Survey (DHS), we calculated the proportion of children who received co-administered and timely vaccine doses. Co-administration was defined as doses administered on the same day with dates recorded on vaccination cards. Vaccines were considered timely if given within four days before to four weeks after the recommended interval for administration.
Results: 10,385 children aged 1–4 years in the Kenyan 2014 DHS dataset had vaccination cards which comprised the study sample. Analysis revealed wide a range for receipt of timely doses, from 90.2% for OPV0 to 56.0% for Measles. Co-administration of the 6-week dose was associated with 2.81 times higher odds of a timely Penta dose 1 (95% CI: 2.28, 3.46) and birth-dose co-administration was associated with a substantial increase in timely BCG vaccination: AOR 7.43 (95% CI: 6.31, 8.75).
Conclusions: Though vaccine coverage in Kenya was high, timely vaccination was markedly low, with resultant implications for population immunity and potential spread of communicable diseases in unvaccinated infants. Co-administration of vaccines, place of residence, wealth index, and child age were consistently related to the odds of timely vaccine receipt. These relationships reinforce the importance of dedicating resources to programs that educate low socio-economic groups about the importance of vaccine co-administration.

1. Introduction

Globally, there were approximately 5.9 million deaths of children under-five in 2015 with almost 20% attributable to vaccine-preventable diseases (VPDs) [1–3]. Despite overwhelming evidence that childhood vaccines yield significant health and economic benefits, less than half of infants and young children are fully vaccinated worldwide [2,4–6]. The African region has the lowest coverage of diphtheria-tetanus-pertussis dose 3 (DTP3) of any World Health Organization (WHO) region (76.0% in 2015) [7]. Incidence of severe episodes of VPDs, like pneumonia and diarrhea, is concomitantly higher in the African region than any other, indicating the continued risk for preventable disease outbreaks [8].

The recommended schedule for vaccinations varies from country to country, but the WHO provides guidance on age-appropriate vaccination and recommended intervals between vaccine doses [9]. Failure to adhere to these guidelines places children at higher risk for not completing their schedule [10,11], unnecessarily prolonging susceptibility to disease and potentially undermining herd immunity to VPDs [10,12,13].

Overall or individual antigen vaccination coverage is often utilized to evaluate the effectiveness of an immunization system. However, assessing timely vaccination coverage may be a more informative and realistic indicator of immunization services in developing countries. Calculating immunization coverage by 12, 24, or 36 months or by 5 years, as is typically done, may mask critical delays in establishing childhood immunity [12,14,15]. Recent studies investigating timeliness of vaccination in low- and middle-income countries (LMICs) have reported significant delays in the receipt of age-appropriate immunizations [9,16,17,18]. Clark

Abbreviations: BCG, Bacillus Calmette-Guérin; DHS, Demographic Health Survey; DTP, diphtheria-tetanus-pertussis; EPI, Expanded Program on Immunization; Hib, *Haemophilus influenzae* type b; MCV, *Measles-containing vaccine*; OPV, oral polio vaccine; PCV10, 10-valent pneumococcal conjugate vaccine; SES, socioeconomic status; TBA, Traditional Birth Attendant; VPDs, vaccine preventable diseases.

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https://doi.org/10.1016/j.vaccine.2018.02.001
0264-410X/

and Sanderson's review of Demographic and Health Survey (DHS) data from 45 LMICs found that on the whole, African countries had lower levels of timely vaccination than the American WHO region [14].

In Kenya, the Expanded Program on Immunization (EPI) provides six different vaccines comprising 10 antigens for free to all children with one dose of Bacillus-Calmette-Guérin (BCG) and oral polio vaccine (OPV) given at birth. OPV, Pentavalent [Penta, containing five antigens: diphtheria-tetanus-pertussis (DTP), hepatitis B (HBV), and Haemophilus influenzae type b (Hib)], Pneumococcal Conjugate Vaccine (PCV) and Rotavirus are all given at 6 weeks and 10 weeks followed by an additional dose of OPV, Penta and PCV at 14 weeks. Measles containing vaccine (MCV) is given at 9 months of age, along with Yellow Fever vaccinations in two high risk areas: Baringo and Elgeyo Marakwet [2,19,20].

Vaccination coverage overall was relatively high in Kenya, with 2014 DHS data showing 96.7% of children received BCG, 87.1% received MCV1, and 79.4% received all EPI vaccines. The DHS also reviewed vaccinations received by 12 months of age, which showed slightly reduced figures from those aforementioned, however no timeliness analysis was conducted [21]. The few studies that have examined timeliness of vaccination among children have identified persistent delays. Estimating timeliness requires knowing the child's vaccination dates, which are recorded on paper vaccination cards. Calhoun et al. found that in Gem sub-division, Kenya, only 2.2% of children had received all recommended vaccines in a timely manner [13]. Maternal age [20], low maternal education [13,22], place of delivery [22], and household size [13,20], have all been shown to be significantly related to delayed receipt of vaccinations in Kenya.

