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Table of Contents

Research Articles

Assessing levels and trends of adult mortality in Sub Saharan Africa using INDEPTH health and demographic surveillance systems

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Abstract

There is still a considerable dearth of knowledge regarding adult mortality and premature deaths in Sub-Saharan Africa (SSA). Attempts to measure adult mortality using censuses and cross-sectional surveys rely mainly on indirect techniques that are affected by common biases. The growing number of Health and Demographic Surveillance Systems (HDSSs) offer a medium-term solution to the dearth of knowledge regarding adult mortality and the main causes in Africa. This paper compares adult mortality estimates from 16 HDSSs in nine countries in SSA based on publicly available data on INDEPTHStats. We use Life Table techniques to examine differences in adult mortality trends and to identify mortality clusters and sex differentials. Results reveal distinctive mortality trends for the three regions of Africa with the Southern and Eastern African regions having relatively higher mortality than the West African region.

Key words: Adult mortality, sub Saharan Africa, health and demographic surveillance systems, INDEPTH, burden of disease

Introduction

Mortality levels are key indicators of population health and crucial to prioritize public health and/or effective allocation of resources. According to (Jha, 2012), counting the dead is one of the world's best investments to reduce premature mortality. However, the majority of deaths occurring in Sub Sahara Africa (SSA) are unrecorded. Indeed, data from the UNSD database and World Health Statistics for 2012 (UNSD, 2015) show that coverage of vital events particularly deaths is very low (below levels that can be considered reasonable for analysis), except for South Africa, Egypt, Mauritius and Seychelles where all, or nearly all deaths are captured. As part of the post-MDGs agenda and the UN pledges in pursuit of Sustainable Development Goals (SDGs) includes the generation of better population-development data to ensure 'a world that counts' where 'nobody is left behind' or un(ac)counted. (Data Revolution Group, 2016; UN, 2015).

Over the last two decades, efforts towards monitoring the MDGs have increased the availability of national level data across Africa. In particular, there have been well over 130 censuses conducted between 1985 and 2014 with most countries respecting the recommended 10-year intercensal interval (UNSD, 2015); over 110 Multiple Indicator Cluster Surveys (MICS) conducted in about 44 African countries between 1995 and 2014 (UNICEF, 2016); over 160 Demographic and Health Surveys (ICF Macro International, 2016) conducted in about 45 African countries between 1990 and 2014; and over 27 Living Standard Measurement Study (LSMS) surveys conducted in 11 African countries (World Bank, 2015). A number of countries relatively well covered by these sources which have been very effective and extremely useful in providing various demographic indicators. However, data deficiency – coverage, completeness, timeliness and regularity – in SSA remains a major problem within the current efforts at setting public health priorities and tracking of progress towards national and global goals from the MDGs to the SDGs.

Even with the increased availability of data in SSA, there is still a considerable dearth of knowledge regarding adult mortality and premature deaths. With very few countries able to maintain reasonably functional civil registration and vital statistics (CRVS), knowledge of adult premature mortality remains somewhat scanty. For most of the aforementioned national surveys, data for estimation of adult mortality are mainly based on sibling survival histories that are affected by reporting errors (Helleringer, *et al.*, 2014; Masquelier, 2013). This data deficiency constraint is further compounded by a methodological challenge since the adult mortality measurement approach is not as robust as the birth histories approach widely used for childhood mortality analysis (Hill, Choi and Timaeus, 2005; Hill and Pebley, 1989; Preston, Heuveline and Guillot, 2001). Moreover, adult mortality is generally a rather infrequent event even in populations with high mortality (Preston, Heuveline and Guillot, 2001).

National censuses which cover the whole population collect information on the deaths that occurred over the 12 months preceding the census date in each household; so the total number of deaths identified is important. These data have long been considered of low quality and as a consequence are rarely used. A recent evaluation study conducted in Senegal comparing and matching national census data with HDSS data showed that the declarations on the deaths over the last 12 months in the household were of reasonable quality for adult deaths and could be used to estimate adult mortality (Masquelier, *et al.*, 2016). Another study conducted in Ghana show some level of consistency between the Census and HDSS data relative to age-sex distribution, crude death rate and mortality pattern (Wak, *et al.*, 2017). Nonetheless, efforts to measure adult mortality using censuses and cross-sectional surveys rely mainly on indirect techniques that are affected by common biases or by the likelihood that assumptions underlying the development of these techniques no longer hold in contemporary LMICs.

