Global Health Action

INDEPTH NETWORK CAUSE-SPECIFIC MORTALITY

# Adult non-communicable disease mortality in Africa and Asia: evidence from INDEPTH Health and Demographic Surveillance System sites

P. Kim Streatfield[1,2,3], Wasif A. Khan[2,3,4], Abbas Bhuiya[3,5,6], Syed M.A. Hanifi[3,5,6], Nurul Alam[3,7,8], Cheik H. Bagagnan[3,9,10], Ali Sié[3,9,10], Pascal Zabré[3,9,10], Bruno Lankoandé[3,11,12], Clementine Rossier[3,11,12], Abdramane B. Soura[3,11,12], Bassirou Bonfoh[3,13,14], Siaka Kone[3,13,14], Eliezer K. Ngoran[3,13,15], Juerg Utzinger[3,13,16], Fisaha Haile[3,17,18], Yohannes A. Melaku[3,17,18], Berhe Weldearegawi[3,17,18], Pierre Gomez[3,19,20], Momodou Jasseh[3,19,20], Patrick Ansah[3,21,22], Cornelius Debpuur[3,21,22], Abraham Oduro[3,21,22], George Wak[3,21,22], Alexander Adjei[3,23,24], Margaret Gyapong[3,23,25], Doris Sarpong[3,23,25], Shashi Kant[3,25,26], Puneet Misra[3,25,26], Sanjay K. Rai[3,25,26], Sanjay Juvekar[3,27,28], Pallavi Lele[3,27,28], Evasius Bauni[3,29,30], George Mochamah[3,29,30], Carolyne Ndila[3,29,30], Thomas N. Williams[3,29,30,31], Kayla F. Laserson[3,32,33], Amek Nyaguara[3,32,33], Frank O. Odhiambo[3,32,33], Penelope Phillips-Howard[3,32,33], Alex Ezeh[3,34,35], Catherine Kyobutungi[3,34,35], Samuel Oti[3,34,35], Amelia Crampin[3,36,37,38], Moffat Nyirenda[3,36,37], Alison Price[3,36,37,38], Valérie Delaunay[3,39,40], Aldiouma Diallo[3,39,40], Laetitia Douillot[3,39,40], Cheikh Sokhna[3,39,40], F. Xavier Gómez-Olivé[3,41,42], Kathleen Kahn[3,41,42,43], Stephen M. Tollman[3,41,42,43], Kobus Herbst[3,44,45], Joël Mossong[3,44,46], Nguyen T.K. Chuc[3,47,48], Martin Bangha[3], Osman A. Sankoh[3,49,50]* and Peter Byass[3,42,51]

[1]Matlab HDSS, Bangladesh; [2]International Centre for Diarrhoeal Disease Research, Bangladesh; [3]INDEPTH Network, Accra, Ghana; [4]Bandarban HDSS, Bangladesh; [5]Chakaria HDSS, Bangladesh; [6]Centre for Equity and Health Systems, International Centre for Diarrhoeal Disease Research, Bangladesh; [7]AMK HDSS, Bangladesh; [8]Centre for Population, Urbanisation and Climate Change, International Centre for Diarrhoeal Disease Research, Bangladesh; [9]Nouna HDSS, Burkina Faso; [10]Nouna Health Research Centre, Nouna, Burkina Faso; [11]Ouagadougou HDSS, Burkina Faso; [12]Institut Supérieur des Sciences de la Population, Université de Ouagadougou, Burkina Faso and Institut d'Études Démographique et du parcours de vie, Université de Genève, Geneva, Switzerland; [13]Taabo HDSS, Côte d'Ivoire; [14]Centre Suisse de Recherches Scientifiques en Côte d'Ivoire, Abidjan, Côte d'Ivoire; [15]Université Félix Houphoët-Boigny, Abidjan, Côte d'Ivoire; [16]Swiss Tropical and Public Health Institute, Basel, Switzerland; [17]Kilite-Awlaelo HDSS, Ethiopia; [18]Department of Public Health, College of Health Sciences, Mekelle University, Mekelle, Ethiopia; [19]Farafenni HDSS, The Gambia; [20]Medical Research Council, The Gambia Unit, Fajara, The Gambia; [21]Navrongo HDSS, Ghana; [22]Navrongo Health Research Centre, Navrongo, Ghana; [23]Dodowa HDSS, Ghana; [24]Dodowa Health Research Centre, Dodowa, Ghana; [25]Ballabgarh HDSS, India; [26]All India Institute of Medical Sciences, New Delhi, India; [27]Vadu HDSS, India; [28]Vadu Rural Health Program, KEM Hospital Research Centre, Pune, India; [29]Kilifi HDSS, Kenya; [30]KEMRI-Wellcome Trust Research Programme, Kilifi, Kenya; [31]Department of Medicine, Imperial College, St. Mary's Hospital, London, United Kingdom; [32]Kisumu HDSS, Kenya; [33]KEMRI/CDC Research and Public Health Collaboration and KEMRI Center for Global Health Research, Kisumu, Kenya; [34]Nairobi HDSS, Kenya; [35]African Population and Health Research Center, Nairobi, Kenya; [36]Karonga HDSS, Malawi; [37]Karonga Prevention Study, Chilumba, Malawi; [38]London School of Hygiene and Tropical Medicine, London, United Kingdom; [39]Niakhar HDSS,

