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# Knowledge Generation for Better Health: Contribution of the INDEPTH Network of HDSS Field Sites

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## Abstract

Data generated by the 49 Health and Demographic Surveillance System (HDSS) field sites run by 43 research centers that make up the INDEPTH Network offer a valuable corrective to the dearth of robust and objective health information in low- and middle-income countries (LMICs). The field sites collect regular data from defined demographic surveillance areas as well as conduct ad-hoc studies to assess policy and program interventions. The data allow policy-makers in Africa, Asia and Oceania where the field sites are located, to track emerging health threats from both infectious and non-communicable diseases, and to assess in real-time the effectiveness of interventions to tackle them.

**Keywords:** Low- and middle-income countries, health and demographic surveillance systems, mortality, infectious disease, non-communicable disease, research for policy, data.

## BACKGROUND

In many low- and middle-income countries (LMICs), available health and population-related data are either outdated or unreliable. Some countries lack the political will to put in place unbiased data collection systems, others lack the requisite resources (McGrail and Black, 2005). Where data are collected, methodological flaws often render them incomparable over time or between different regions, and therefore are of limited relevance for policy (United Nations, 2014). Their impact on health, as a consequence, is negligible.

The dearth of data can be seen in something as basic as birth registration. In sub-Saharan Africa only 44 percent of births are recorded. In South Asia only 39 percent are recorded (United Nations Children's Fund, 2013). This deficiency extends to other vital indicators. A United Nations team, for example, found that with regard to data on countries' efforts to achieve the Millennium Development Goals (MDGs), 'there is no five-year period when the availability of data is more than 70% of what is required' (United Nations, 2014). Another study found stark discrepancies between immunization rates reported by governments and those collected by international agencies (Sandefur and Glassman, 2014). Maternal mortality data, meanwhile, are estimated based on only 16 percent of all births, malaria mortality data on only 15 percent of all deaths (Melamed, 2014).

The 49 Health and Demographic Surveillance Systems (HDSSs) run by 43 research centres that make up the INDEPTH Network are an exception to this rule. These field sites, based in twenty LMICs in Africa, Asia and Oceania, have for decades systematically collected robust data on a range of population and health issues. Their methods involve regular visits to thousands of households in a defined rural or urban area, which have enabled them to amass an enormous database on the health and major life events of millions of individuals. Standard data, collected by all the field sites on average every six months, cover births, deaths, morbidity, pregnancy outcomes, migration and household income. The surveys track trends in fertility and mortality, and trace the evolution of communicable and non-communicable disease threats. Sites also conduct ad-hoc studies, either alone or in collaboration with other HDSSs, and have tested the effectiveness of many policy interventions that have subsequently been rolled out by health care systems across the world. HDSSs currently gather data on more than 3.8 million individuals, many of whom are among the most vulnerable to health threats and live in areas that are hard to reach.

This paper summarises research evidence that demonstrates the role of INDEPTH sites in generating knowledge for improved

health. It draws on published, peer-reviewed studies produced by the sites and by working groups established by INDEPTH to address particular health topics to show how high-quality data generation can have concrete impacts on population health.

## MATERIALS AND METHODS

This review draws on two sources of information. The first are profiles of INDEPTH sites which were peer-reviewed and published in the *International Journal of Epidemiology* between 2008 and 2015. The profiles describe the location of sites, the demographic make-up of the research sample, their main areas of focus, their data collection methods, their strengths and weaknesses, and the main findings and publications that have resulted from their research. A total of 29 HDSSs submitted profiles, 4 from Asia and 25 from Africa. For this review we draw on the main findings and publications section of each profile to highlight the major achievements of sites in terms of generating improved knowledge of health issues in the communities and countries in which they operate.<sup>1</sup> The aim was to select studies and findings that provide a broad picture of the data sites generated and the policy-relevant results they produce.

The second information source is peer-reviewed published studies based on data produced by the nine health-related INDEPTH Working Groups. These groups bring together scientists from multiple HDSSs to address specific health problems. The groups cover Vaccination and Child Survival; Maternal and Newborn Health; Environment and Health; Sexual and Reproductive Health; Antibiotic Resistance; Migration, Urbanisation and Health; Health Systems; Mortality Analysis and Cause of Death; and Adult Health and Aging. Again, our review summarises the findings of the published papers, selecting those that demonstrate how INDEPTH sites contribute to knowledge generation for improved health and provide a broad picture of the data sites generated, as published in peer-reviewed journals.

## FINDINGS

The four main health-related strands of research conducted by HDSSs encompass overall health trends, maternal and newborn health, infectious diseases, and non-communicable diseases. We look at each in turn, first providing examples of health improvements or declines as detected in regular data collection rounds, and then, where available, discussing policy and programme interventions whose effectiveness has been studied by HDSSs.

