HEALTH & DEMOGRAPHIC SURVEILLANCE SYSTEM PROFILE

Profile: The KEMRI/CDC Health and Demographic Surveillance System—Western Kenya

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The KEMRI/Centers for Disease Control and Prevention (CDC) Health and Demographic Surveillance System (HDSS) is located in Rarieda, Siaya and Gem Districts (Siaya County), lying northeast of Lake Victoria in Nyanza Province, western Kenya. The KEMRI/CDC HDSS, with approximately 220 000 inhabitants, has been the foundation for a variety of studies, including evaluations of insecticide-treated bed nets, burden of diarrhoeal disease and tuberculosis, malaria parasitaemia and anaemia, treatment strategies and immunological correlates of malaria infection, and numerous HIV, tuberculosis, malaria and diarrhoeal disease treatment and vaccine efficacy and effectiveness trials for more than a decade. Current studies include operations research to measure the uptake and effectiveness of the programmatic implementation of integrated malaria control strategies, HIV services, newly introduced vaccines and clinical trials. The HDSS provides general demographic and health information (such as population age structure and density, fertility rates, birth and death rates, in- and out-migrations, patterns of health care access and utilization and the local economics of health care) as well as disease- or intervention-specific information. The HDSS also collects verbal autopsy information on all deaths. Studies take advantage of the sampling frame inherent in the HDSS, whether at individual, household/compound or neighbourhood level.

Why was the HDSS set up?

The KEMRI/CDC Health and Demographic Surveillance System (HDSS) was created as part of a large insecticide-treated bed net (ITN) trial in the same area and continued after the trial concluded, after recognizing that the infrastructure established was able to generate multi-disciplinary research data that successfully feeds into policy, with implications at local, national and international levels. The KEMRI/CDC surveillance infrastructure provides longitudinal population-based demographic information, data on the burden of diseases, including those that are the most common causes of morbidity and mortality in Kenya and East Africa and information on access and utilization of health services and generates data on specific outcomes through topic-specific studies. The HDSS also provides a robust sampling frame for epidemiological studies and evaluations of public health interventions.

What does it cover now?

In the initial stages, the objective of the KEMRI/CDC HDSS was tailored around malaria morbidity and mortality studies and interventions, including the evaluation of entomological indicators, and exploratory research on other diseases. With time, the KEMRI/CDC HDSS has expanded its mandate and has grown into a comprehensive platform used for a wide range of disease-specific observational studies and clinical trials. In 2009, KEMRI/CDC enhanced disease burden (influenza and rotavirus) surveillance in preparation for vaccine introduction, by collecting naso- and oropharyngeal swabs and stool samples in three outpatient and two inpatient health facilities within the study area. Currently (as of 2011), KEMRI/CDC researchers are evaluating the safety and impact of introduction of the 10-valent pneumococcal conjugate vaccine into the national childhood vaccination programme: developing and validating a pharmacovigilance system to assess the safety of anti-malarial drug exposure in early pregnancy, investigating the impact of sending reminders by short message service and providing transport reimbursement to mothers for the timely uptake of childhood vaccination, conducting a pilot to evaluate the validity of verbal autopsy versus physical autopsy for respiratory disease, evaluating the social and financial costs of maternal mortality and evaluating sexual and reproductive health behaviours and the uptake and impact of the increase in HIV care and treatment services available. We are currently conducting, or have already completed, key treatment and vaccine clinical trials in our HDSS. These include Phase 3 trials of intermittent presumptive treatment of malaria in infants and pregnant women (one in HIV-infected pregnant women), a Phase 3 trial of the Merck Rotateq® rotavirus vaccine (Merck & Co., Inc.), an HIV treatment trial among discordant couples, two Phase 3 trials of the RTS,S malaria vaccine (one among HIV-infected infants) and a Phase 2B trial of a tuberculosis (TB) vaccine, among others. Through the HDSS, KEMRI/CDC researchers conduct comprehensive community engagement activities and meet regularly with the key stakeholders in the area, including a set of Community Advisory Boards, chiefs, teachers, health facility clinicians, district medical and educational officers and politicians to discuss planned studies, consider unmet needs and disseminate results. Through a comprehensive communications department linked to the HDSS, KEMRI/CDC researchers also engage the community and key stakeholders through print, radio and television media. The KEMRI/CDC HDSS has been a member of the International Network for the Demographic Evaluation of Populations and Their Health in Developing Countries (INDEPTH) since 2001.