Authors are listed arbitrarily in order of their site code, and alphabetically within each site.

Global Health Action 2014. © 2014 INDEPTH Network. This is an Open Access article distributed under the terms of the Creative Commons CC-BY 4.0 License (http://creativecommons.org/licenses/by/4.0/), allowing third parties to copy and redistribute the material in any medium or format and to remix, transform, and build upon the material for any purpose, even commercially, provided the original work is properly cited and states its license.



Citation: Glob Health Action 2014, **7**: 25365 - http://dx.doi.org/10.3402/gha.v7.25365
(page number not for citation purpose)

Senegal; [40]Institut de Recherche pour le Developpement (IRD), Dakar, Sénégal; [41]Agincourt HDSS, South Africa; [42]MRC/Wits Rural Public Health and Health Transitions Research Unit (Agincourt), School of Public Health, Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, South Africa; [43]Umeå Centre for Global Health Research, Umeå University, Umeå, Sweden; [44]Africa Centre HDSS, South Africa; [45]Africa Centre for Health and Population Studies, University of KwaZulu-Natal, Somkhele, KwaZulu-Natal, South Africa; [46]National Health Laboratory, Surveillance & Epidemiology of Infectious Diseases, Dudelange, Luxembourg; [47]FilaBavi HDSS, Vietnam; [48]Health System Research, Hanoi Medical University, Hanoi, Vietnam; [49]School of Public Health, Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, South Africa; [50]Hanoi Medical University, Hanoi, Vietnam; [51]WHO Collaborating Centre for Verbal Autopsy, Umeå Centre for Global Health Research, Umeå University, Umeå, Sweden

***Background***: Mortality from non-communicable diseases (NCDs) is a major global issue, as other categories of mortality have diminished and life expectancy has increased. The World Health Organization's Member States have called for a 25% reduction in premature NCD mortality by 2025, which can only be achieved by substantial reductions in risk factors and improvements in the management of chronic conditions. A high burden of NCD mortality among much older people, who have survived other hazards, is inevitable. The INDEPTH Network collects detailed individual data within defined Health and Demographic Surveillance sites. By registering deaths and carrying out verbal autopsies to determine cause of death across many such sites, using standardised methods, the Network seeks to generate population-based mortality statistics that are not otherwise available.
***Objective***: To describe patterns of adult NCD mortality from INDEPTH Network sites across Africa and Asia, according to the WHO 2012 verbal autopsy (VA) cause categories, with separate consideration of premature (15–64 years) and older (65+ years) NCD mortality.
***Design***: All adult deaths at INDEPTH sites are routinely registered and followed up with VA interviews. For this study, VA archives were transformed into the WHO 2012 VA standard format and processed using the InterVA-4 model to assign cause of death. Routine surveillance data also provide person-time denominators for mortality rates.
***Results***: A total of 80,726 adult (over 15 years) deaths were documented over 7,423,497 person-years of observation. NCDs were attributed as the cause for 35.6% of these deaths. Slightly less than half of adult NCD deaths occurred in the 15–64 age group. Detailed results are presented by age and sex for leading causes of NCD mortality. Per-site rates of NCD mortality were significantly correlated with rates of HIV/AIDS-related mortality.
***Conclusions***: These findings present important evidence on the distribution of NCD mortality across a wide range of African and Asian settings. This comes against a background of global concern about the burden of NCD mortality, especially among adults aged under 70, and provides an important baseline for future work.