This, therefore, calls for new and innovative ways of measuring demographic events, particularly adult mortality in poor settings where the burden of disease and mortality is highest and the majority of the deaths occur outside the health care facilities. The growing number of Health and Demographic Surveillance Systems (HDSSs) grouped under the INDEPTH Network offers a temporary solution to the paucity of knowledge regarding adult mortality and premature deaths in LMICs and SSA in particular. The INDEPTH Network is an international organization that coordinates the activities of HDSSs mainly in the remote areas in Africa, Asia and Oceania, with the majority of them located in SSA. With a current membership of 46 centers running 53 HDSS field sites (as at 2016), the INDEPTH members collectively monitor on a continuous basis a population of over 4.0 million people annually and generate vital information on population and health dynamics of small well-defined geographic areas within their respective countries. An important aspect of the INDEPTH HDSSs is the harmonization and standardization of research tools and the strong collaboration among individual sites. No doubt this tends to enhance the quality of data and also allows for comparative analysis.

The operations of these HDSS sites provide a unique opportunity to not only examine general mortality dynamics in these areas but also to examine mortality experiences of specific groups either by age or sex as well as to compare the demographic dynamics across sites. This paper utilizes this rich resource to compare adult mortality estimates from 16 HDSSs in nine countries in SSA. Life table techniques are used to generate the adult mortality estimates, specifically the probability of a 15-year old dying before the 60th birthday (45q15). We examine differences in adult mortality and their trends by three geographic regions and sex differentials.

Data and Methods

Data for this analysis come from 16 INDEPTH member HDSS centers across nine countries in Sub-Saharan Africa that have contributed with data, from 2005 to 2012. The INDEPTH Network launched in 2013 the INDEPTHStats (online data visualization platform) and the INDEPTH Data Repository (online data archive) of fully documented, harmonized high-quality longitudinal datasets from INDEPTH member HDSS centers (Herbst, *et al.*, 2015). These HDSSs are located within three geographical regions in SSA (South, East and West) and are taken into consideration accordingly in this analysis. From Eastern Africa, we included Kilifi, Kisumu and Nairobi in Kenya; Magu and Rufiji in Tanzania and Iganga-Mayuge in Uganda. Specific HDSSs contributing data for this analysis from Southern Africa are Agincourt, Africa Centre and Dikgale in South Africa; Karonga in Malawi and Manhica in Mozambique. From West Africa, we analysed data from Farafenni in The Gambia; Kintampo and Navrongo in Ghana and Mlomp and Niakhar in Senegal.

The selected HDSSs provide a good geographic representation of SSA except for the Central Africa region where there is, as yet no HDSS running. The 16 HDSSs selected for this analysis collectively monitor a total population of over 1.5 million people annually. The sizes of these HDSSs both in terms of demographic surveillance area (DSA) and the surveillance population vary considerably, with the sizes of the DSA currently ranging from 70sq.km for Mlomp in Senegal to as large as 7,162sq.km for Kintampo in Ghana. With regard to the population under surveillance, Mlomp also has the lowest of about 8,200 people, whilst Kilifi covers a population of about 280,000. Table 1 shows the selected HDSS and their respective population under surveillance. It must be mentioned that some of the sites started initially with smaller sizes (both DSA and population) but have expanded their areas and increased their populations over the years. A case in point is Dikgale in South Africa that initially covered an area of 71sq.km and about 8,071 people until 2010, when it was expanded (Alberts, *et al.*, 2015). Furthermore, some of the HDSS are known to maintain areas beyond their routine DSA for implementing interventions and other studies. A case in point is Kintampo (Owusu, *et al.*, 2012).

There are also different or varied reasons that underlie the initial setting up of these HDSSs at the various remote locations but most of them (if not all) were established primarily to serve as a platform for conducting impact evaluations of community-based health and/or socio economic interventions, particularly assessing the impact of burden of disease (BoD) on health systems reform as in Rufiji (Mrema, *et al.*, 2015); understanding incidence and prevalence of childhood infectious diseases and control efforts as in Kilifi (Scott, *et al.*, 2012) and in Manhica (Sacoor, *et al.*,2013); assessing the impact of primary health care (PHC) on morbidity and mortality as in Farafenni; (Jasseh, *et al.*, 2015) or evaluating interventions geared towards the needs of the urban poor as in the case of Nairobi (Beguy, *et al.*, 2015). Also, it was in response to the rapid progression of the HIV pandemic in various parts of Africa that a number of HDSSs were set up especially in Eastern and Southern Africa to serve as platforms for monitoring the spread and impact of HIV/AIDS, HIV-related infections diseases and evaluating interventions to mitigate the impact. This is the particular case of Africa Centre (Tanser, *et al.*, 2008), Karonga (Crampin, *et al.*, 2012), Magu (Kishamawe, *et al.*, 2015), and Manhica (Sacoor, *et al.*, 2013). Similar to this, for post-apartheid South Africa, is Digkale that was set up mainly for monitoring the spread of non-communicable diseases (NCDs) and their risk factors (Alberts, *et al.*, 2015) and Agincourt that was established to support district health system development (Kahn, *et al.*, 2012).