Where is the HDSS area?

The study site is located in Rarieda, Siaya and Gem Districts in Siaya County, lying northeast of Lake Victoria in Nyanza Province, western Kenya, at a distance of ∼40 km from the offices and laboratories of the KEMRI/CDC Research and Public Health Collaboration (Figure 1). These are contiguous administrative areas situated at −0.220S–0.230N latitude, 34.530W–34.280E longitude. Rainfall is seasonal with the heaviest 'long' rains usually occurring from March through May and 'short' rains falling between October and December with bimodal peaks in April–May and November–December. Average temperature ranges between 17°C and 35°C at a mean altitude of approximately 1070 metres above sea level. Most of the houses are built of mud, cement or brick with roofs of iron sheets or thatched grass. Agricultural fields tend to lie adjacent to the compounds. Malaria is endemic in this area, with transmission occurring throughout the year; HIV and TB prevalence are some of the highest in the country. There are 36 health facilities in the HDSS, including one district hospital, two privately owned hospitals, 11 health centres and 22 dispensaries (Figure 2). The HDSS has, through collaboration with the Ministry of Health, strengthened health facility-based surveillance within the HDSS, enabling the collection of high quality data from these facilities, with continuous surveillance in two key inpatient facilities and three outpatient facilities.

Who is covered by the HDSS and how often have they been followed up?

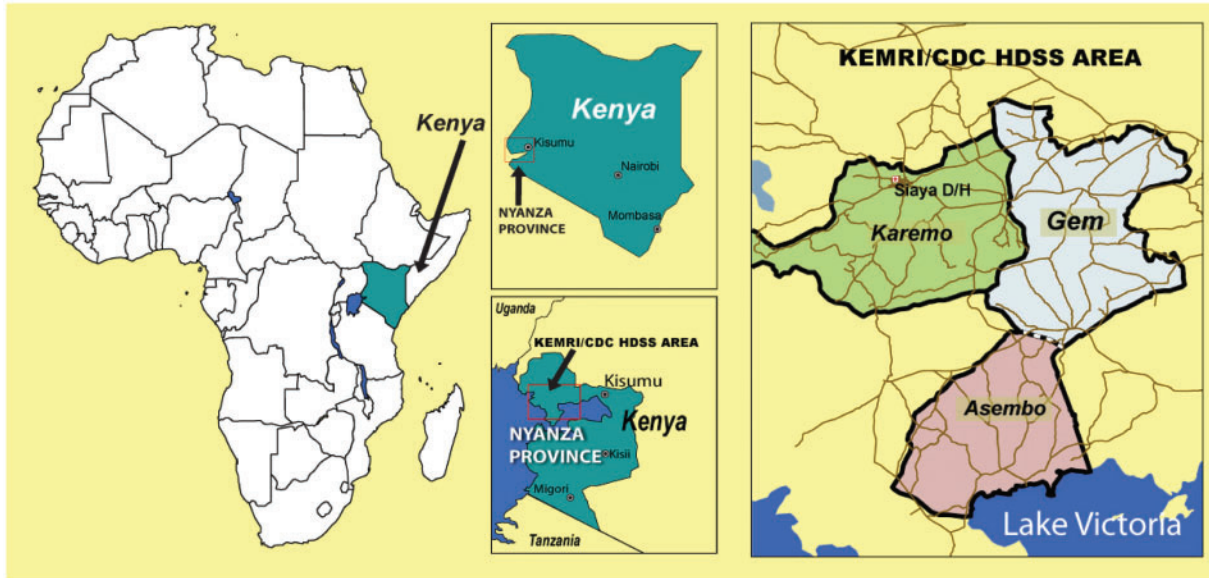The KEMRI/CDC HDSS follows a population of approximately 220 000 individuals; it has a typical
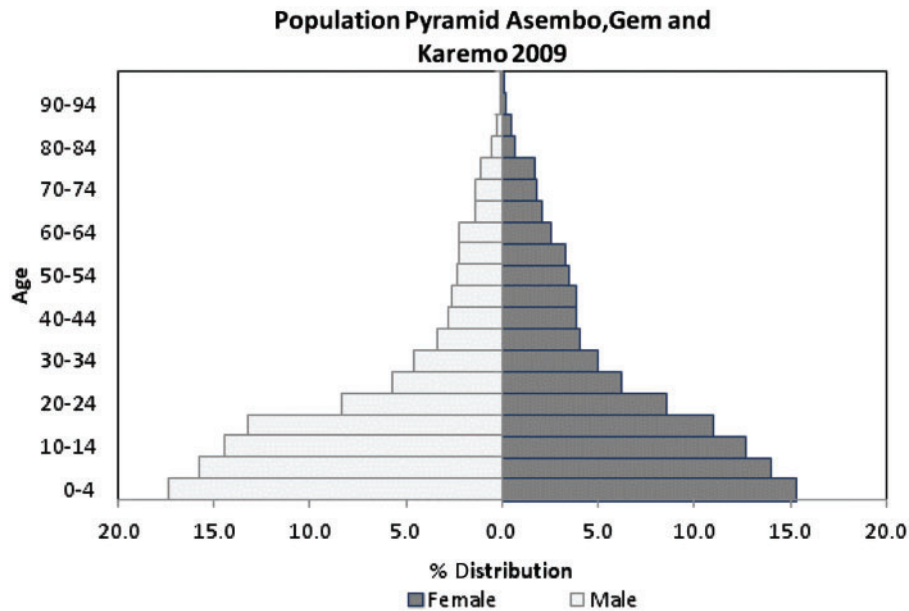
Figure 1 KEMRI/CDC Health and Demographic Surveillance System, Kenya