Keywords: *adults*; *non-communicable disease*; *Africa*; *Asia*; *mortality*; *INDEPTH Network*; *verbal autopsy*; *InterVA*

Responsible Editors: Heiko Becher, University of Hamburg, Germany; Nawi Ng, Umeå University, Sweden.

*Correspondence to: Osman A. Sankoh, INDEPTH Network, PO Box KD213, Kanda, Accra, Ghana, Email: osman.sankoh@indepth-network.org

This paper is part of the Special Issue: *INDEPTH Network Cause-Specific Mortality.* More papers from this issue can be found at http://www.globalhealthaction.net

Received: 3 July 2014; Revised: 30 August 2014; Accepted: 2 September 2014; Published: 29 October 2014

Mortality due to non-communicable diseases (NCDs) of various kinds has become an increasing focus of attention in recent years (1), including at a special meeting of the UN General Assembly in September 2011 (2). This has happened both because of rapid increases in major NCD risk factors to which billions of people globally are exposed and also because many populations are ageing more successfully as a result of various reductions in early-life mortality and increases in mid-life survival. Consequently, more people globally are experiencing the consequences of NCD risk factors in middle and later life, according to the classic theories of epidemiological transition (3). In 2012, WHO Member States at the World Health Assembly made a resolution to 'adopt a global target of a 25% reduction in premature mortality from non-communicable diseases by 2025' (4), although this has been widely misquoted with the omission of the word 'premature'. The biological reality is that human beings who survive into their 80s and 90s, thereby having avoided death from many other causes, are extremely likely to die of NCDs. The public health imperatives around NCDs therefore relate to preventing or delaying NCD incidence (including risk factor management) and effectively managing chronic conditions in the decades of mid-life.