## OVERALL HEALTH TRENDS

### *Trends and patterns*

The overall health trend at INDEPTH member sites over the past three decades has been one of improved health, leading to increasing life expectancy. The value of HDSSs' regular data collection, however, lies in its ability to identify areas where improvement has been slower or absent, and thereby to show health policy-makers where they should direct their investments.

The HDSS surveillance area at Farafenni in Gambia is an example of steady health improvements. Life expectancy at the site increased from 53 to 66 years between 1993–1997 and 2008–2012. This was driven largely by reductions in infant mortality that fell from 73 to 23 deaths per 1,000 live births over the period, and in under-5 mortality that fell from 182 to 44 deaths per 1,000 live births (Jasseh, *et al.*, 2015). In neighbouring Senegal, researchers at Bandafassi HDSS found that under-5 mortality declined from 490 to 155 deaths per 1,000 live births between the early 1970s and the early 2000s. This contributed to life expectancy more than doubling over the same period (Pison, *et al.*, 2014). Further west in Senegal, the Niakhar HDSS has revealed dramatic improvements in health over the past two decades. Between 1994–1999 and 2009–2011, neonatal mortality fell from 30.1 to 7.9 deaths per 1,000 live births, infant mortality from 79.2 to 31.2 deaths per 1,000 live births, and under-5 mortality from 201 to 76.2 deaths per 1,000 live births. Life expectancy for males increased by eleven years over the same period, and that for females by almost seventeen years (Delaunay, *et al.*, 2013).

It is not only in West Africa that HDSSs have identified major health improvements. At the Rufiji HDSS in Tanzania in East Africa, where under-5 mortality more than halved between 1999 and 2012, female life expectancy increased by 11.6 years over the same period, and male life expectancy by 4.4 years (Mrema, *et al.*, 2015). The detailed data gathered by HDSSs allows for the nuances behind these overall trends to be teased out. Researchers at Rufiji have shown that food insecurity is a key driver of morbidity at all ages, and that there is a significant association between poverty and higher under-5 mortality. Mortality increases, moreover, as average monthly temperatures fall – again, findings such as these can give policy-makers a clear steer as to when and among which groups they should focus their investments.

The picture is not uniformly rosy, however, and data from other HDSS sites in Africa show that the continent – even its

Sub-Saharan portion – cannot be viewed by policy-makers as one homogenous entity. Ifakara HDSS in Tanzania that has both a rural and an urban surveillance area, has seen a 51 percent decline in under-5 mortality in the rural site between 2000 and 2012, but barely any decline at the urban site. Life expectancy at the rural site has now overtaken that at the urban site (Geubbels, *et al.*, 2015). At Agincourt HDSS in South Africa, life expectancy declined sharply between 1994 and 2009, due largely to the impact of HIV/AIDS. For males it fell from 68 to 56 years, and for females from 73 to 64 years (Kahn, *et al.*, 2012). Other southern African sites have also seen mortality increases as a result of HIV/AIDS. At Manhica HDSS in Mozambique, which at the peak of the epidemic had an adult HIV prevalence rate of 39.9 percent, adult mortality increased between 1997 and 2011 at the same time as under-5 mortality halved (Saco, *et al.*, 2013).

### *Intervention studies*

A number of HDSS sites have attempted to measure the impact of broad-based health policies on the health trends and patterns identified earlier. At Farafenni in Gambia, researchers traced the beginning of mortality declines to the introduction of a national primary health care programme in 1982. Prior to the programme's launch, for example, infant mortality had been as high as 142 deaths per 1,000 live births, but by 1993 it had fallen to 73 deaths per 1,000 live births (Jasseh, *et al.*, 2015). At the Navrongo HDSS in northern Ghana, intervention studies have found that placing nurses within communities along with trained local volunteers had significant positive impacts on childhood immunization rates and child health outcomes (Binka, *et al.*, 1995). And at Rufiji HDSS in Tanzania, an investigation of the effect of the World Health Organization's Integrated Management of Childhood Illness (IMCI) scheme found improvements in child health as well as a 44 percent cost reduction in the annual cost of caring for children below the age of five years compared with routine care for children who were not part of the scheme. The reduction was due mainly – although not solely – to reduced hospitalization rates for children covered by the scheme (Adam, *et al.*, 2005). IMCI was subsequently implemented across Tanzania.

But while Gambia's primary healthcare program appears to have been successful, similar efforts elsewhere have had less impact on overall health. In a randomized controlled trial at Dodowa HDSS in south-eastern Ghana, researchers found that although the introduction of free primary care had led to increased use of formal healthcare services, it was not associated with improvements in health outcomes for the

treatment group compared with the control group (Ansah, *et al.*, 2009). In Bangladesh, the Chakaria HDSS found that increased rates of immunization and use of health services had not been accompanied by decline in infant mortality (Hanifi, *et al.*, 2012). These studies provide lessons for policy-makers, showing that one-size-fits-all policies and programs may not be effective in all settings, and highlighting the need for continued monitoring of interventions to ensure that they are having the intended impacts on health.