Figure 2 KEMRI/CDC Health and Demographic Surveillance System, Health Facilities Map

Population Pyramid Asembo, Gem and Karemo 2009

Figure 3 Population Pyramid Asembo, Gem and Karemo, KEMRI/CDC HDSS, 2009

rural African population profile with 44.6% of the population under 15 years of age and only 5.5% over 65 years of age (Figure 3). The population is predominantly rural and culturally homogeneous; over 95% people are members of the Luo ethnic community and live through subsistence farming and local trading. These residents (defined as those residing in the study area for at least four consecutive months or infants born to residents) live in 385 villages spread over 700 km², in 54 869 households and 39 009 compounds. The HDSS population is visited every 4 months: January–April, May–August and September–December.

Continuous health facility surveillance for persons 12 years of age and under and for selected adults started in 2002 in 12 health facilities; after 2010, due to reduced funding for the HDSS, KEMRI/CDC has been present in two inpatient facilities and three outpatient health facilities in the HDSS study area.

What has been measured and how have the HDSS databases been constructed?

During the HDSS data collection 'rounds', information on births, deaths, pregnancies, migrations, morbidity, parent survival status, immunization for children aged under 2 years, educational status, religion, marriage status and ethnicity is collected. At the household level, house details and information on ITNs are collected (Table 1). Since 2008, education status of all household members and the household's socio-

economic status have been collected once every 2 years; between 2003 and 2008, these data were collected annually. For all deaths, both residents and non-residents, verbal autopsies are administered to the caretakers of the deceased on average 3 months after death to ascertain the signs and symptoms of the terminal illness relevant for assigning cause of death. In 2006, annual parasitaemia and anaemia surveys were implemented, and in 2007, additional data collection on individual immunization status of children aged <2 years (both at home and in health facilities), self-reported HIV status, care and treatment uptake, marital status/history and familial relationships and routine surveys of ITNs were initiated. Also in 2008, KEMRI/CDC introduced door-to-door home-based HIV counselling and testing throughout the HDSS; the entire adult (aged 13 years or more) population of the HDSS has now been offered HIV testing at least once, with over 85% acceptance. For inpatients at Siaya District Hospital, data are collected on immunization status (aged under 2 years), signs and symptoms of malaria, influenza, acute gastroenteritis and other morbidities, HIV/AIDS testing and diagnostic and treatment information for relating to children aged ⩽12 years and adults who meet criteria for respiratory illness. These data enhance HDSS surveillance as they are linked to each individual's demographic surveillance data using the personal identification numbers and fingerprinting. Specimens/samples are collected for malaria, influenza, rotavirus and HIV surveillance in the selected health facilities, in addition to other specimens that may be collected for specific studies.