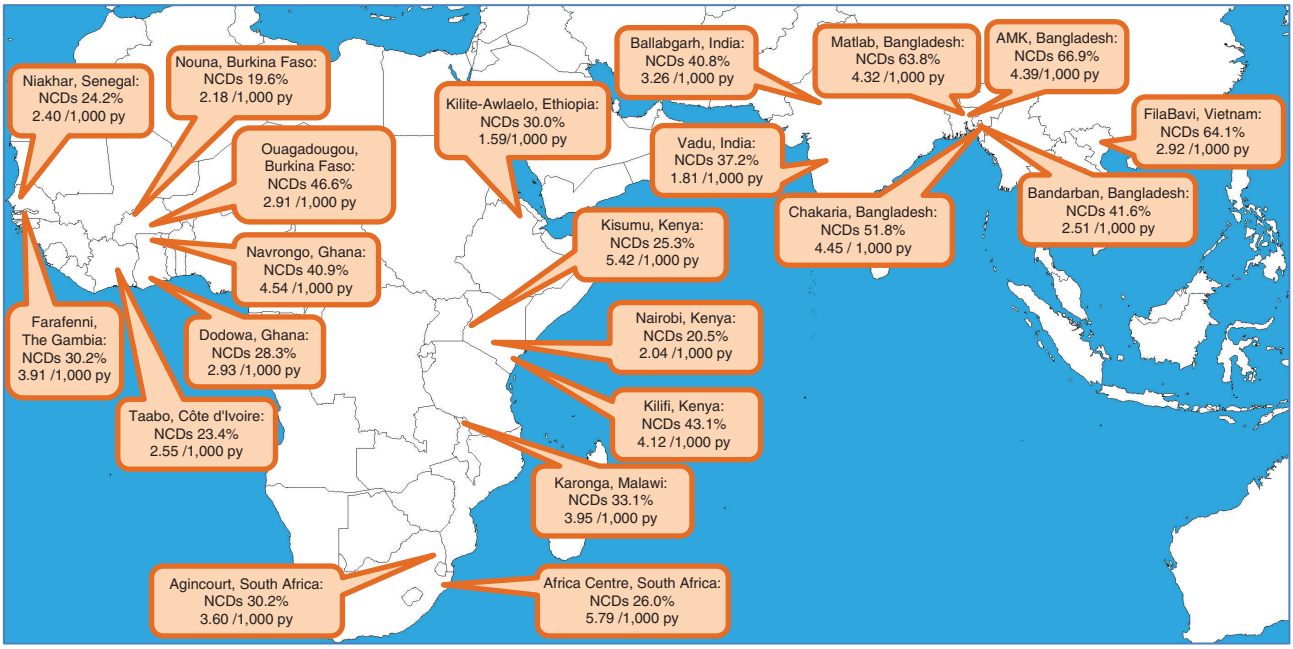


*Fig. 1.* Map showing age–sex–time standardised proportions of mortality due to non-communicable diseases and age–sex–time standardised non-communicable disease mortality rates per 1,000 person-years, for 21 INDEPTH sites.

There has been much written about epidemics of NCD morbidity and mortality globally, and particularly in low- and middle-income countries (5). While it is certainly true that there are many more NCD deaths now than there have been previously, it is critical to understand the medical, social, and demographic drivers of these changes, in addition to trends in specific risk factors, diseases, and health systems responses. This is important in terms of positioning the burden of NCDs appropriately in future development agendas (6).

The INDEPTH Network works with Health and Demographic Surveillance sites (HDSS) across Africa and Asia, which each follow circumscribed populations on a longitudinal basis. Core data collected include person-time at risk, together with deaths and, by means of verbal autopsy (VA), assessment of cause of death (7).

Our aim in this paper is to document deaths among adults (15 years upwards) on the basis of a dataset collected at 22 INDEPTH HDSSs covering Africa and Asia (8), looking particularly at those deaths attributable to NCDs. Although these 22 sites are not designed to be a representative sample, they enable comparisons to be made over widely differing situations.

## Methods

The overall INDEPTH dataset (9) from which these adult NCD mortality analyses are drawn is described in detail elsewhere (8). Across the 22 participating sites (10–31), there was documentation on 80,726 deaths in 7,423,497 person-years of observation for people aged 15 and over. VA interviews were successfully completed on 72,330 (89.6%) of the deaths that occurred. A summary of the detailed methods used in common for this series of multi-site papers is shown in Box 1. NCD mortality was defined as neoplasms, metabolic, cardiovascular, respiratory, abdominal, neurological and other NCDs, corresponding to chapters in WHO 2012 VA standard.

*Box 1.* Summary of methodology based on the detailed description in the introductory paper (8).

**Age–sex–time standardisation**

To avoid effects of differences and changes in age–sex structures of populations, mortality fractions and rates have been adjusted using the INDEPTH 2013 population standard (32). A weighting factor was calculated for each site, age group, sex, and year category in relation to the standard for the corresponding age group and sex, and incorporated into the overall dataset. This is referred to in this paper as age–sex-time standardisation in the contexts where it is used.

**Cause of death assignment**

The InterVA-4 (version 4.02) probabilistic model was used for all the cause of death assignments in the overall dataset (33). InterVA-4 is fully compliant with the WHO 2012 VA standard and generates causes of death categorised by ICD-10 groups (34). The data reported here were collected before the WHO 2012 VA standard was available, but were transformed into the WHO 2012 and InterVA-4 format to optimise cross-site standardisation in cause of death

attribution. For a small proportion of deaths, VA interviews were not successfully completed; a few others contained inadequate information to arrive at a cause of death. InterVA-4 assigns causes of death (maximum 3) with associated likelihoods; thus, cases for which likely causes did not total to 100% were also assigned a residual indeterminate component. This served as a means of encapsulating uncertainty in cause of death at the individual level within the overall dataset, as well as accounting for 100% of every death.