A few HDSS grew out of the early large scale insecticide-treated bed net (ITN) trials where, after successful completion of these trials, the platforms were maintained to continue generating research data in recognition of the infrastructure established. This was the case of Kisumu (Odhiambo, *et al.*, 2012) and Navrongo (Oduro, *et al.*, 2012). In the particular case of Navrongo, the ITN trial was actually preceded by another large trial, the Ghana VAST Project (Oduro, *et al.*, 2012). In addition to the main rationale of setting up a platform for trial, the establishment is guided in part by the practical need for a capacity building platform for university faculty, researchers and students, for instance Agincourt (Kahn, *et al.*, 2012), Niakhar (Delaunay, *et al.*, 2013), and Mlomp (Pison, *et al.*, 2002). Over the years, these HDSSs have expanded (and are expanding) into comprehensive platforms for a wide range of disease-specific observational studies and clinical trials (Osman, *et al.*, 2015).

Table 1: HDSS Population included in this analysis

HDSS/Region	Country	Surveillance Population	Available Data Years	Urban %*
Southern Africa				
Africa Centre	South Africa	90,065	2000–2012	38
Agincourt	South Africa	87,040	1993–2012	R
Dikgale**	South Africa	36,000	1996–2012	R
Karonga	Malawi	35,730	2003–2012	16
Manhica	Mozambique	95,000	2000–2012	15
East Africa				
Kilifi	Kenya	281,816	2004–2012	22.2
Kisumu	Kenya	220,000	2003–2012	R-P
Nairobi	Kenya	67,901	2002–2012	U
Magu	Tanzania	34,347	1994–2012	50.2
Rufiji	Tanzania	105,503	1999–2012	30.6
Iganga/Mayuge	Uganda	79,794	2005–2012	R-P
West Africa				
Farafenni	Gambia	51,391	1993–2012	61
Kintampo	Ghana	142,396	2005–2012	29
Navrongo	Ghana	156,000	1996–2012	20
Mlomp	Senegal	8,200	1990–2012	R
Niakhar	Senegal	43,713	1990–2012	R
		1,533,896		

Notes: * P, peri-urban; R, rural; U, urban (% TBD).

** Up to 2010 when it was expanded, Dikgale initially covered 8071 (Alberts *et al.*, 2015)

Despite the differences between the HDSSs, the methodology of data collection is similar and typically involves the monitoring of populations of a well-defined geographical area. Trained fieldworkers periodically visit each household to record demographic events that have occurred in these households and the residential status since the last visit. Frequency of visits to households for information update (on vital events and residency status) varies by HDSSs (even for those selected for this analysis) and ranges between once and thrice in a year.

Vital events recorded and updated include births, deaths, in- and out-migrations, marital status and vaccination status of children below three years of age, among others. An important aspect of the HDSS is the conduct of verbal autopsies (VA) that is used for the determination of the main causes of death within the population under surveillance. Data are collected from the field either by using paper-based questionnaires or electronic data capture devices. These data are then checked for inconsistencies and possible errors and corrected before entry and storage takes place. In addition to individual HDSSs generating their demographic and health outputs according to their respective needs, the INDEPTH-Network has developed a common platform/process to assist member centers with data extraction, harmonization, quality control, documentation using DDI (Herbst, *et al.*, 2015) as well as the standardized computation of key demographic indicators.

This process allows for sharing/archiving well-documented quality HDSS data on the INDEPTH Data Repository (http://indepth-network.org/data-stats/indepth-data-repository) and for the online display of key demographic indicators of member centres on INDEPTHStats (http://indepth-network.org/data-stats/indepthstats). This is aimed at making available health and demographic information to researchers, policy-makers, among others that can guide their decision making (www.indepth-network.org). For the quality control process as well as the generation of the key indicators, these include the application of standard life table technique to all the datasets from the respective member centers. Preston, Heuveline and Guillot (2001) provide a detailed description and illustration of the life table technique. Plausibility checks and reports are generated, fed back to the respective members iteratively until a final consensus is reached with the HDSS on the suitability of the dataset and indicators for release on the data repository and display on INDEPTHStats respectively. Among the key mortality indicators generated through this process and displayed on the INDEPTHStats is adult mortality (45q15) and life expectancy at birth (e0) as well as life expectancy at age 15 (e15) which are used for this analysis.