Through novel technological innovations, researchers in the KEMRI/CDC HDSS have developed

Table 1 Information collected at compound, household and individual level at each round of the KEMRI/CDC HDSS

Subject	Information
General	Date of visit
Compound	Longitude, latitude
	Locations—houses
	Compound head details :3 names
Household	Household administrator
	Socio-economic status
	Water use and treatment
	ITN ownership and use
	Relationships
	Number of people sleeping in house
Location	House details (construction type)
	Number of rooms and type of floor
	Kitchens
Individuals	Three names
	Date of birth
	Fingerprints
	Mother's details
	Father's details
	Ethnicity
	Gender
	Religion
Residents	Migrations
	Morbidity
	Immunization (under 2 years of age)
	Death
	Education (5–24 years of age)
Deaths	Date of death
	Cause of death (verbal autopsy)
Births	Date of birth
	Mother ID and 3 names
	Gender
	Three names
	Ethnicity and religion
	Father's details
In-migration	Three names
	Mother's details
	Father's details
	Gender
	Date of birth
	Place of origin
	Date of in-migration
	Reason for in-migration
	Information for return migrants
	Education (5–24 years of age)

(continued)

Table 1 Continued

Subject	Information
Out-migration	Destination
	Date of out-migration
	Reason for out-migration
Migration (within area)	Date of trans-migration
	Reason for leaving one compound for another
	Three names
	Original/destination compound
	Date of birth
	Gender
Pregnancy	Date of notification
	Expected date of delivery
	Outcome of delivery: live birth, multiple live birth, stillbirth, miscarriage, maternal death

electronic data collection applications and processing for all aspects of data collection and have improved on data quality and reduced turn-around time of data to information use. In June 2008, data collection using personal digital assistants (HTC Advantage) was initiated, then moved to data collection on netbooks (Mecer Classmate) in September 2011; these are tools that allow for linkage of data between household and health facility records and across studies. Trained community interviewers use an electronic application (developed in Visual Studio.Net) in the PDA/netbook to collect data. Called Mobile Household Registration System (mHRS), it was adapted from the Household Registration System (HRS) and customized for mobile appliances by KEMRI/CDC programmers to facilitate electronic data collection. Household Registration System is a software application used by most HDSS's to host the database for information collected on paper forms and entered via screens.[1] Data collected are stored in Microsoft-SQL databases that have been designed based on the Reference Demographic Surveillance Data Model.[1]

The databases are securely stored in servers within a fire-walled network protected from external unauthorized access. Data files and all linkage processes are password protected and their access is controlled by the database administrator under direction from the HDSS steering committee. In addition to data collected at the rounds, all births, deaths and pregnancies are also identified through a parallel continuous community reporting system; this parallel system helps to improve the capture of these events, in particular, neonatal deaths that may have been missed through the surveillance rounds. After birth, infants immediately receive a temporary code on their

Community interviewer interviewing an HDSS participant

Donation of insecticide treated bed nets to internally displaced persons in the HDSS, following post-election violence in Kenya

immunization card, which is linked to their mother's identification number until they receive their own HDSS unique identification number. For some studies, photograph identification cards supplement numerical identification. Table 1 provides more specific information on data collected and database structure.

Key findings and publications

Each year, since the inception of the HDSS, we have measured and continuously monitored the health and demographic dynamics in this geographically defined population, including birth rates, mortality rates, causes of death, morbidity, migration and socio-economic indicators.[2] Data from the KEMRI/CDC HDSS have played a central role in key public health findings, which have influenced and determined national and international policy.

Findings of malaria research from the KEMRI/CDC HDSS led to a pivotal public health discovery that bed nets reduce community infant mortality by 26%,[3] and that over time, bed net use does not reverse gains in mortality reduction in young children.[4] The KEMRI/CDC HDSS platform has been used to measure low coverage of intermittent preventive treatment of malaria in pregnant women (IPTp)[5] and with the HDSS findings, established an iterative process, working with the Ministry of Health, to implement strategies to improve IPTp coverage, then measure the results of those strategies.[6] Our HDSS served as an important platform to determine that the combination of IPTp and daily iron supplementation for 12 weeks is most effective in the treatment of mild to moderate childhood anaemia[7] and that sickle cell trait protects against all-cause mortality, severe malarial anaemia and high density parasitaemia in an area with intense malaria transmission.[8] Research on the efficacy of IPT for infants in the HDSS has also been performed, and found that the use of long-acting regimens such as SP plus 3 days of artesunate or 3 days of

