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COMPARISON OF GOVERNMENT STATISTICS AND DEMOGRAPHIC SURVEILLANCE TO MONITOR MORTALITY IN CHILDREN LESS THAN FIVE YEARS OLD IN RURAL WESTERN KENYA

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Abstract. Estimates of mortality in children less than five years old using government civil registration statistics (passive surveillance) were compared against statistics generated by active demographic surveillance during a randomized controlled trial of permethrin-treated bed nets (ITNs) in western Kenya. Mortality rates were two-fold lower when estimated through civil registration compared with active prospective surveillance (rate ratio [RR] = 0.51, 95% confidence interval [CI] = 0.44–0.59). While civil registration underestimated deaths, particularly in the neonatal period, the age distribution of deaths in children 1–59 months of age was the same as with active surveillance. Seasonal mortality trends were also similar. There was no agreement between cause of death recorded by active and passive surveillance. Verbal autopsy estimated that half of all deaths were associated with malaria and pneumonia, but civil registration markedly under-reported these illnesses; incidence RR (95% CI) = 0.18 (0.14–0.24), and 0.05 (0.03–0.08), respectively, while over-reporting deaths due to measles (RR = 15.5 [95% CI = 7.3–33.2]). Government statistics under-represent mortality, particularly neonatal mortality, in children less than five years of age in rural areas of Kenya. They can provide accurate information on the age-distribution of deaths among children 1–59 months old, and on seasonal trends, but not on disease-specific mortality.

INTRODUCTION

The high burden of infectious diseases in early childhood in sub-Saharan Africa results in one in four to one in five children dying before their fifth birthday.[1,2] Malaria, respiratory disease, diarrhea, anemia, and increasingly infection with human immunodeficiency virus (HIV) contribute heavily to this burden. Recent international initiatives to reduce this burden include Roll Back Malaria, the Global AIDS Program Initiative, and the Global Alliance for Vaccines and Immunizations. Roll Back Malaria has pledged to decrease the malaria burden by half by 2010, necessitating access to child mortality data before and during implementation of malaria control interventions.[3] Measurement of the impact of interventions, particularly on child survival at the periphery of the health care system, is difficult. Previous studies have shown that some 90% of deaths among children in rural areas occur at home.[4] Thus, surveillance through hospitals can misrepresent the burden of fatal disease occurring in rural communities. Child mortality in rural areas can be more accurately measured through demographic surveillance systems, developed for community-based research studies.[5] Maintaining a demographic surveillance system is expensive and is primarily used to monitor selected populations during evaluation of specific interventions. The use of a demographic surveillance system for routine reporting of deaths exceeds the health budget of many countries. To evaluate large-scale interventions, national programs may need to include mortality estimates generated by routine surveillance systems. A previous study on the coast of Kenya reported that civil registration of child deaths detected only 30% of all deaths.[6] Since then, the Kenyan government has strengthened the surveillance system by upgrading the death registration forms and improving their distribution (Principal Registrar, personal communication).

During a randomized controlled trial of permethrin-treated bed nets (ITNs) in rural western Kenya, we compared data from routine government mortality surveillance through civil registration in the study site with those generated from an active demographic surveillance system over the same 12-month period.[7,8] Mortality rates are estimated by attaching national census and local demographic census figures to the passive and active mortality statistics, respectively. Assignment of cause of deaths is also explored in this rural population.

METHODS

Study site and population. The study was implemented in Rarieda Division, locally known as Asembo, an area of 200 km^2 with a population of approximately 55,000 living in 79 villages in western Kenya. The study population was under active demographic surveillance established for monitoring the impact of ITNs on child morbidity and mortality. More detailed information on the population, study area, and methods of evaluation for the randomized controlled trial on ITNs are presented elsewhere.[7,8] The population living in the area is mainly Luo, who live as subsistence farmers in highly dispersed family compounds surrounded by their fields.[9] Past studies have shown that morbidity and mortality in children less than five years old is high, with an infant mortality rate of 109/1,000 in the late 1980s that increased to 176/1,000 in the early 1990s.[2,10] Cause of death in this area is poorly defined, but has been associated with malaria, HIV, and anemia.[2,10–12]

Passive surveillance. In Kenya, it is a legal requirement that all deaths be notified as part of the civil registration process (Figure 1). A death registration form is completed in duplicate at the local administrative office, and a burial permit is then issued to the bereaved family. Death registration forms and their copies are collated and sent to the district registrar office of births and deaths each month. Forms are then collated by month of reporting at the district registrar office. In