## MATERNAL AND NEWBORN HEALTH

### *Trends and patterns*

All INDEPTH member centers routinely track fertility as well as pregnancies and births and deaths of newborns. They therefore offer a robust platform to evaluate progress in reducing maternal and neonatal mortality, and to test the effectiveness of interventions.

Fertility rates have declined at most INDEPTH member sites in recent decades. Asia in particular has seen rapid reductions. In Chakaria in Bangladesh, for example, the fertility rate fell from 5.1 to 2.7 children per woman in just 11 years from 1999 (Hanifi, *et al.*, 2012). Women at the Ballabgarh HDSS in northern India have an average of 2.5 children (Kant, *et al.*, 2013), while those at the Birbhum HDSS in West Bengal, India, average 2.2 children, close to the replacement rate (Ghosh, *et al.*, 2014).

In African HDSS sites, fertility has fallen more sharply in urban than rural areas. The fertility rates, for example at the Ouagadougou and Nairobi HDSSs, both of which are based in urban settings, are 2.5 and 2.7 children per woman respectively (Rossier, *et al.*, 2012; Beguy, *et al.*, 2015). At Ifakara in Tanzania, the urban rate is 3.0 children per woman, while the rural rate is 4.4 (Geubbels, *et al.*, 2015). At predominantly rural sites, on the other hand, such as Kaya and Nanoro in Burkina Faso (with fertility rates of 6.9 and 5.6 children per woman, respectively), Nahuche in Nigeria (7.4) and Niakhar and Bandafassi in Senegal (6.4 and 6.5 children per woman, respectively), fertility has declined slowly, if at all (Kouanda, *et al.*, 2013; Derra, *et al.*, 2012; Alabi, *et al.*, 2014; Delaunay, *et al.*, 2013; Pison, *et al.*, 2014).

Notwithstanding reductions in fertility, maternal mortality and neonatal mortality remain high in many parts of Africa. At Nahuche in Nigeria, for example, maternal mortality stood at 1049 deaths per 100,000 live births in 2012 (Alabi, *et al.*, 2014). At Nairobi HDSS in Kenya, maternal mortality in slum areas was found to be 709 deaths per 100,000 live births – much higher than the national average (Beguy, *et al.*, 2015).

Among the reasons for continued maternal mortality identified by HDSSs is the lack of obstetric care in many areas as well as high rates of unintended pregnancy. Researchers at Kersa HDSS in Ethiopia found that 28 percent of pregnancies in the area were unintended, and that these pregnancies were associated with higher rates of pregnancy loss (Assefa, *et al.*, 2013; Kassa, *et al.*, 2012). A study by Ifakara HDSS found that women who had not intended their pregnancies accessed antenatal care significantly later than other women, thereby increasing the risk of complications (Exavery, *et al.*, 2013).

Improvements in neonatal mortality have been uneven across African HDSS sites. In the Niakhar demographic surveillance area in Senegal, neonatal mortality fell from 30.1 to 7.9 deaths per 1000 live births between 1994–1998 and 2009–2011 (Delaunay, *et al.*, 2013). At Rufiji HDSS in Tanzania, which has seen impressive improvements in other health indicators, neonatal mortality has declined only slowly, from 35 to 24 deaths per 1,000 live births between 1999 and 2012 (Mrema, *et al.*, 2015). At Ifakara, also in Tanzania, neonatal mortality in 2011 ranged from 34 deaths per 1000 live births in urban areas to 22.7 deaths in rural areas (Geubbels, *et al.*, 2015). These variations highlight possible areas of focus for health policy-makers.

### *Intervention studies*

As with the broad-based health policies and programmes discussed above, interventions to tackle maternal and neonatal mortality have shown mixed results at HDSS sites.

The lack of obstetric care in poor settings is a key constraint on improving maternal and newborn health. A study at Ifakara HDSS found that health workers who are not physicians can be an effective substitute for physicians in remote areas if they are trained to provide comprehensive emergency obstetric care for mothers. A further study at the site showed how the drug Misoprostol is an effective tool for preventing post-partum haemorrhage (Nyamtema, *et al.*, 2011; Ifakara Health Institute, *et al.*, 20011). Less encouragingly, a study by Bandafassi HDSS found that though a new hospital in the district had opened in rural Senegal offering obstetric and gynaecological care and surgery, it had no impact on the prevention of maternal mortality (Pison, *et al.*, 2014). A study at Kaya HDSS in Burkina Faso, moreover, found that although the HDSS provided free deliveries, 14 percent of local mothers continued to give birth at home, while among women who lived more than five kilometres away from health facilities, 59 percent gave birth at home (Kouanda, *et al.*, 2013).