amodiaquine-artesunate administered at routine immunization visits provided a protective efficacy against clinical malaria of 25.7% [95% confidence interval (CI) 6.3,41.1] and 25.9% (95% CI 6.8, 41.0), respectively, even in the presence of high coverage of ITNs.[9] Alongside the clinical research in the HDSS, entomological indicators are continuously monitored, including the entomological inoculation rate, spatial and temporal dynamics of vectors[10] and changes in the malaria vector composition.[11]

In the field of HIV, KEMRI/CDC is a registered National Institutes of Health clinical research trial site. As part of a prevalence survey among 13–34-year-olds in 2003–04, researchers in the KEMRI/CDC HDSS implemented door-to-door HIV counselling and testing for the first time in western Kenya and reported an overall HIV prevalence of 15.4%, showing also a significant increase in HIV prevalence among female adolescents.[12] In 2008–11, comprehensive door-to-door home-based HIV counselling and testing in the entire HDSS was conducted. More recently, the HDSS platform, in a multi-centre trial, contributed to the discovery of the breakthrough finding that early ART for the HIV-infected member of a discordant couple reduced HIV transmission in the HIV-uninfected partner by 96%.[13]

Researchers in the KEMRI/CDC HDSS also conducted the first TB prevalence survey in Kenya in the HDSS platform, finding a high prevalence of 6 TB cases per 1000 persons, and observing that many TB cases are undetected in this community.[14] This study also allowed the quantification of excess mortality associated with the TB/HIV syndemic in our context.[15]

Key research on enteric pathogens has revealed high anti-microbial resistance in our HDSS area;[16] we maintain continuous diarrhoeal disease surveillance and we are currently participating in a multi-centre case-control study of acute diarrhoea in children 0–59 months of age (Global Enterics Multi-center Study), using the HDSS.[17]

Table 2 Key demographic indicators by year 2003–08, KEMRI/CDC HDSS

Indicator	2003	2004	2005	2006	2007	2008[a]	2008[b]
Infant mortality ratio (no. of infant deaths per 1000 live births)	131.9	124.7	116.2	85.8	76.0	113.3	110.5
Child mortality rate (no. of child {age 1–4 years} deaths per 1000 person years)	32.2	33.6	27.8	24.9	16.5	30.6	28.8
Child mortality ratio (no. of child {age 1–4 years} deaths per 1000 live births)	108.7	118.4	98.6	83.8	58.8	103.8	96.2
Under-five mortality rate (deaths per 1000 person years)	54.8	53.7	47.2	38.5	29.5	48.7	47.1
Under-five mortality ratio (deaths per 1000 live births)	239.5	242.6	214.2	166.6	167.0	212.2	202.8
Maternal mortality ratio (deaths per 100 000 live births)	846.6	838.3	523.7	1002.7	601.9	683.2	628.3
Crude death rate (deaths per 1000 residents)	23.8	23.1	21.5	20.0	15.9	19.5	19.2
Life expectancy at birth (years)	38	38.8	40.8	43.3	46.5	45	44.7
Crude out-migration rate (no. of out-migrations per 1000 person years)	137.5	133.3	123.4	110.8	111	124.1	127.4
Crude in-migration rate (no. of in-migrations per 1000 person years)	129.7	117.1	118	112.1	115	134.6	129.8
Crude birth rate (no. of births per 1000 residents)	37.7	36.1	35.6	36.6	36.8	37.4	37.9
Total fertility rate (no. of children per woman)	5.4	5.2	5.2	5.3	5.3	5.3	5.3