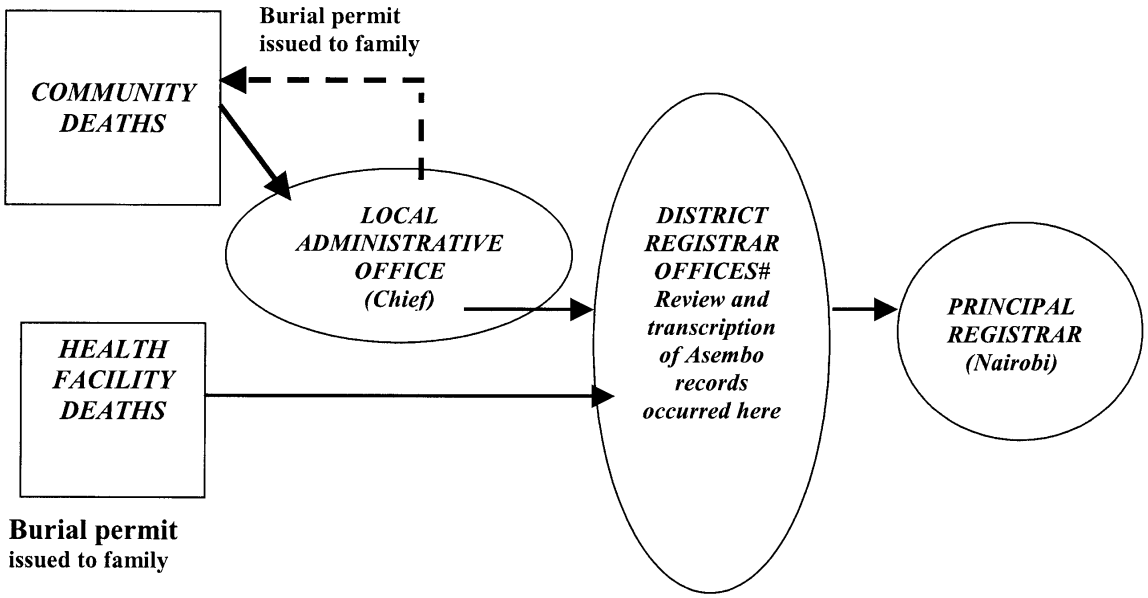

FIGURE 1. Flow of information on deaths through civil registration in Kenya. #District Registrar of Births and Deaths located at district offices in Siaya and Bondo towns.

any death that occurs in a health facility, the attending medical officer completes a burial permit and a death notification form. Similarly, the permit for burial is issued to the family and both the original and duplicate copy of death registration forms are forwarded to the registrar's office. The burial permit is issued to the family free of charge if the death is reported within six months of the event, the time limit legally allowed for reporting. The government imposes fines for late reporting or failure to report deaths although, in practice, these penalties are not enforced.

From July 1998, a manual search of all civil registration forms was conducted each month at the two district administrative offices of the Registrar of Births and Deaths located in Siaya and Bondo. Notification forms of deceased children less than five years old who lived in the study site and who died between January 1996 and December 1998 were transcribed onto study forms by project staff. Cause of death on the death registration form is defined as natural (e.g., infectious disease), or unnatural (e.g., trauma, accident). For natural causes, 15 common illnesses are listed, of which one may be ticked. In addition, there is an open line for "other, specify." For unnatural causes, involvement of the police or a magistrate is mandatory. Information abstracted from the notification forms included the child's full name, age, sex, date of death, place of residence, and cause of death. The study period was set as April 1, 1997 to March 31, 1998.

Active surveillance. In 1996, a demographic surveillance system was established in Asembo to actively monitor morbidity and mortality of children during the randomized controlled trial. Child mortality was monitored through biannual household census and by weekly vital registration. A summary description of the methods used to estimate deaths in the demographic surveillance system site is presented elsewhere.[8] A census was conducted biannually through house-to-house visits made by local staff (mostly trained traditional birth attendants) who recorded onto a standard questionnaire the names and ages of all members of the household, in- and out-migrations, and names and dates of all births and deaths. After the first census, field staff used pre-printed forms with the names of all persons present in each household at the previous census to assist in data collection. Vital registration was a complementary mortality surveillance method used to continuously gather information on child deaths. Traditional birth attendants (usually the same persons who conducted bi-annual census) living in their own villages completed a report form on all deaths in their village in the previous week. The report form was designed to capture the same data as a census. Forms were forwarded to the project sector office for review by the vital event monitoring team.