INDEPTH has a Working Group on Maternal and Newborn Health that has engaged 22 member sites and has secured funding from Save the Children and the South Africa Medical Research Council. The group, established in 2010, carries out comparative analysis of data from multiple HDSS sites. An intervention study conducted by group members at the Iganga/Mayuge HDSS in Uganda found that home visits by community health workers to new mothers helped increase rates of immediate breastfeeding and improve mothers' care for their newborn children (Waiswa, *et al.*, 2015).

## INFECTIOUS DISEASES

### *Trends and patterns*

Many of the countries in which INDEPTH members operate are in the early stages of the health transition. While Asian sites have seen chronic diseases take over from infectious diseases as the main cause of mortality, at most African sites the latter are still the biggest threat. Malaria, HIV/AIDS, acute respiratory infections (ARIs) and diarrhoeal diseases – the primary causes of mortality at most sites have been the subject of intensive study by HDSSs.

Sites in West Africa are the hardest hit by malaria, followed by those in East Africa (there are as yet no HDSSs in Central Africa). Malaria is the leading cause of death at Taabo HDSS in Cote d'Ivoire, accounting for 13 percent of all deaths, and at Kaya in Burkina Faso, where it causes 20 percent of deaths (Kone, *et al.*, 2014; Kouanda, *et al.*, 2014). It also causes over 8 percent of deaths at the sites in Kisumu in Kenya, Niakhar in Senegal, Dodowa in Ghana, and Farafenni in Gambia. At the urban Nairobi HDSS in Kenya it accounts for only 1 percent of deaths, although at another urban site – Ouagadougou in Burkina Faso – it causes 9.5 percent of deaths (again, HDSS data highlights the flaws in considering all of Africa, or even all of urban Africa, as one entity for health policy purposes) (Streatfield *et al.*, 2014a). Malaria mortality rates are significantly higher among children (particularly among those below the age of 5) than among adults – at Nahuche HDSS in Nigeria, malaria is the leading cause of death among children, but among adults intestinal infectious diseases are a bigger threat (Alabi, *et al.*, 2014). Malaria mortality rates tend to rise again as adults reach old age, almost to the same level as those among young children (Streatfield, *et al.*, 2014a).

The detailed data collected by INDEPTH sites allow for close examination of the causes of malaria infection. The Bandafassi HDSS in Senegal, for example, showed how malaria mortality more than doubled during the 1990s as the parasite became

resistant to the traditional antimalarial treatment, chloroquine (Trape, *et al.*, 1998). Researchers at Taabo HDSS in Cote d'Ivoire showed a strong association between anaemia and infections with the deadliest malaria-causing parasite, plasmodium falciparum, in infants (Righetti, *et al.*, 2012). Knowledge of the disease is also a factor – at Kersa HDSS in Ethiopia, only 60 percent of mothers knew that malaria was transmitted by mosquito bites (Assefa, *et al.*, 2015). Malaria can also increase vulnerability to other diseases – a study at Kilifi HDSS in Kenya found that prior infection with the plasmodium falciparum parasite was a strong predictor of invasive bacterial disease (Scott, *et al.*, 2011).

While malaria is primarily a threat to West and East Africa, HIV/AIDS has hit southern Africa hardest. A number of INDEPTH sites operate in settings that have been at the heart of the HIV/AIDS pandemic, and they have traced the evolution of the disease since it was first detected in the early 1980s. At the Agincourt, Dikgale and Africa Centre HDSSs in South Africa, HIV/AIDS is the leading cause of death, and has had a dramatic negative effect on life expectancy. At Agincourt, between 1994 and 2009, male life expectancy fell by twelve years, and female life expectancy by nine years (Kahn, *et al.*, 2012). At the same time, infant mortality rose from 25 to 39 deaths per 1,000 live births. At Dikgale, the mortality rate doubled between 1998 and 2006 (Alberts, *et al.*, 2015). At the Africa Centre in KwaZulu-Natal, where in the year 2000 HIV/AIDS caused 73 percent of male deaths and 61 percent of female deaths, mortality from the disease was associated with an increase in orphanhood, household breakdown, reduced economic resources and a weakened ability to cope with financial and health shocks (Tanser, *et al.*, 2008).

As with malaria, HDSS sites have been able to identify some of the vulnerabilities to and causes of the spread of HIV/AIDS. In the Africa Centre's demographic surveillance area, HIV prevalence rates were much higher in informal settlements near the national road than in remote rural areas (more than 35 percent prevalence compared with less than 10 percent respectively) (Tanser, *et al.*, 2009). Agincourt HDSS found that AIDS-related mortality was highest among returning migrants (Kahn, *et al.*, 2012), a finding supported by an Africa Centre study that showed HIV prevalence rates among male migrants were double those among non-migrants (Lurie, *et al.*, 2003). At Magu HDSS in Tanzania, researchers conducted qualitative research that showed stigma as a major barrier to accessing HIV/AIDS services. As with malaria, moreover, a lack of knowledge about the disease can hinder efforts to tackle it – more than one-third of individuals in the Mage study area believe that prayer

can cure the disease (Mshana, *et al.*, 2006; Roura, *et al.*, 2009; Roura, *et al.*, 2010).