[a]Indicators include Asembo and Gem only.
[b]Indicators include Asembo, Gem and Karemo.
Note: Detailed appendices of the indicators available upon request from the principle investigators of the KEMRI/CDC HDSS are mid-year population, 2008; age-specific in- and out-migration rates 2008; age-specific mortality rates and life expectancy 2008; age-specific fertility rates, 2008.
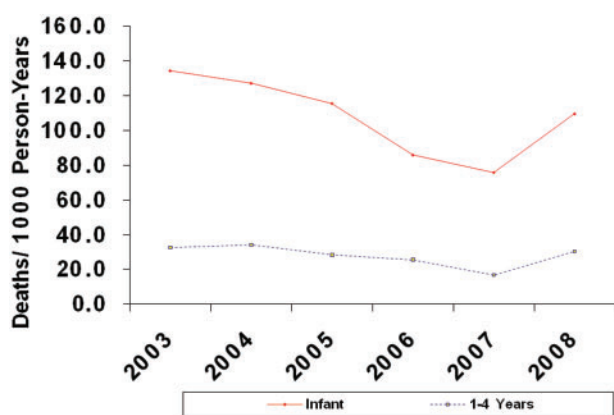

Figure 4 All cause childhood mortality KEMRI/CDC HDSS, 2003–08*. *From: Hamel MJ, Adazu K, Obor D et al. A reversal in reductions of child mortality in western Kenya, 2003-2009. *Am J Trop Med Hyg* **85**:597–605

The KEMRI/CDC HDSS serves as an ideal platform for multi-site clinical trials: in a Phase 3 Merck Rotateq® rotavirus vaccine trial, a vaccine efficacy of 83.4% was measured in Kenya in infants in the first year of life receiving the vaccine as part of routine immunizations;[18] in the Phase 3 RTS,S malaria vaccine trial, an efficacy of 55.8% was measured against clinical malaria in children 5–17 months old.[19]

Finally, with over a decade of comprehensive surveillance data (Table 2), HDSS researchers have identified and reported a worrying reversal in the decline of childhood mortality associated with an increase in clinical and severe malaria prevalence in the community and in health facilities despite high ITN coverage and good anti-malarial drug policy[20] (Figure 4). Lack of stocks of essential anti-malarial drugs (Artemether/lumefantrine), increased malaria transmission, and disruption of services during civil unrest may have contributed to this recorded mortality increase. The HDSS has also facilitated the measurement of a 26% reduction in HIV/TB mortality associated with an increase in HIV service delivery[21] (Figure 5). This evaluation revealed that as the number of facilities offering HIV services expanded from 1 (2003) to 17 (2008), receipt of these services by HIV-positive residents increased from <1% to 29.5%, and anti-retroviral therapy coverage reached 64.0% of adults with CD4 <250. Further, the HDSS platform allowed an investigation of the impact of the movement of internally displaced persons (IDPs) into the HDSS following the post-election violence that occurred as a result of the 2007 controversial presidential elections in Kenya.[22] These data revealed that IDPs aged 15–49 years were 34% more likely to die than HDSS residents, and that more deaths due to HIV were experienced among IDPs than the resident HDSS population (53% vs 25–29%), likely due to disruption in access to medication and services. This evaluation demonstrated the capacity of the surveillance system to measure an unprecedented event and its impact.
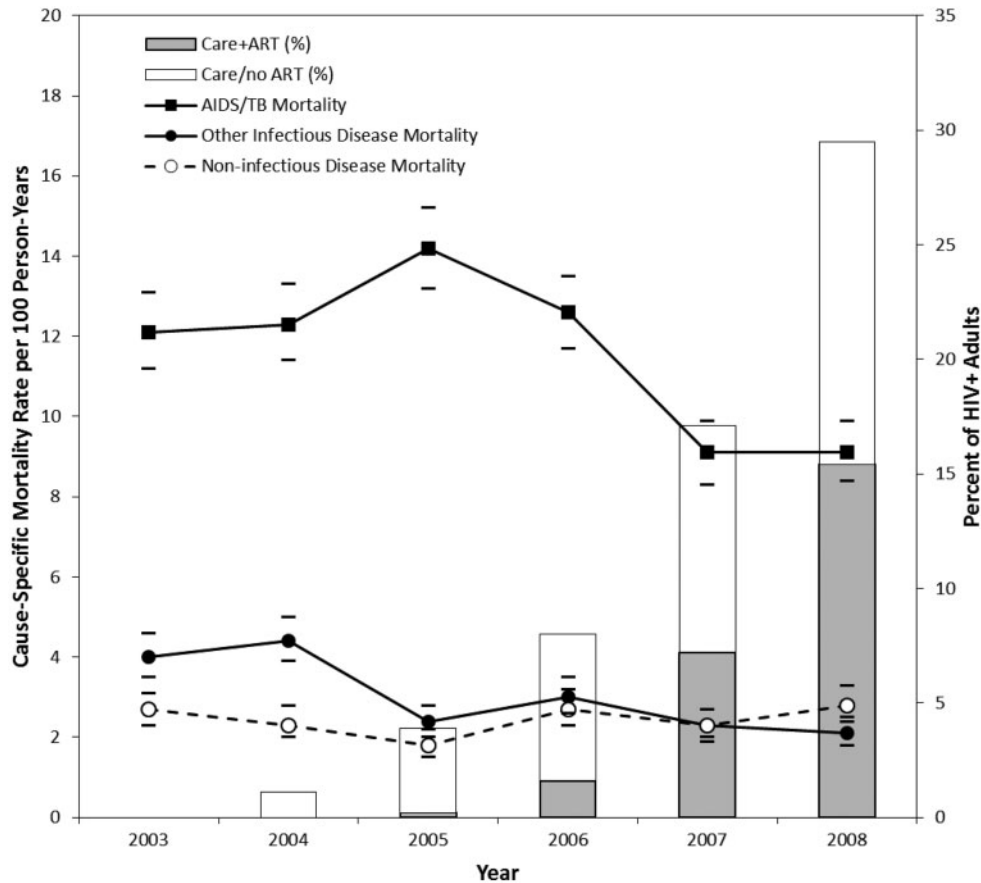
Figure 5 Population cause-specific mortality rates and 95% confidence intervals (lines, y-axis on left), and estimated proportion of HIV-positive patients in care and receiving ART (stacked bars, y-axis on right), by year, KEMRI/CDC HDSS, 2003–08*.   *Source: Gargano JW, Laserson K, Muttai H *et al*. The adult population impact of HIV care and antiretroviral therapy (ART)—Nyanza Province, Kenya, 2003–2008. *AIDS*, Vol. 26, Wolters Kluwer Health, 2012