Vital event monitoring, an adaptation of verbal autopsy,[13] was conducted to verify each reported death by interviewing the parents or guardians of the deceased child in their home using a standard questionnaire within 12 weeks of the death. During follow-up, the name, dates of birth and death, and place of residence of the child, the chronology of symptoms leading to the child's death, and events occurring at the time of deaths were documented. Deaths of children living in Asembo recorded to be less than five years of age and reported to have died between April 1997 and March 1998 were included in the analysis. Duplicates from vital registration and census were identified after data entry by selecting the report closest to the time of death as the most accurate. Cause of death was defined by verbal autopsy, following standard methods described elsewhere.[13,14] Three independent clinical officers reviewed the recorded clinical history and symptoms of each child and each allotted up to three causes of death per child. Where causes of death conflicted between clinical officers, cases were reviewed and a consensus reached on the final (up to three) causes of death.

Definitions. Neonatal mortality refers to deaths in infants from the time of birth until one month of age (<1 month). Under-five mortality refers to deaths in children from the time of birth until their fifth birthday (<60 months), and post-neonatal under-five mortality refers to deaths occurring

in children after one month of age (1–59 months). Post-neonatal infant mortality refers to deaths in children from one month until one year of age. Post-infant mortality refers to deaths of young children from one year of age until their fifth birthday. These definitions were used because the ages of children in the civil registration were recorded in weeks, months, or years, not in days. We assumed any children recorded in civil registration as five years old was more than 59 months of age; thus, they were excluded from analysis. No data were available from this source on stillbirths.

Statistical analysis. Analysis was performed using SPSS software (SPSS for Windows, Release 10.0; SPSS, Inc., Chicago, IL). Confidence intervals for mortality rates and confidence intervals for rate ratios of mortality rates were calculated using the Poisson distribution in StatXact 4.0 for windows (version 4.01; Cytel Software Corp., Cambridge, MA).

Deaths recorded through civil registration were compared with deaths recorded by the two separate active surveillance methods, weekly vital registration and biannual census. It was also compared with the aggregated total number of deaths assessed by either vital registration or census, which was determined after confirmation and follow-up using vital event monitoring. Differences in the age distribution of deaths and the proportions of deaths by month were determined using the Pearson chi-square statistic in cross-tabulations. Two-sided P values <0.05 were considered statistically significant. A comparison of the age and month distributions of deaths was also done by plotting the absolute number and the proportion of deaths by age category and by month for the passive against active surveillance methods. R^2 values were estimated using weighted linear regression, which included an intercept, with the number of observations per age or month group as the weight variable. Mortality rates and 95% confidence intervals (CIs) were calculated using national census data (1999) for Asembo as the denominator for civil registration deaths, and the biannual census obtained through the local demographic surveillance system (November 1997) for Asembo (i.e., the census closest to the mid-point of the 12-month study) as the denominator for deaths determined through active surveillance. The proportion of all deaths attributed to a given cause in civil registration records (which allowed only a single cause to be given) was compared with the proportion of child deaths allocated the same cause by verbal autopsy. In the latter, verbal autopsy could distinguish up to three causes of death per child, without designation of a 'prime cause'. Proportions were calculated using total child deaths, including those with missing observations for cause of death as the denominator. Deaths in civil registration records were compared with those verified through active surveillance. Matches were defined if the child's record in both systems had the same full name, date of death (same month/year), sex, and place of residence. Using StatXact, we calculated kappa coefficients and 95% CIs using these matched cases to assess the observed agreement of causality between civil registration and verbal autopsy. An attempt to link ITN status to civil registration records, with the intention of assessing the efficiency of civil registration to monitor ITN efficacy, was abandoned because civil registration records did not routinely document village of residence of the deceased child.

Ethical clearance and informed consent. The bed net trial was approved by the institutional review boards of the Kenya Medical Research Institute (Nairobi, Kenya) and by the Centers for Disease Control and Prevention (Atlanta, GA). Bereaved parents were verbally instructed on the purpose of vital event monitoring and signed written approval prior to interview.

RESULTS

For the year April 1997 to March 1998, civil registration recorded 263 deaths (47.1% males) in children less than five years old years from Asembo. More than three-fourths of all deaths were reported within three months of the event, with only 5% reported after the six-month legal stipulation. Of the 263 deaths recorded, 249 (94.7%) were community deaths and 14 (5.3%) were deaths occurring while the child was an in-patient at a health facility. Of the 14 facility deaths, eight occurred in the local mission hospital in Asembo and the remainder occurred in district hospitals within a 50-km radius of Asembo. Over the same study year, the two active surveillance methods, weekly vital registration and biannual census, separately detected 459 and 472 deaths, respectively. Verification of all actively identified deaths through vital event monitoring defined 518 under-five deaths in Asembo, of which 455 (87.8%) died in the community, 45 (8.7%) in a health facility, and 18 (3%) in other, undefined locations. Six percent of the community deaths were children who died on their way to, or from, a health facility.