A review of 540 HIV/AIDS published studies by multiple HDSS sites between 1999 and 2012 found that alcohol consumption and lower educational attainment were associated with higher risks of HIV infection. The association with socio-economic status, however, was mixed, with studies at some HDSS sites showing a link between poverty and HIV/AIDS prevalence and others showing that wealthier individuals were more at risk (Sankoh, *et al.*, 2014). Such findings emphasise the importance of developing policies that are tailored to the environment in which they are to be implemented – the detailed, robust data generated by HDSS sites are vital for guiding policy-makers towards interventions that are likely to be most effective.

Acute respiratory infections and diarrhoeal diseases are other leading causes of infectious disease morbidity and mortality at HDSS sites in Africa. At both Manhica HDSS in Mozambique and Farafenni HDSS in Gambia, ARIs are second only to malaria as the leading cause of death (Saco, *et al.*, 2013; Jasseh, *et al.*, 2015). At Nairobi HDSS in Kenya, diarrhoeal diseases are the leading cause of death among under-5s, ahead of pneumonia. Both are much more prevalent during rainy seasons (Beguy, *et al.*, 2015). And at Kersa in Ethiopia, the two-week prevalence of diarrhoeal disease among under-5s is 23 percent. Inconsistent use of oral rehydration therapy and a dearth of latrine facilities among local households (only 36 percent of which have latrines) contribute to diarrhoeal disease's status as the primary killer of under-5s in the demographic surveillance area (Assefa, *et al.*, 2015).

### **Intervention studies**

INDEPTH member sites have conducted numerous studies on interventions to prevent and treat malaria, HIV/AIDS and other infectious diseases. The results have greatly influenced national and international health policies, and their recommendations have been integrated into programs across the developing world.

Malaria interventions studied by HDSSs cover both prevention methods and treatment. Malaria prevention methods studied include insecticide-treated bed nets (ITNs), intermittent preventive treatment (IPT) with anti-malarial drugs, and vaccines. Early trials at Farafenni HDSS in Gambia showed the effectiveness of ITNs in reducing malaria morbidity and mortality in children. Between 1998–2000 and 2004–08, malaria mortality among under-5s fell by more than two-thirds

as bed nets were rolled out across the demographic surveillance area (Jasseh, *et al.*, 2015). Navrongo HDSS in Ghana found that ITNs reduced all-cause morbidity and mortality in children by 17 percent (Oduro, *et al.*, 2012), while more recent research by Kisumu HDSS in Kenya found that ITNs were associated with a 26 percent reduction in community infant mortality (Odhiambo, *et al.*, 2012).

Ensuring that families use bed nets is as important as proving their effectiveness. A study at Ifakara HDSS in Tanzania showed that a social marketing campaign to promote ITN use was associated with a 27 percent increase in the survival of children aged between one month and four years, and that discount vouchers were an effective way of subsidising ITN use. The latter scheme was subsequently incorporated into Tanzania's national voucher scheme for ITN subsidies (Schellenburg, 2001; Mushi, *et al.*, 2003). Less positively, research at Mbita HDSS near Lake Victoria in Kenya showed that many of the bed nets that were provided free by the government were put to use as fishing nets or for drying fish (Wanyua, *et al.*, 2013).

With regard to intermittent preventive treatment for malaria, a randomised, placebo-controlled double-blind trial at Niakhar HDSS showed that IPT was effective in preventing seasonal malaria morbidity among under-5s. This finding was taken on board by the World Health Organization and incorporated into its international guidelines for areas with seasonal malaria (Cisse, *et al.*, 2006). Evaluations at Manhica HDSS showed that using sulfadoxine-pyrimethamine as IPT for malaria in pregnant women and infants was effective in preventing malaria in malaria-endemic areas (Macete *et al.*, 2006 ; Menendez *et al.*, 2008). Another study, at Kisumu HDSS, found that IPT for pregnant women combined with daily iron supplementation for 12 weeks is an effective treatment for mild to moderate childhood anaemia (Desai, *et al.*, 2003).

HDSSs have been at the forefront of malaria vaccine trials. The Malaria Clinical Trials Alliance, a programme led by INDEPTH, has strengthened ten African HDSS sites' ability to conduct clinical trials for malaria vaccines by providing training and upgrading infrastructure. Manhica HDSS was the site for the first clinical trials of the RTS,S/AS02A vaccine, which was shown to have efficacy against clinical (36 percent efficacy) and severe malaria (49 percent) in under-5s (Saco, *et al.*, 2013; Sacarlal, *et al.*, 2009). Kombewa HDSS in Kenya hosted a clinical trial of the RTS,S/AS01 vaccine, which demonstrated a halving in episodes of clinical and severe malaria in children aged 5–17 months (Agnandji, *et al.*, 2012).