The adult mortality rate (45q15) is normally the probability that a person alive at age 15 will die before reaching age 60 (given prevailing mortality conditions). However, in this paper we have adopted the common practice of presenting the mortality rates per 1000 (in the subsequent figures and tables) because this can be easily interpreted (or visualized practically) in terms of deaths per thousand individuals.

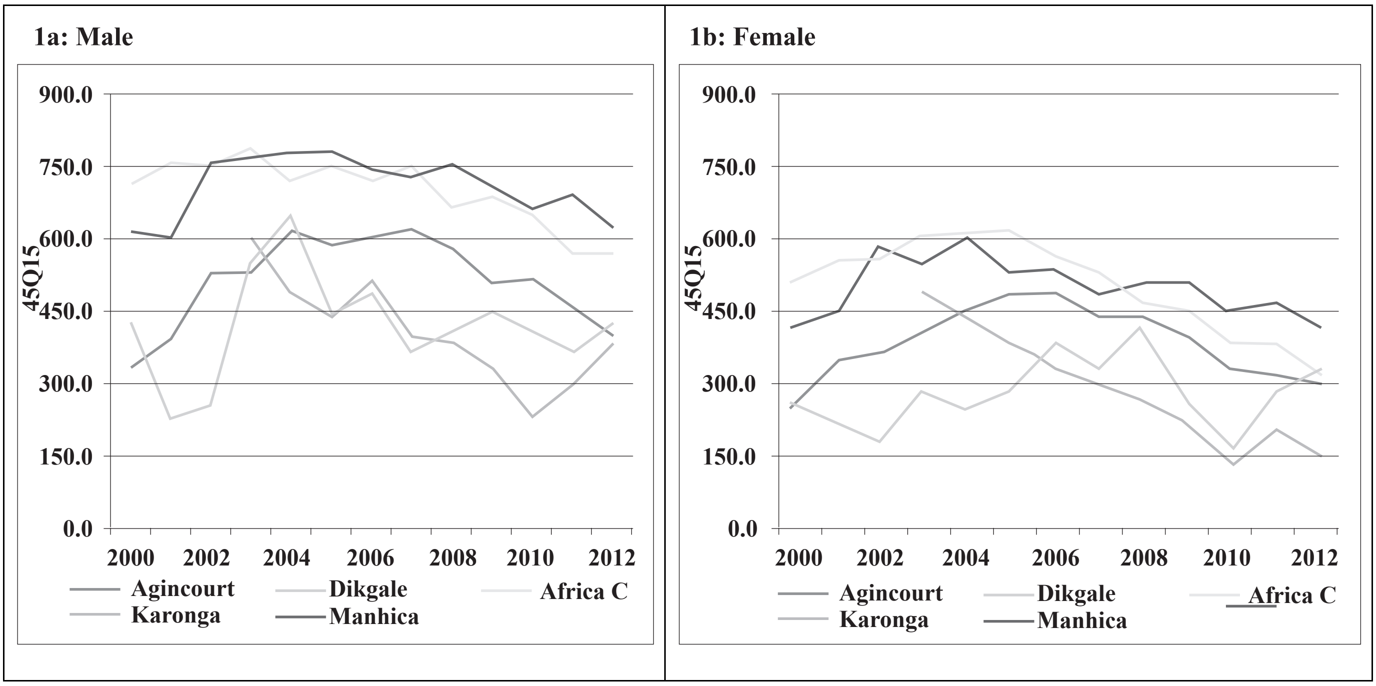
Results

The results reveal distinctive mortality trends for the three regions of Africa, apparently consistent with the different diseases profiles observed in these regions over the period, with Southern and Eastern African countries predominantly afflicted with the HIV/AIDS pandemic. Based on the results, adult mortality is generally lower in the West African region than the other two regions. This is contrary to the higher mortality experienced in western Africa compared to southern and eastern Africa in the 1960s (Hill, 1991; Timaeus, 1991; Masquelier, *et al.*, 2014). Male mortality is generally higher than female in all regions, except for Nairobi where females apparently seem to be experiencing higher mortality.