Mortality trends. Using the under-five population of 8,035 children estimated from the household census conducted through the demographic surveillance system in November 1997, we determined that mortality rates were 58.7 (95% CI = 53.6–64.3), 57.1 (52.0–62.6), and 64.5 (59.0–70.3) per 1,000 child-years based on biannual census, vital registration, and vital event monitoring, respectively. The under-five year mortality rate using the 263 deaths reported by civil registration and a population of 8,035 children was 32.7 (28.9–36.9), thus half of the estimate obtained by vital event monitoring (rate ratio = 0.51, 95% CI = 0.44–0.59). The civil registration mortality rate was also calculated using the under-five population based on the closest national census, conducted in 1999 (Central Bureau of Statistics, 2000). This estimated that 9,612 children less than five years of age reside in Asembo. Based on this figure, the crude under-five mortality rate defined solely using government statistics was 27.4 (95% CI = 24.2–30.9)/1,000 per year, or 0.42 (95% CI = 0.37–0.49) of the estimate using vital event monitoring.

Stratification by age categories showed that an equal proportion of deaths in each age group was under-reported by civil registration (Figure 2), but that neonatal deaths were significantly under-reported compared with other ages (Figures 2 and 3). In civil registration, only 4.6% of under-five deaths were neonatal deaths compared with 13.1% by vital registration ($P < 0.0001$) and 11.7% through census ($P = 0.001$). However, the proportion of post-neonatal and post-infant deaths reported were similar between the passive and active surveillance methods (Figure 3). Thus, while the absolute number of deaths by age category was consistently under-reported, particularly neonatal deaths, the overall age distribution of deaths of children 1–59 months old was similar.

Seasonal reporting of deaths in both passive and active surveillance were strongly correlated (civil registration versus

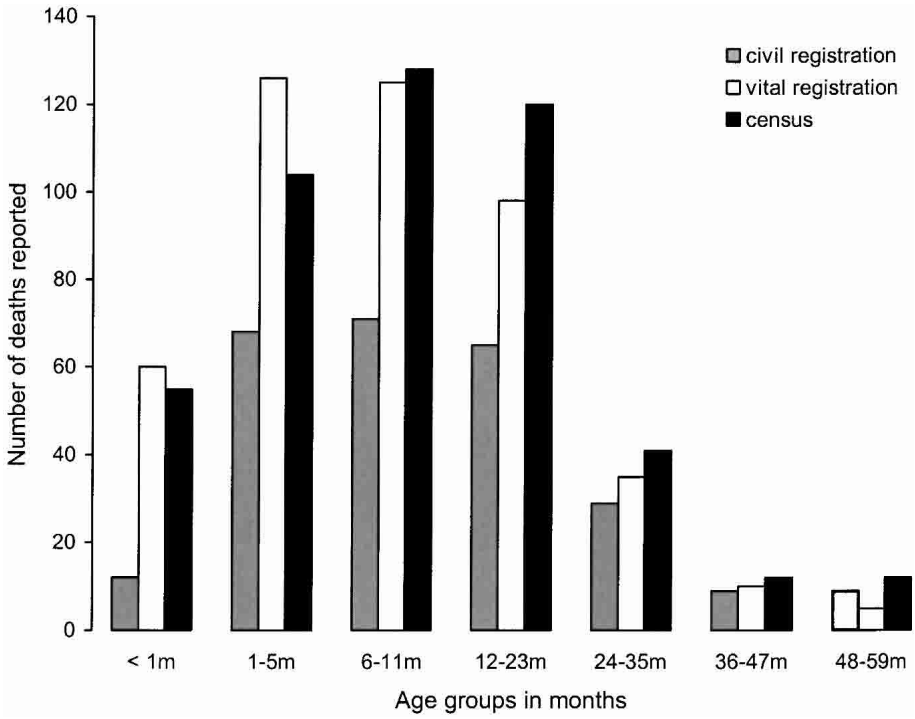

FIGURE 2. Comparison of absolute numbers of deaths by age at death detected through passive and active surveillance methods in Asembo, Kenya, April 1, 1997 to March 31, 1998.

vital event monitoring, $R^2 = 0.80$) and showed similar marked seasonal mortality trends (Figures 3 and 4). Civil registration identified the same peaks (May–August 1997), and troughs (April and the third quarter of 1997) as active surveillance. The period May–August constituted 45% (vital event monitoring) and 51% (civil registration) of the total annual deaths in all surveillance systems ($P = 0.32$). Comparison of the distribution of deaths by month by cross-tabulation also showed no significant differences between civil registration and census ($P = 0.55$), vital registration ($P = 0.19$), or vital event monitoring ($P = 0.8$).