**Overall dataset**

The overall public-domain dataset (9) thus contains between one and four records for each death, with the sum of likelihoods for each individual being unity. Each record includes a specific cause of death, its likelihood, and its age–sex–time weighting.

In this context, all of these data are secondary datasets derived from primary data collected separately by each participating site. In all cases, the primary data collection was covered by site-level ethical approvals relating to ongoing health and demographic surveillance in those specific locations. No individual identity or household location data were included in the secondary data and no specific ethical approvals were required for these pooled analyses.

## Results

After age–sex–time standardisation, 81814.1 deaths were documented, of which 73288.7 were covered by VA interviews; the InterVA-4 model was unable to assign any cause of death for 3458.3 deaths (4.2%), and residual uncertainties (residual likelihoods in cases where likely cause(s) of death did not total to 100%) accounted for 5864.2 deaths (7.2%). As a consequence of sites returning data over a range of time periods, 4.6% of the person-time observed occurred before 2000, 30.0% from 2000 to 2005, and 69.4% from 2006 to 2012.

Non-NCD causes were attributed to 35478.5 deaths (43.4%), while 28487.7 deaths (34.8%) were attributed to 20 specific WHO 2012 cause of death categories, plus the residual 'other and unspecified NCD' category. Since the Purworejo, Indonesia, site achieved limited coverage of adult VAs, and did not report for the period 2006–2012, that site is excluded from the following analyses (1173.4 deaths in 185,306 person-years).

Figure 1 maps the 21 INDEPTH sites, showing the age–sex–time standardised NCD-specific fraction of adult mortality and the age–sex–time standardised NCD-specific mortality rate per 1,000 person-years for each site. This shows a relatively narrow range of variation across sites, while the sites with the highest proportions of NCD-attributable mortality are not necessarily those with the highest rates. Generally, higher proportions of NCD mortality, but not always higher rates, were found in Asia compared to Africa. The urban site in Ouagadougou, Burkina Faso, returned the highest proportion of NCD mortality in Africa (46.6%), while the Africa Centre, South Africa, site reported the highest rate of NCD mortality (5.79 per 1,000 person-years). The highest proportion and rate of NCD mortality in Asia was 66.9% and 4.39 per 1,000 person-years, respectively, at the AMK, Bangladesh, site.

Table 1 shows mortality rates per 1,000 person-years for NCD causes. Age groupings follow the WHO 2012 categories (15–49, 50–64, 65+). NCD mortality rates were substantially lower in the 15–49 age group (range 0.31 to 2.76 per 1,000 person-years across all sites and periods) compared to the 50–64 age group (range 2.81 to 14.06 per 1,000 person-years) and more so compared to the 65-plus age group (range 10.72 to 97.20 per 1,000 person-years).

Figure 2 shows the age–sex–time standardised mortality rates by site for sub-categories of NCD causes of death (neoplasms, metabolic, cardiovascular, respiratory, abdominal, neurological and other NCDs, according to chapters in WHO 2012 VA standard (34)) for 21 INDEPTH HDSS sites. These categories differ slightly from the four main NCD groups that are commonly considered in the global NCD literature, namely cancer, diabetes, cardiovascular disease, and chronic respiratory disease. Cancer and cardiovascular disease map directly to the WHO 2012 VA neoplasms and cardiovascular disease chapters, respectively. Diabetes accounted for 72% of deaths in the metabolic disease chapter, and chronic obstructive pulmonary disease accounted for 65% of deaths in the chronic respiratory disease chapter.