We also observed interesting distinctive trends among the three regions which are sharply consistent with the life-threatening events and/or lifesaving actions experienced in the region during the studied period. It is observed that the HDSSs in the Southern region; Africa Centre and Agincourt (both in South Africa) and Manhiça (in Mozambique), are among those with correspondingly highest probability of death for both males and females in Africa (Figures 1a and 1b). The mortality trend over the 12-year period in this region faced a rise in levels during the initial years, peaked at some points, and experienced a decline thereafter. An exception to this trend is Karonga HDSS in Malawi that experienced a general decline, with a unique peak in 2006, for both males and females over the period and an increase in probability of dying thereafter up to 2012. On the other hand, female adult mortality in Karonga has shown a different trend compared to their male counterparts experiencing a consistent decline in the probability of dying up to 2010 with a slight increase in 2011 and then a fall in 2012 (Figures 1a and 1b).

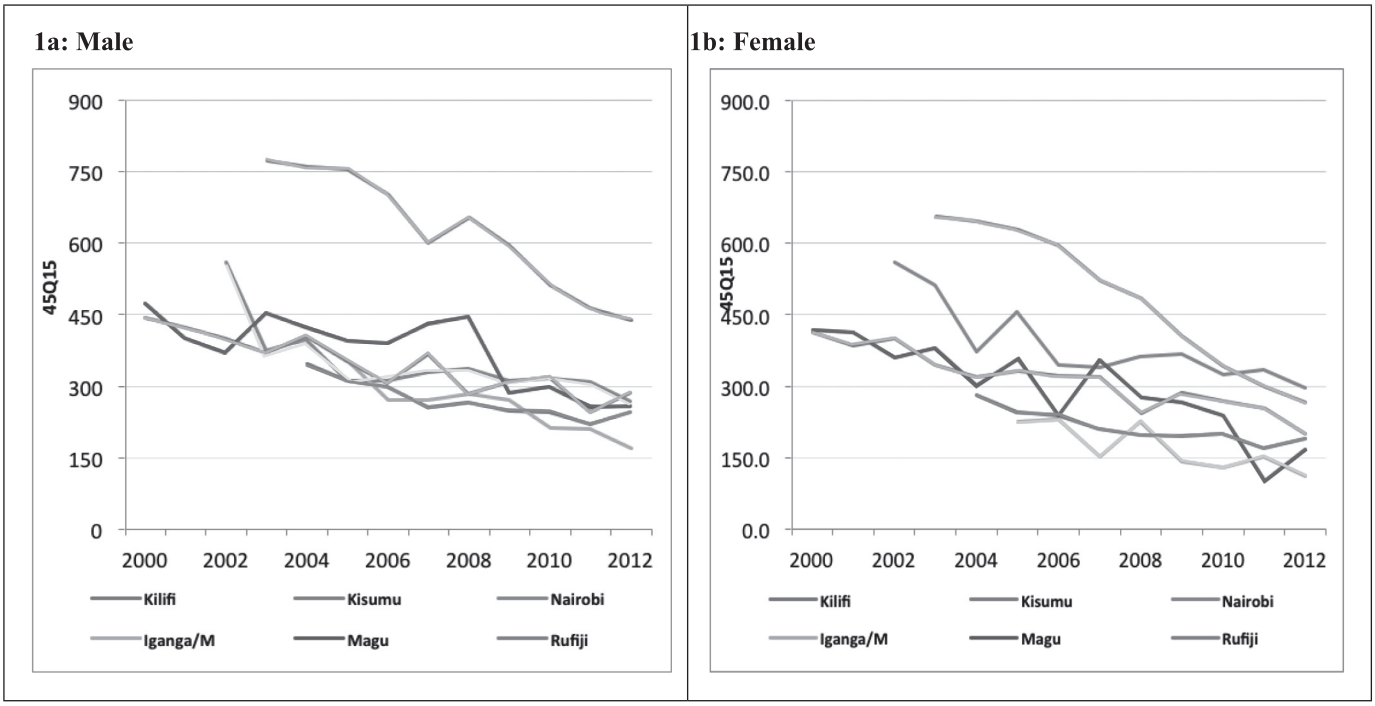
With respect to the HDSSs in the East African region, it is observed that they experienced a general decline of mortality over the period under review (Figures 2a and 2b). For instance Kisumu (Kenya) with the highest adult mortality for both sexes among the six HDSSs, witnessed a sharp drop from a high of about 750 per 1,000 in 2003 to about 450 in 2012.

FIGURE 1: TREND IN ADULT MORTALITY (45Q15) FOR HDSSS IN SOUTHERN AFRICA, 2000–2012



Notes: The adult mortality rate (45q15); the probability of dying between age 15 and age 60 is expressed per thousand person years lived

FIGURE 2: TREND IN ADULT MORTALITY (45Q15) FOR HDSSS IN EAST AFRICA, 2000–2012



Notes: The adult mortality rate (45q15); the probability of dying between age 15 and age 60 is expressed per thousand person years lived.