The Kenyan vaccination schedule relies on repeated co-administration of OPV, Penta, and PCV in order to establish immunity in children and reduce the risk of contracting preventable infectious diseases [23]. However, co-administration depends on health clinics stocking multiple vaccines and the capacity to administer them on the same day, as well as families' acceptance of children receiving multiple injections at the same time. Failure to co-administer vaccines adds considerable burden to caregivers, who must repeatedly visit the health clinic to receive each vaccine. Studies examining the relationship between co-administration of vaccinations and timeliness have not been previously completed for Kenya. The objectives of this study were to (1) estimate the proportion of timely vaccinations in Kenya using a nationally representative sample, (2) estimate the proportion of vaccination doses that were co-administered and (3) assess the relationship between vaccine co-administration and timeliness of vaccine receipt.

2. Methods

2.1. Study population

The DHS program, funded by USAID, has facilitated more than 300 surveys in over 90 countries and is a widely used, standardized survey producing comparable, nationally representative data on fertility, family planning, maternal and child health, and health systems functioning across the globe [24]. The most recent DHS in Kenya was carried out in 2014 using a two-stage, stratified sampling design. All eight regions in Kenya (Coast, North Eastern, Eastern, Central, Rift Valley, Western, Nyanza, and Nairobi) were included, and 92 sampling strata encompassed all counties including rural and urban areas. The primary sampling units (PSUs) were Census enumeration areas, and were selected with a probability proportional to size methodology using population sizes from the 2009 Census. Within each of the 1612 PSUs, 25 households were selected without replacement. The Kenya National Bureau of Statistics conducted in-person interviews with all eligible women 15–49 years of age in the household about reproductive health, maternal care, immunizations received by her child(ren), and childcare practices from May 2014-October 2014.The Kenya DHS dataset is publically available at http://www.dhsprogram.com.

2.2. Derived variables

The primary outcome was a two-way categorization of timely and untimely vaccinations relative to the vaccination milestones of birth, 6 weeks, 10 weeks, 14 weeks and 9 months. Age at vaccination was determined by subtracting the birthdate from the vaccination date as indicated on the child's immunization card. Incomplete/partial and negative vaccination dates, i.e. vaccination dates before a child's date of birth, were excluded from analysis. Timely vaccinations were defined by providing a 4 day "early" grace period ahead of the recommended milestone age and a 4 week "late" grace period after the recommended age based on the Kenya EPI schedule, as shown in Table 1. Untimely vaccinations were defined as any vaccines received outside of this interval.

Co-administration of vaccinations was defined as receipt of two separate vaccines, which are recommended to be administered on the same schedule, that are given on the same day and recorded on the vaccination card. If there was no provided date for a vaccine, that vaccine (or multiple vaccines) was excluded (i.e., treated as missing) from the co-administration analysis (though co-administration may have occurred, its occurrence could not be assessed without a recorded date). If one dose was missing date information but the other dose not, it was treated as a vaccination event without co-administration. Birth setting was determined by combining assistance at birth and place of delivery, and categorizing into five categories: public institution, private institution, and non-institutional (home/other) with either a trained attendant (doctor/nurse/midwife), traditional birth attendant (lay community members who assist with childbirth), or no attendant (relative/friend/other/no assistance).

Due to small sample sizes among religious groups represented in the DHS dataset, "No Religion" was collapsed into "Other", leaving the following categories: Protestant/Other Christian, Muslim, Roman Catholic, and Other. Similarly, small sample sizes among some of the 23 Kenyan Ethnic groups represented in the DHS resulted in collapsing Embu, Maasai, Meru, Taita/Taveta, Turkana,

Table 1
Recommended vaccination schedule in Kenya and operational definition of timely vaccinations.

Vaccine[b]	Recommended schedule	Timely vaccination
OPV0, BCG	At birth[a]	Birth – 4 weeks
Penta1, OPV1, PCV1, Rota2	6 wks[a]	(6 wks – 4 days) – 10 wks
Penta2, OPV2, PCV2, Rota2	10 wks[a]	(10 wks – 4 days) – 14 wks
Penta3, OPV3, PCV3	14 wks[a]	(14 wks – 4 days) – 18 wks
Measles	9 mos	(9 mos – 4 days) – 10 mos

[a] We refer to birth doses and 6, 10, and 14 week doses of Penta/Polio vaccines as opportunities for co-administration.
[b] PCV and Rotavirus were omitted from timeliness analysis due to recent introduction into Kenya's EPI.