Cause of death. Cause of death was recorded in 258 (98%) of the 263 deaths reported through civil registration, of which 255 were defined within the stated 15 illness categories, and three 'other' were recorded as cardiac arrest. The latter three were part of the 12 in-patient deaths, the remainder of which were recorded as anemia (three deaths), and one each from malaria, fever, pneumonia, sepsis, cholera, and 'undefined'. A comparison of perceived causes of death was made between civil registration and verbal autopsies of children 1–59 months old (Table 1). For community deaths, civil registration allowed one cause of death per child as opposed to three for health facility deaths, although in the latter case only one cause was indicated for deaths during the period the study. Verbal autopsy used in active surveillance provided up to three final causes per child, resulting in 857 causes for 462 of the 463 deaths. In civil registration, malaria, pneumonia, and anemia were reported in 23%, 6%, and 2% of deaths, respectively. More than half of all deaths were reportedly due to measles. Conversely, verbal autopsy attributed malaria and pneumonia to 57% and 56% of all child deaths, anemia and dehydration each to 19% of deaths, and measles to 1.5% of deaths.

Of the 263 deaths recorded through civil registration, 50 cases matched with deaths recorded from active surveillance for all criteria (name, sex, residence, date of death), suggesting they were identical children. The value of kappa coefficients for each of the causes of death was less than 0.10 for all observations, with malaria the highest at 0.097 (95% CI = –0.11–0.28). All other CIs also overlapped with zero, indicating no correlation in reported causes of death between passive and active surveillance.

DISCUSSION

Accurate estimation of child deaths in rural areas is a challenge of increasing relevance to public health programs faced with the need to prioritize limited resources to care for those at highest risk. Use of hospital-based estimates of disease burden to represent disease patterns in surrounding rural communities can be flawed. Malaria and HIV programs require community-based (rural) estimates of child mortality, particularly where distribution patterns may differ greatly from urban environments.

In this paper, we present a comparison of mortality estimates of deaths in western Kenya between expensive but accurate measurement through a demographic surveillance system and relatively cheap, passively gathered statistics obtained through routine government surveillance. This study suggests that passive surveillance may offer comparable data on age-specific and seasonal patterns of child deaths in this rural African setting. Despite significant under-reporting of neonatal deaths, the overall age distribution of deaths in children 1–59 months old was very similar between the systems. These systems estimate that between 82% and 90% of under-