Table 2: Probability of dying between ages 15 and 60 (45q15) for select years 2002, 2007, 2012 by sex

HDSS & Region	Male			Female		
	2002	2007	2012	2002	2007	2012
Southern Africa						
Africa Centre	747.6	745.7	565.7	557.1	539.1	326.2
Agincourt	527.1	613.5	401.2	376.2	449.7	307.5
Dikgale	254.8	368.2	419.2	188.0	338.8	338.0
Karonga	N/A	390.4	373.5	N/A	307.9	157.3
Manhica	753.9	724.6	620.4	590.2	492.2	431.2
East Africa						
Kilifi	N/A	253.9	243.9	N/A	209.6	189.3
Kisumu	N/A	597.2	435.9	N/A	519.6	265.5
Nairobi	559.6	328.1	268.0	559.3	338.1	296.0
Iganga Mayuge	N/A	271.3	169.1	N/A	150.7	111.6
Magu	368.3	429.0	257.5	358.5	355.2	168.6
Rufiji	399.6	365.7	284.9	399.0	317.8	198.2
West Africa						
Farafenni	325.1	347.0	274.5	309.9	213.3	220.7
Kintampo	N/A	342.6	327.7	N/A	225.8	199.0
Navrongo	508.3	441.6	528.3	335.1	233.9	218.2
Mlomp	519.1	220.0	238.3	363.9	141.6	163.8
Niakhar	246.6	295.3	218.5	225.8	174.1	198.8

Notes: N/A- refers to periods when the centers in question have no data because they were not fully operational as an HDSS Moreover, the adult mortality rate or the probability of dying between age 15 and age 60 (45q15) is expressed per thousand person years lived.

For the West African region, a fluctuating but slow decline in mortality was experienced, particularly for females. Among the sites in this region, Navrongo exhibits the highest mortality among males and also for females for most part of the period. Also, whilst all the sites have experienced some reductions between the start and the end of the analysis period, Navrongo recorded an increase. For instance, in 2000 the probability of dying for males was about 520 per 1,000 and reached about 550 per 1,000 in 2012. There is no particular reason that can be attributed to this trend, until further enquiry is conducted. An observable pattern for the West African sites (except for Niakhar in Senegal) is the increase in mortality for the males after 2010 and 2011. In particular, male mortality has increased for Navrongo and Kintampo (both in Ghana) from 2006. The two areas have relatively higher male probability of dying than the other HDSSs and also exhibit a similar male mortality trend from 2008 onwards. Mortality trend for all sites show some fluctuations over the period, particularly in the sites like Mlomp where the size of the population under surveillance is small and the adult mortality relatively low.

However, some of the peaks are real and correspond to particular epidemics or events. For example, the high mortality in Mlomp in 2002 for both sexes is linked to a tragic event which affected the population of the HDSS, the sinking of the ferryboat Le Joola, on 26 September 2002, off the coast of the Gambia. This ferry linked Ziguinchor, the regional capital, to Dakar, the national capital of Senegal. Its sinking resulted in the death of nearly all its passengers, or nearly 2,000 people, mostly young adults, among which 35 were inhabitants of the Mlomp HDSS (Emmanuelle, *et al.*, 2010). Another example, the high level of adult mortality in Niakhar during the period 2005-2007, with a peak in 2005 specially for females, is linked to epidemic outbreaks of cholera in Senegal (http://www.who.int/gho/database/) which affected in particular the region of Niakhar.

Generally, female adult mortality is lower than male mortality for all sites in the West Africa region. Another noticeable feature of the female adult mortality trend in the region is the decline over the period, with some clustering in 2012 for all the sites. Just like the male mortality, female mortality for the Navrongo site is the highest at the beginning and end of the analysis period. Similar to males, the level and trend of female mortality for Navrongo and Kintampo (both in Ghana) are similar, with less fluctuation (peaks and troughs) compared to the other sites.

Table 3 presents the mortality trends using two conventional life expectancy measures: at birth (e0) and the average remaining years of life at age 15 (e15). Since life expectancy at birth (e0) is influenced more by childhood mortality than adult mortality, the best proxy measure of adult mortality in such an analysis is life expectancy at age 15(e15). Though, this is not the objective here, comparing e0 to e15, we get a clear indication that childhood mortality has been decreasing more rapidly in these Sub-Saharan Africa sites relative to adult mortality (except for the three sites in South Africa). In other words, the improvements in adult mortality across these sites have been rather modest relative to the improvements in child mortality. In effect, the difference in e0 and e15 across the sites for 2000 was in the neighborhood of five years (except for the three South Africa sites where the difference reaches of exceeds 10 years). Meanwhile by 2012, the difference for all sites is in the neighborhood of 10 years plus.