Malaria treatment methods studied in recent years by HDSSs have focused on antimalarial drugs. At Kombewa, studies proved the efficacy of dispersible Coartem for paediatric use, leading to the subsequent licensing of the drug. A placebo-controlled trial at Navrongo HDSS found that pre-referral use of rectal artesunate for severe malaria can decrease death and severe disability in children (Gomes, *et al.*, 2009). A study at Ifakara found that sulfadoxine-pyrimethamine was an effective first-line treatment against malaria, but that introducing artemisinin-based combination therapy had a minimal impact on child mortality. The researchers concluded that the latter is over-prescribed in Tanzania (Kabanywanyi, *et al.*, 2007). INDEPTH's Effectiveness and Safety Studies of Antimalarials in Africa (INESS), moreover, have seen seven sites collaborating to assess the effectiveness of antimalarial drugs. This marks the first time that African researchers have led Phase IV antimalarial studies in Africa.

HDSS sites have also tracked the spread of resistance to antimalarial drugs. As well as the research at Bandafassi discussed above, Niakhar HDSS in Senegal found that resistance to chloroquine treatment spread rapidly in the 1990s. The rate of chloroquine-resistant infections grew from 10 percent in 1993 to 44 percent just three years later. Child mortality rose over this period, before declining in the 2000s because of increased use of ITNs and a change in the drugs used for anti-malarial treatment (Delaunay, *et al.*, 2013).

Interventions to prevent and treat HIV/AIDS have also been studied extensively by HDSSs. Prevention methods include treatment of sexually transmitted diseases (STDs), which researchers at Magu HDSS in Tanzania found helped prevent HIV transmission among populations exhibiting high STD rates and high-risk sexual behaviour (Korenromp, *et al.*, 2005). Male circumcision has also been shown to be an effective means of reducing transmission, and studies at the Africa Centre HDSS have found that the procedure has high rates of acceptability among both men and women, but that there is a need for many more practitioners to be trained if the procedure is to be rolled out widely (Scott, *et al.*, 2005; Newell and Barnighausen, 2007).

In terms of treatment, antiretroviral therapy (ART) has had a major impact on HIV/AIDS-related mortality at HDSS sites. One study at Kisumu found that increased HIV service delivery (that is, an expansion in the number of facilities providing HIV services and an increase in use of ART) was associated with a 26 percent decline in HIV and tuberculosis mortality (Gargano, *et al.*, 2012). Another showed that early provision of ART to an HIV-infected partner whose sexual partner was uninfected reduced transmission by 96 percent (Cohen, *et al.*, 2011). The sharp rise in mortality at Dikgale HDSS in South Africa was reversed

once ART became widely available – having doubled between 1998 and 2006, mortality fell by more than one-quarter by 2013 (Alberts, *et al.*, 2015). At Karonga in Malawi, adult mortality almost halved between 2005 and 2010, and life expectancy increased by 11 years (Crampin, *et al.*, 2012). At Kyamulibwa in Uganda, HIV prevalence increased between 2000 and 2010 as a result of more people surviving with the disease (Asiki, *et al.*, 2013).

Finally, a number of HDSS sites have highlighted how vulnerability to infectious diseases is reduced by good nutrition and by vaccination. Malnutrition is a problem in many of the areas in which HDSSs operate. At Birbhum in India, 40 percent of adults are under-nourished (Ghosh, *et al.*, 2014). At the Nairobi HDSS, only 20 percent of households are food-secure, while 60 percent of children aged between 18 and 20 months are stunted, one-quarter severely (Fotso, *et al.*, 2012). Similarly, at Nahuca in Nigeria, where infant and child mortality have declined only slowly, 70 percent of under-5s are stunted, 54 percent severely (Alabi, *et al.*, 2014).

Several sites have shown the benefits of good nutrition in terms of preventing disease and increasing the ability to withstand it (Arthur, *et al.*, 2015). A recent review of 67 published studies by members of the INDEPTH network emphasised the effectiveness of early and exclusive breastfeeding in reducing infant and child mortality (Arthur, *et al.*, 2015). At Navrongo HDSS in Ghana, vitamin A supplementation was found to reduce child deaths by 20 percent (Ghana VAST Study Team, 1993 ; Binka, *et al.*, 1994). Conversely, studies at other sites in West Africa have found no effect of such supplementation or of zinc supplementation on key health indicators (Arthur, *et al.*, 2015).