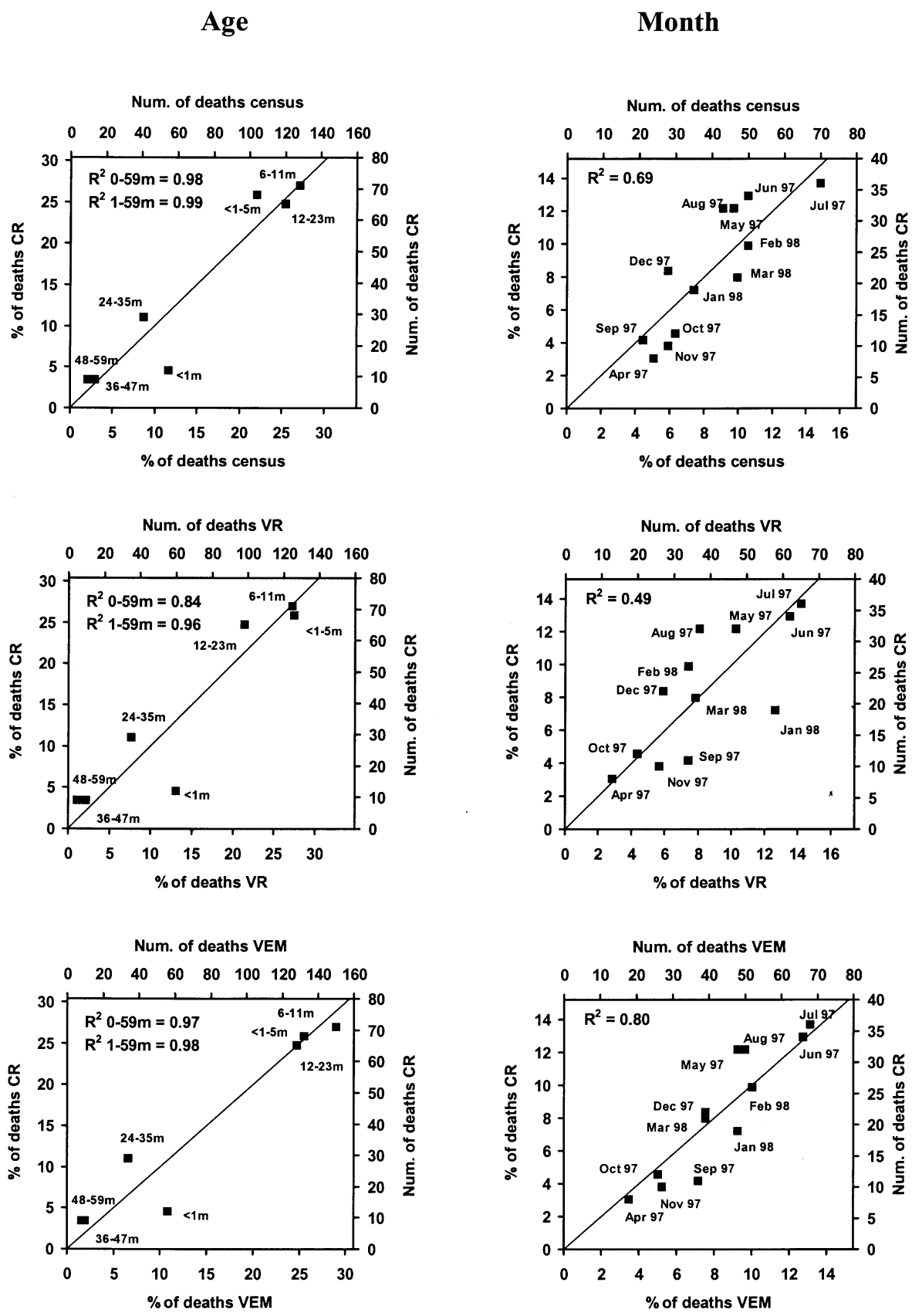

FIGURE 3. Correlation between civil registration (CR) and census (**upper graphs**), and vital registration (VR) (**middle graphs**), and vital event monitoring (VEM) (**lower graphs**) for the age and month distribution of deaths in children < 60 months (m) of age in Kenya. Each right y-axis and upper x-axis represents the absolute number (Num.) of deaths, each left y-axis (y_2) and lower x-axis (x_2) represent the proportion of recorded deaths with that surveillance method. For example, in the 12-month observation period, 68 of the 518 deaths (13.1%) recorded with VEM and 36 of the 263 deaths (14.1%) recorded with CR occurred in July 1997 (**bottom right graph**). The cumulative proportion of deaths for each surveillance method is always 100%. The diagonal lines represent reference regression lines with a slope of 1 and no intercept of the proportions of deaths from two surveillance methods ($y_2 = 1x_2$).