The KEMRI/CDC HDSS has also facilitated the measurement of cost-effectiveness of interventions[23] and was a pioneer in geocoding households and other geographical features of interest to make spatially oriented information available to all researchers.[24] In addition to being used to establish the community effect of bed nets,[25] the geographical information captured in the HDSS has been used to map childhood mortality[26] and to evaluate the impact of residence distance from a health facility on attendance at that facility.[27]

HDSS data generated longitudinally on maternal mortality, adolescent and young people deaths and trauma are being used for development of future research and public health strategies, with further publications under development.

Future analysis plans

Future plans for the KEMRI/CDC HDSS include evaluating the efficacy and effectiveness of malaria prevention tools, including the RTS,S vaccine,

insecticide-treated durable wall liners, indoor residual spraying in an area with perennial transmission, new malaria in pregnancy drug regimens and strategies and interventions targeting symptomatic and asymptomatic malaria infections. Researchers in the HDSS also plan to continue surveillance of the burden of malaria and anaemia at the health facility and community levels and to expand pharmacovigilance of anti-malarials, other drugs and vaccine introduction. Further, malaria transmission intensity will continue to be measured using entomological inoculation rates in the communities as programmatic vector control interventions are rolled out or expanded. The burden and distribution of HIV/AIDS and TB will continue to be measured, as well as the socio-demographic and behavioural risk factors associated with their acquisition and impact of targeted intervention strategies, including new TB vaccines, treatments and programmes. Surveillance of diarrhoeal diseases and evaluation of a aetiologies as well as anti-microbial resistance will also continue. Critical impact evaluations, such as evaluations of safe water interventions and the effectiveness and impact of rotavirus/other