Discussion and conclusion

Demographic data for mortality analysis has improved over the past decade following the establishment of HDSS centres across Africa and Asia. This analysis has utilized data from several HDSS centres in Africa to compare the levels and trends of adult mortality in Sub-Saharan Africa. While mortality remains high in the sub region, the results have also revealed differences in the levels and trends in adult mortality among the various geographical regions of Eastern, Southern and Western Africa. The existence of these differences can be attributed to the differences in the diseases burden of these regions and countries. While the southern and eastern African sites have relatively higher mortality, the West African sites have relatively lower adult mortality rates. There are however, country differentials within each region as well as site differentials within each country where there are two or more sites.

Several factors may be responsible for the relatively high adult mortality in the southern and eastern Africa regions compared to the western African countries. The most important of these is the effect of HIV that has had a significant but devastating contribution to the disease burden and the associated high mortality levels of these countries (Birnbaum, Murray and Lozano, 2011; Herbst, *et al.*, 2015; Dorrington, *et al.*, 2001; Masquelier, *et al.*, 2014). However, since 2004 the introduction, access and uptake of antiretroviral therapy (ART) has expanded in the southern African region, reaching up to 1.8 million people in South Africa (Johnson, 2012; Simelela and Venter, 2014), which has contributed to reduce the HIV scourge in South Africa in particular and the southern and eastern African region in general.

Indeed, the trend noted here is consistent with another study on mortality trends following the era of ART in Kenya, where the largest mortality decline was observed in Kisumu (Reniers, *et al.*, 2014). This suggest that rapid decline in mortality is partly due to the introduction and expansion of ART over the years (Van't Hoog, *et al.*, 2012). Surprisingly, it is observed that the Kisumu site experienced an exceptional increase in male mortality in 2008 following consistent decline over the years before. This sudden increase has been attributed to the post-election conflict that erupted in Kenya in general and Kisumu in particular where the effect of the conflict was felt most (Feikin, *et al.*, 2010; Reniers, *et al.*, 2014). It is believed that apart from the direct effect of the conflict on mortality, it also disrupted the uptake of ART during the time of the conflict. Nairobi also experienced a slight increase in male mortality during the post-election conflict in 2008 and 2010, as depicted in the graph in Figure 1a.

Apart from the introduction and subsequent expansion of ARTs, education and awareness creation over the years on the devastating effects of HIV as well as measures to avoid contracting the disease have contributed in diverse ways in reducing HIV infection and

Table 3: Life expectancy at birth (e0) and at age 15 (e15) for period 2002-2012 by sex

	Male						**Female**					
HDSS & Region	**2002**		**2007**		**2012**		**2002**		**2007**		**2012**	
Southern Africa	e0	e15	e0	e15	e0	e15	e0	e15	e0	e15	e0	e15
Africa Centre	41.4	32.4	45.5	33.8	54.4	41.8	49.6	39.8	54.1	41.8	65.1	53.5
Agincourt	54.2	43.7	50.6	40.3	60.9	48.0	61.3	51.4	58.5	48.3	67.7	56.0
Dikgale	67.1	52.1	63.0	50.3	61.4	48.1	69.3	58.5	67.5	54.7	68.5	55.1
Karonga	N/A	N/A	62.3	53.2	63.5	53.9	N/A	N/A	62.5	52.8	67.5	58.6
Manhica	39.5	33.8	43.2	34.8	49.7	39.1	47.2	40.6	53.4	45.2	59.4	49.6
East Africa												
Iganga Mayuge	N/A	N/A	62.8	54.0	70.0	61.0	N/A	N/A	68.1	57.8	72.8	64.0
Kilifi	N/A	N/A	67.2	55.6	66.0	53.7	N/A	N/A	72.2	60.5	72.8	60.3
Kisumu	N/A	N/A	46.7	40.2	54.6	46.5	N/A	N/A	49.6	42.9	63.8	55.2
Nairobi	54.5	54.6	61.2	51.7	72.1	62.5	52.2	51.7	62.3	51.9	66.0	56.2
Magu	53.8	48.8	53.8	46.1	65.1	55.3	57.2	50.4	57.2	50.0	71.0	59.5
Rufiji	53.6	49.1	57.9	49.9	65.4	56.7	52.9	47.7	64.5	54.5	72.5	61.8
West Africa												
Farafenni	55.1	48.4	57.8	48.0	61.7	52.0	57.2	51.2	67.6	57.6	67.4	56.3
Kintampo	N/A	N/A	61.9	52.1	63.2	53.3	N/A	N/A	67.8	59.2	72.3	61.6
Navrongo	47.6	43.5	54.8	46.2	54.9	43.9	53.7	48.6	63.2	54.6	66.5	55.2
Mlomp	48.8	42.8	65.3	55.4	66.4	54.2	53.9	46.3	76.9	65.7	77.0	63.7
Niakhar	58.4	55.0	61.5	51.9	63.5	54.3	60.5	57.1	67.4	57.8	67.2	57.5