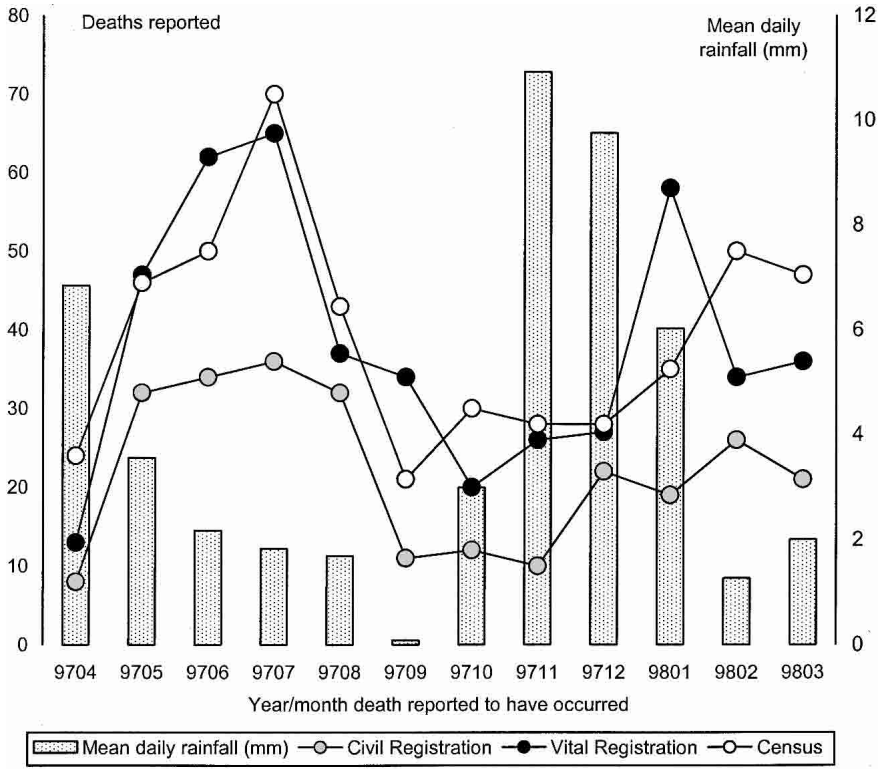

FIGURE 4. Seasonal mortality trends in Asembo, Kenya, estimated through passive and active surveillance, with a bimodal rainfall pattern.

five deaths occur in children less than 24 months of age. In a separate study of a birth cohort followed actively between 1992 and 1996 in Asembo Bay, 88% of deaths in children less than five years old were in those less than 24 months of age.[2] Cross-sectional surveys conducted in the same study period estimated that 73% of children less than five years of age with severe anemia (hemoglobin level < 7 g/dL) were less than two years old (ter Kuile FO, unpublished data). Seasonal patterns in child mortality were striking. In both passive and active systems, each reported just less than half of the total annual child deaths within the four-month period of May–August following the long rainy season. Reporting of sick child visits to peripheral health facilities shows the same trend, with a shorter time lapse between peak rainfall and illness episode.[15] Both passive and active surveillance systems confirmed the results of previous studies from other parts of Africa, which estimated that more than 90% of under-five child deaths occur within the home.[4] In addition, active surveillance esti-

TABLE 1

Comparison of causes of child (1–59 months old) deaths detected by active and passive surveillance*

Cause of death	Passive (civil registration)		Active (verbal autopsy)		Passive/active rate ratio (95% CI)
	Number of deaths with cause	Mortality rate/1,000	Number of deaths with cause	Mortality rate/1,000	
Malaria†	57	5.9	264	32.9	0.18 (0.14–0.24)
Pneumonia‡	14	1.5	258	32.1	0.05 (0.03–0.08)
Dehydration	0	–	90	11.2	–
Anemia	5	0.5	89	11.1	0.05 (0.02–0.12)
Meningitis	0	–	40	5.0	–
Diarrhea	11	1.1	32	4.0	0.29 (0.14–0.57)
Malnutrition	11	1.1	28	3.5	0.33 (0.16–0.66)
Fever	4	0.4	14	1.7	0.24 (0.08–0.73)
TB	2	0.2	10	1.2	0.17 (0.04–0.76)
Measles	130	13.5	7	0.9	15.52 (7.26–33.21)
HIV	0	–	4	0.5	–
Trauma	0	–	4	0.5	–
Other	11	–	18	–	–
Total causes	246		857		
Total deaths	246		462		

* Neonatal deaths excluded (civil registration [CR] = 12 and verbal autopsy [VA] = 56). Total deaths (1–59 m): CR = 251, cause missing for 5; VA = 463, cause missing for 1. In VA, 857 causes of death were allotted to 462 deceased children. In CR, only one cause of death was given in the burial records for 246 deceased children. Diarrhea/gastroenteritis VA includes dysentery (14), cholera (1); CR includes cholera (2). Denominators for active surveillance were based on the demographic surveillance system census population of November 1997 (8,035); those for passive surveillance were based on the 1999 national census (9,612). TB = tuberculosis; HIV = human immunodeficiency virus.

† Includes cerebral malaria (VA = 1 and CR = 1).

‡ Cases in CR include cough (2) and respiratory distress (2).

mated that an additional 6% of deaths occurred in children who died on their way to, or from, a health facility.

In addition to the study of civil registration records evaluated from Asembo, we also reviewed the civil registration records of 1,382 deaths in children less than five years old living in four divisions (Bondo, Madiany, Yala, and Wagai) contiguous to Asembo over the same 12-month period. These Divisions lay north, northwest, and west of the main study area, and had a population of 276,000 in an area of 1,017.3 km^2. Data from these sites were consistent with those generated from Asembo in terms of the proportion of deaths by age and seasonal mortality trends in association with rainfall. Thus, passive surveillance in this area (and not specific alone to the study site) may contribute useful epidemiologic data on age-specific and seasonal mortality trends in children less than five years old in these rural areas.