new vaccine introduction, including influenza, human papillomavirus vaccines and vaccines to prevent *Shigella*, non-typhi *Salmonella*, respiratory syncytial virus and other high-burden pathogens, as they are developed will be a central HDSS activity. Schistosomiasis/geohelminth burden and geographical distribution will be further characterized and the best approaches to mass drug administration and the impact of helminth infections on childhood vaccine efficacy will be evaluated. Research on adolescent health will be expanded, including investigation of school absenteeism, and potential menstrual management solutions, as menarche is reported to be a major reason for missed schooling and potential drop-out among girls,[28] and child well-being. Plans for the future also include building a more comprehensive maternal/child health set of evaluations with an emphasis on a birth cohort (including additional evaluations of orphanhood), descriptive analyses of fertility and the impact of birth spacing, integrated management of pregnancy-related illnesses and evaluation of interventions to reduce maternal mortality (Table 2), and measurement of the burden of non-communicable diseases, in particular birth defects and cervical cancer. HDSS activities will expand to include new investigations of non-communicable diseases risk factors, including measuring tobacco use and alcohol misuse. In combination with several HDSS's in the INDEPTH Network, researchers from the KEMRI/CDC HDSS hope to conduct a large-scale evaluation of the validity of verbal autopsy comparing verbal autopsy results with physical autopsy results in the same individuals, building upon the pilot being performed in 2012 for respiratory disease.

Strengths and weaknesses

The KEMRI/CDC HDSS has faced challenges with respect to linking household and health facility data; however, these challenges have been mitigated by having fingerprinted almost the entire HDSS resident population and continuously updating this database. The KEMRI/CDC HDSS has been challenged by the linking of newborns to their household and clinic data; this was improved through the use of a temporary code on the immunization card given to mothers at the birth of their child and linked to the mother's HDSS unique identification number. The ability to link socio-demographic data collection to the scale-up of both HIV and malaria service delivery provided through the US President's Emergency Plan for AIDS Relief and President's Malaria Initiative initiatives, respectively, has presented a unique opportunity to measure the impact of interventions in the HDSS and also to target services to the pockets of the study population that are not receiving services. Initially, our turn-around time of data was quite slow, as paper forms had to be scanned and checked for quality, which was time-consuming; the move to complete electronic data collection has shortened this considerably, minimized errors, reduced the use of paper and allows for real-time data acquisition and analysis. The HDSS still experiences delays in resolving migrations. As our HDSS serves as the backbone for numerous KEMRI/CDC research activities, it provides a platform where researchers from different disciplines work in the same area, facilitating productive cross-collaboration efforts. The HDSS also serves as a resource centre for fellows, PhD students and masters' students offering experience and data sources needed to develop public health research human resources. Indeed, over this period, KEMRI/CDC has trained/facilitated 15 PhD's, 67 master's, and 44 bachelor degrees, many of which relied upon projects and studies conducted in the HDSS.

Another strength of the KEMRI/CDC HDSS is that the Siaya District Hospital, a major clinical facility, is within the confines of the HDSS, which facilitates linkages between household information and clinical data and allows hospital-based studies and evaluations. Further, although our HDSS started as an INDEPTH site in 2001, the HDSS was initiated in the early 1990s; thus, almost two decades of historical health indicator data are available. Finally, strengths can also translate into weaknesses when numerous opportunities for research enquiry over-extends human capacity and the goodwill of the population; thus population-based research efforts should constantly reference back to the perceived needs of the persons they presume to serve.

Data sharing and collaboration

Researchers in the KEMRI/CDC HDSS welcome internal and external collaborations. It has been especially fruitful to link to other HDSS's through the INDEPTH Network; the standardization of data collection across this network facilitates the ability to combine data from HDSS's and examine rare events and look across differing geo-ecologies. The KEMRI/CDC HDSS shares data with external collaborators through a formal data sharing process. The latter mentioned are the guidelines we use to create a data sharing agreement. Dr Frank Odhiambo (fodhiambo@kemricdc.org) is the point of contact for all data requests.

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KEY MESSAGES

- The KEMRI/CDC HDSS is an established platform, comprising approximately 220 000 residents in western Kenya, who are followed longitudinally, allowing both the health of individuals and populations to be followed over time and the measurement of the cumulative impact of repeated 'events'.

- The KEMRI/CDC HDSS is situated in an area of rural Kenya with some of the worst health indicators and the highest syndrome/aetiology-specific disease burdens in the country including malaria, HIV and TB.

- The KEMRI/CDC HDSS encompasses world-class certified laboratory facilities with rapid response testing, to support clinical field research and allow linkage between clinical and epidemiological data.

- The KEMRI/CDC HDSS has a sub-population under intense fortnightly household surveillance for illness and health-seeking, providing timely clinical outcome data usually only available from in-hospital observational studies.

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