Notes: N/A- refers to periods when the centers in question have no data because they were not fully operational as an HDSS e15 - Average expected remaining years of life at age 15

prevalence rates in these countries (Foss, *et al.*, 2007). The noted increase in adult mortality rates in the Southern Africa region during this period, as shown in Figure 2 coincides with the time of the HIV scourge associated with high mortality prior to the introduction of free ART treatment. For instance, South Africa hosts the largest concentration of people living with HIV/AIDS in the world with an estimated 20 percent of the world's HIV persons (Simelela and Venter, 2014; Shisana, *et al.*, 2014). Age-standardized mortality rate among infected adults at the time is reported to be between nine to 25 times those uninfected; and the probability of dying between ages 15 and 60 years in the most endemic populations had reached 0.6 among men (Porter and Zaba, 2004; Timaeus and Jasseh, 2004). However, general decline in mortality started in 2005 following the introduction of ART in South Africa in particular and southern Africa in general (Reniers, *et al.*, 2014). Other recent publications have further highlighted the impact of ART on reducing population level mortality. However, a few studies have also shown that among the 90% of the population that do not have HIV, there has been almost no change in mortality over time (Asiki, *et al.*, 2016, Bor, *et al.*, 2013, Price, *et al.*, 2016).

All sites selected for this analysis have shown excess male mortality as expected. However, excess female mortality is experienced in the Nairobi site. This could possibly be attributed to the slum conditions in Nairobi for which females could be more vulnerable to diseases and other environmental hardships. Further studies are, therefore, needed to understand the causes of the excess female adult mortality in Nairobi slums. Similarly, Navrongo is observed to have a higher male mortality in western Africa compared to the other HDSSs within the sub-region. This also needs further interrogation to understand the contributing factors. It is noticed that male mortality in western Africa sites has increased towards the end of the analysis period for almost all sites. This calls for further critical assessment using more recent data to examine the level for evidence of continuous rise and actions to mitigate the increase where confirmed.

Annual mortality levels over a certain period give rise to trends. Policy-makers rely on these trends to draw up policies to reduce these high rates going forward. However, the irregularity in the trends for some sites makes it difficult to predict with some certainty the future levels of mortality in these areas. These irregularities (peaks and troughs) observed in some sites could be due to the small size of the population under surveillance. Depending on the size of the population covered, a small change in the number of events (adult deaths) registered relative to the previous period could result in a drastic change (increase or decrease) in the rates. For instance, Dikgale in southern Africa and Karonga in Malawi have populations of less than 40,000 people under surveillance. This could be the reason for the pronounced fluctuations observed in their mortality trends compared to the other areas over the period. Similarly, within the western African HDSSs, Mlomp, Farafenni and Niakhar have more pronounced irregular mortality trend that may be due, in part, to the number of people under surveillance in these HDSSs compared to Navrongo and Kintampo. Indeed, the West Africa region has been less hit by the HIV/AIDS pandemic and that probably has accounted for the lower mortality levels experienced here compared to the Southern and Eastern African regions.

In order to continue to achieve successes in health and longevity through better health and demographic information to inform policy, there is the need to address the problem of health and demographic data paucity in Africa. Inertia has been one major reason why few data have been collected on adult deaths (Timaeus, 1999). Health intervention priority has not included adult mortality and this has led to scanty data on adult deaths for any meaningful analysis. However, with the advent of HDSS, analysis on adult mortality and their causes have become possible, offering the opportunity for the appropriate intervention to curb the high rates observed in various remote areas. Since deaths in these areas are recorded on a continuous basis, it is now possible not only to examine adult mortality rates, but also to determine the causes by age and sex as was done in a separate study that culminated in a GHA supplement on overall patterns of mortality including 9 of the 16 HDSS included in this analysis (Streatfield, *et al.*, 2014).

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