Passive mortality surveillance clearly under-represented the true burden of deaths in the study area. The reported under-five mortality rate was 32.7 (95% CI = 28.9–36.9) per 1,000 child-years, half that estimated from active surveillance. Nevertheless, this rate compares favorably with the under-five mortality rate estimated in the Demographic and Health Survey of 21/1,000 per year,[16] the rate quoted internationally.[17] It is also an improvement on mortality ascertainment reported in a previous study on the coast of Kenya, in which civil registration identified 34% of under-five child deaths.[6] Passive surveillance was particularly poor at determining neonatal mortality because it provided a severely underestimated rate of 6/1,000 compared with rates of 27 and 30/1,000 estimated via vital registration and census, and 32/1,000 detected in the separate longitudinal follow-up of a mother-child birth cohort in Asembo.[2] Reasons for poor reporting of neonatal deaths through civil registration were not explored, but probably relate to Luo funeral customs.[9] Older children have public burials that attract community attention, whereas newborns are buried with little public ceremony, decreasing the perceived need to report such deaths to the authorities.

Definition of cause of death detected with passive surveillance was compared with cause determined by the verbal autopsy technique. This comparison likely masks the inaccuracy of cause determined by civil registration because verbal autopsy itself is recognized to be an imperfect method, particularly in areas with holoendemic malaria.[14] Verbal autopsy best identifies causes of death with distinctive features, not found in other causes of death, such as injuries and measles. With approximately 80% of children less than five years old parasitemic at any time,[18] many deaths are characterized by vague symptoms and signs that overlap with malaria, pneumonia, diarrhea, and HIV, and in the presence of persistent parasitemia, it is difficult to differentiate specific causes of death based only on observed symptoms prior to death. Deaths indirectly associated with malaria, such as anemia, are under-represented. The results imply that the lay reporters' knowledge on causes of death is still poor, particularly with regard to measles. Measles outbreaks were responsible for more deaths than malaria in the early 1980s in Saradidi, a part of Asembo.[19] Verbal autopsy determined that less than 2% of deaths in the current study had symptoms compatible with measles. Caregivers continue to perceive measles as a major cause of death, regardless of childhood vaccination programs. This highlights an important limitation of passive surveillance systems; their effectiveness to detect disease-specific trends in mortality will remain severely compromised when parents or guardians are required to determine the cause of death.

Is there a role for passive surveillance systems that sufficiently monitor seasonal and age-specific trends in all-cause mortality over time but insufficiently address cause of death? The goal of Roll Back Malaria is to reduce malaria mortality by half by the year 2010.[3] If the majority of malaria-associated deaths occur in children, most of whom die in rural areas of sub-Saharan Africa, it is difficult to envisage how, even within demographic surveillance sites, specific deaths can be accurately attributed to malaria. This becomes more apparent with the HIV pandemic. Estimates of HIV-associated child mortality in rural areas are difficult to extrapolate because of an absence of HIV testing, and no robust case definition adequate for an outpatient setting. Modeling has been used to determine the proportion of deaths that are likely to be HIV-related.[12] Kenya is included among seven countries of sub-Saharan Africa that account for 60% of all HIV-attributable child deaths. In our study site, with the seroprevalence rate in pregnant women estimated to be 14% in the mid-1990s (Centers for Disease Control and Prevention, unpublished data), we estimate that one-fifth of child deaths may have been attributed to HIV infection.[8] With the overlap in symptoms, it will be difficult to ascribe cause of death to either malaria or HIV in rural areas with a high prevalence of both diseases.

At the outset of this study, we had envisaged that civil registration might offer an opportunity to monitor the impact of ITNs on child mortality. As with the active surveillance,[20] we planned to use reported village of residence of the child to assign randomization group. However, when we evaluated civil registration records, it was found that while the majority recorded the location or sub-location of residence, less than 40% had accurately recorded their village of residence. This limitation will prevent assessment of the effectiveness of any village-based control intervention, but will not hamper studies involving interventions with larger randomization units.

We conclude that mortality statistics routinely generated through civil registration, once validated to establish quality and internal consistency over time, may contribute usefully but not solely to an evaluation of the effect of major disease control programs on all-cause child mortality in rural areas of Kenya. We recommend that routine mortality surveillance systems in other countries of sub-Saharan Africa also be examined.

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