Vaccines' effect on reducing morbidity and mortality from infectious disease has also been widely documented. At Bandafassi HDSS, child mortality was 40 percent lower in the six years following the acceleration of Senegal's Expanded Program on Immunization than in the six years preceding it (Desgrees and Pison, 1996; Pison and Desgrees, 1997). Researchers at Niakhar were instrumental in highlighting the positive effects of measles immunization in reducing child morbidity and mortality (Samb, *et al.*, 1997, Whittle *et al.*, 1999). Another study at the same site led to meningococcal A conjugate vaccine for meningitis being recommended internationally by the World Health Organization (Sow, *et al.*, 2011). The Kisumu HDSS demonstrated an efficacy of 83 percent for the Merck RotaTeq rotavirus vaccine for infants (Armah, *et al.*, 2010), while the Kilifi HDSS showed how a conjugate vaccine for Hib



disease reduced incidence of invasive Hib disease in under-5s by 88% within three years (Cowgill, *et al.*, 2006).

INDEPTH's Working Group on Vaccination and Child Survival is looking more deeply into the effect of nutrient supplementation and vaccines. Its multi-site study, OPTIMUNISE, is using HDSS data to measure the effectiveness of vaccines, micronutrient supplements and de-worming programmes on child health. INDEPTH member centres published 70 papers between 2011 and 2016 on these topics.<sup>2</sup> Another working group is examining the spread of antibiotic resistance in low- and middle-income Asian and African countries. The seven HDSS sites involved are assessing antibiotic access and consumption practices with a view to making recommendations for health policy-makers on the optimal means of improving antibiotic use and reducing the risk of resistance.

## INFECTIOUS DISEASES

### *Trends and patterns*

As life expectancy in the demographic surveillance areas monitored by INDEPTH member sites improves, non-communicable diseases, many of which are associated with aging, are becoming more prevalent. Sites in Asia are further along this road than those in Africa, although there are signs in some African countries that the relative importance of infectious and non-communicable diseases is beginning to shift. With such diseases being a recent phenomenon at many sites, data on them is less extensive than that on infectious diseases, and the focus of studies has so far been on highlighting trends in NCD prevalence and mortality, and identifying risk factors for NCDs, rather than on testing policy and programme interventions.

INDEPTH's Working Group on Mortality Analysis and Cause of Death has shown that of over 80,000 adult deaths registered at INDEPTH sites over 15 years, 36 percent were cause by NCDs, with cancers and cardiovascular disease the main killers at most sites (Streatfield, *et al.*, 2014b). NCD mortality rates were much higher among adults aged 50 years and over than in younger age groups, and highest of all among those aged 65 or over. A significant association was found, moreover, between high rates of HIV prevalence and high rates of NCD mortality, suggesting that HIV infection increases susceptibility to NCDs and reduces the ability to fight them off.

In Asia, at the HDSS at Chi Linh in Vietnam, non-communicable diseases (NCDs) are the leading cause of death. For men the leading killer is cancer, and for women stroke (Tran, *et al.*, 2013). At Birbhum in India, NCDs account for 66 percent of

deaths and infectious diseases for 14 percent (Ghosh, *et al.*, 2014). Even among poorer households, the health transition at Birbhum is well underway.

HDSS sites in Asia have shown how the risk factors for NCDs are becoming more widespread. Risk factors for NCDs that are regularly tracked by HDSSs include behaviours such as smoking, alcohol consumption, exercise and diet. Many sites also monitor research subjects' weight and height, as well as their blood pressure and blood glucose levels (Geubbels, *et al.*, 2015). For example, the proportion of smokers at Chakaria HDSS in Bangladesh fell from 41 percent to 27 percent between 1994 and 2008, although the latter figure remains much higher than the national average. Researchers identified an inverse association between propensity to smoke and socioeconomic status (Hanifi, *et al.*, 2012). At Birbhum, 66 percent of men and 24 percent of women use tobacco (Ghosh, *et al.* 2014). Residents of the demographic surveillance area at Ballabgarh exhibit many of the risk factors for non-communicable diseases. Two-thirds of men and one-quarter of women smoke, while between 2003–4 and 2011–12 the proportion of individuals who consume five or more daily servings of fruit or vegetables fell from 6.3 percent to 0.8 percent for males and from 2.5 percent to 0.1 percent for females (Kant, *et al.*, 2013). Possibly partly as a consequence, the proportion of men who are overweight doubled to 26 percent over the period, while for women it increased from 24 percent to 31 percent.

Evidence is beginning to emerge of an increase in NCDs in Africa. At Ouagadougou HDSS, NCDs accounted for 46.6 percent of all adult deaths (Streatfield, *et al.*, 2014b). At the rural HDSS at Ifakara in Tanzania, the share of NCDs as a cause of death in adults rose from 16 percent to 24 percent between 2003 and 2007 (Narh-Bana, *et al.*, 2012). Cerebrovascular disease and epilepsy were among the most important NCDs, while individuals with less education had a higher risk of dying as a result of an NCD than those who were more educated. At the Agincourt and Dikgale HDSSs in South Africa, both of which have been hard hit by HIV/AIDS, the prevalence of risk factors for NCDs is on the rise. Researchers at Agincourt found that more than 20 percent of adolescent girls were overweight or obese, and that high blood pressure and obesity were increasing among adult women (Kimani-Murage, *et al.*, 2010; Thorogood, *et al.*, 2007). Studies at Dikgale found that risk factors for chronic disease including cardiovascular disease were as high among the rural population at the site as those in urban areas of South Africa (Alberts, *et al.*, 2005).

Another important cause of deaths at many HDSS sites are injuries. These include accidental and deliberate injuries. At Chi Linh HDSS in Vietnam, road traffic injuries are the third leading cause of adult deaths (Tran, *et al.*, 2013). Traffic accidents are also a major cause of death at Nairobi HDSS in Kenya, along with deaths due to illegal liquor (Beguy, *et al.*, 2015). At Rufiji HDSS in Tanzania, men are three times more likely than women to die of injuries, with injuries causing 4 percent of deaths in the demographic surveillance area (Ae-Ngibisi, *et al.*, 2012).

Deliberate injuries also take a toll. At Nairobi HDSS firearms are a leading cause of adult NCD deaths (Beguy, *et al.*, 2015). At Kersa in Ethiopia, 20 percent of women report having suffered violence at the hands of their intimate partners. The rate of female genital mutilation at the site is 88 percent (Assefa, *et al.*, 2015). In Asia, female foeticide has been reported at some sites. Sex-selective abortion is illegal in Vietnam, as is knowing the sex of the foetus, yet at the Chi Linh HDSS 84 percent of expectant mothers knew the sex of their unborn child and 18.5 percent admitted using sex-selective methods. This has resulted in a gender ratio at birth of 106.4 boys for every 100 girls (Tran, *et al.* 2013). Female foeticide is also a significant killer at Ballabgarh HDSS in India. The male to female ratio at the site in 2011 was 113:100 (Kant, *et al.*, 2013).

### **Intervention studies**

There have hitherto been few studies into interventions for NCDs at INDEPTH sites. Most of the treatments are trialled in high-income countries, and the problems for LMICs relate more to rolling out such treatments and encouraging healthy lifestyles as a means to prevent disease. INDEPTH's Adult Health and Aging working group has begun to study NCDs in older adults at three African HDSS sites. It is assessing factors such as physical and cognitive functioning and productivity with a view to making recommendations for policies that will

help delay or prevent the onset of NCDs. The working group obtained funding for this study from the National Institute on Aging and the National Institutes of Health in 2013, but has yet to publish results.

## **DISCUSSION**

The above examples of data produced by INDEPTH members' HDSSs highlight the value of robust, objective data for health policy. The data on overall health trends and on the prevalence of infectious and non-communicable diseases provide a guide for policy-makers who are looking to target their resources towards the most pressing health problems in their societies. Intervention studies provide guidance as to which interventions are effective and ineffective, and among which population groups they are most likely to have a positive impact.

The data on trends and patterns in health demonstrate the importance of tailoring policies to particular settings and particular populations. In Africa, for example, the prevalence of infectious and non-communicable diseases is far from uniform either between or within countries. There are differences between regions and between urban and rural areas, differences between socio-economic groups, differences between males and females and between people of different ages, and in some cases seasonal differences in the prevalence of disease threats. Regular data collection by HDSSs shows these differences clearly, and allows for much more nuanced policy-making than do one-off surveys, while the expertise of the scientists working at the sites is vital for pinpointing emerging threats and defining the most appropriate responses to them. Many studies produced by INDEPTH sites have had major concrete impacts on health in LMICs, and as the health transition continues from high prevalence of infectious diseases to increasing rates of NCDs, their regular, systematic data collection over the long-term offers policy-makers an important weapon as they develop new approaches to tackling these changing threats.

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## **Notes**

<sup>1</sup> Site profiles were reviewed for HDSS sites at Agincourt (South Africa), Ballabgarh (India), Bandafassi (Senegal), Birbhum (India), Chakaria (Bangladesh), Chililab (Vietnam), Dikgale (South Africa), Dodowa (Ghana), Farafenni (Gambia), Ifakara (Tanzania), Karonga (Malawi), Kaya (Burkina Faso), Kersa (Ethiopia), Kilifi (Kenya), Kisumu (Kenya), Kombewa (Kenya), Kyamulibwa (Uganda), Magu

(Tanzania), Manhica (Mozambique), Mbita (Kenya), Mtubatuba (Africa Centre - South Africa), Nahuche (Nigeria), Nairobi (Kenya), Nanoro (Burkina Faso), Navrongo (Burkina Faso), Niakhar (Senegal), Ouagadougou (Burkina Faso), Rufiji (Tanzania), Taabo (Cote d'Ivoire)

<sup>2</sup> For full list, see: <http://www.indepth-network.org/projects/optimize/optimize-reports-and-publications>

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