The population burden of premature NCD mortality has to be considered in terms of relative numbers of deaths between age groups, rather than only cause-specific rates, because of the very different population proportions in various age groups. While the mortality rate ratios for NCD mortality between the 15–64 and over-65 year age groups varied from 1:7 (Navrongo, Ghana) to 1:107 (Nairobi, Kenya), with a median of 1:18 (Niakhar, Senegal), this does not mean that the overwhelming burden of NCD mortality in terms of numbers of deaths lay within the over-65 age group. Person-time for the over-65 age group ranged from 1.4% of that for the 15–64 age group (Nairobi, Kenya) to 13.8% (FilaBavi, Vietnam), with a median of 8.2% (Chakaria, Bangladesh). NCD mortality rates for the 15–64 year age group ranged from 0.12 per 1,000 person-years in the Matlab, Bangladesh, site to 0.77 per 1,000 person-years in the Africa Centre, South Africa, site. Similarly for the over-65 age group, the range was from 1.24 in FilaBavi, Vietnam, to 13.4 in Nairobi, Kenya. Consequently, the numbers of NCD deaths in the 15–64 age group, which might be considered as 'premature' NCD mortality, were considerable. Figure 3 presents the percentages of adult NCD deaths for the 15–64



Citation: Glob Health Action 2014, **7**: 25365 - http://dx.doi.org/10.3402/gha.v7.25365

*Table 1.* NCD mortality rates per 1,000 person-years by site, age group and period

| Age group | 15–49 years | | | 50–64 years | | | 65+ years | | |
|---|---|---|---|---|---|---|---|---|---|
| Period | <2000 | 2000–2005 | 2006–2012 | <2000 | 2000–2005 | 2006–2012 | <2000 | 2000–2005 | 2006–2012 |
| Matlab, Bangladesh | | 0.81 | 0.83 | | 6.33 | 7.41 | | 37.55 | 41.27 |
| Bandarban, Bangladesh | | | 0.83 | | | 4.80 | | | 18.31 |
| Chakaria, Bangladesh | | | 0.77 | | | 7.09 | | | 35.58 |
| AMK, Bangladesh | | 0.87 | 0.75 | | 6.60 | 7.12 | | 45.29 | 43.82 |
| Nouna, Burkina Faso | 0.70 | 0.48 | 0.27 | 7.11 | 3.64 | 2.80 | 23.22 | 16.81 | 9.67 |
| Ouagadougou, Burkina Faso | | | 0.63 | | | 5.87 | | | 21.29 |
| Taabo, Côte d'Ivoire | | | 0.67 | | | 3.77 | | | 16.91 |
| Kilite Awlaelo, Ethiopia | | | 0.49 | | | 1.52 | | | 12.32 |
| Farafenni, The Gambia | 1.07 | 0.85 | 0.65 | 7.61 | 6.93 | 4.06 | 24.57 | 29.12 | 21.58 |
| Navrongo, Ghana | | 1.87 | 1.72 | | 10.16 | 8.96 | | 26.82 | 24.51 |
| Dodowa, Ghana | | | 0.84 | | | 5.55 | | | 19.07 |
| Ballabgarh, India | | | 0.56 | | | 6.00 | | | 30.44 |
| Vadu, India | | | 0.43 | | | 3.90 | | | 17.46 |
| Kilifi, Kenya | | | 0.65 | | | 5.45 | | | 27.68 |
| Kisumu, Kenya | | 2.44 | 1.65 | | 7.96 | 7.36 | | 25.95 | 32.05 |
| Nairobi, Kenya | | 0.45 | 0.61 | | 4.21 | 2.76 | | 12.64 | 19.37 |
| Karonga, Malawi | | 1.63 | 0.79 | | 5.70 | 4.70 | | 27.81 | 23.31 |
| Niakhar, Senegal | | 0.76 | 0.56 | | 3.15 | 2.54 | | 24.22 | 16.15 |
| Agincourt, South Africa | 0.53 | 1.02 | 1.25 | 4.01 | 6.88 | 7.79 | 17.10 | 22.48 | 27.26 |
| Africa Centre, South Africa | | 1.26 | 1.06 | | 10.54 | 10.50 | | 36.86 | 36.93 |
| FilaBavi, Vietnam | | | 0.96 | | | 3.76 | | | 28.63 |

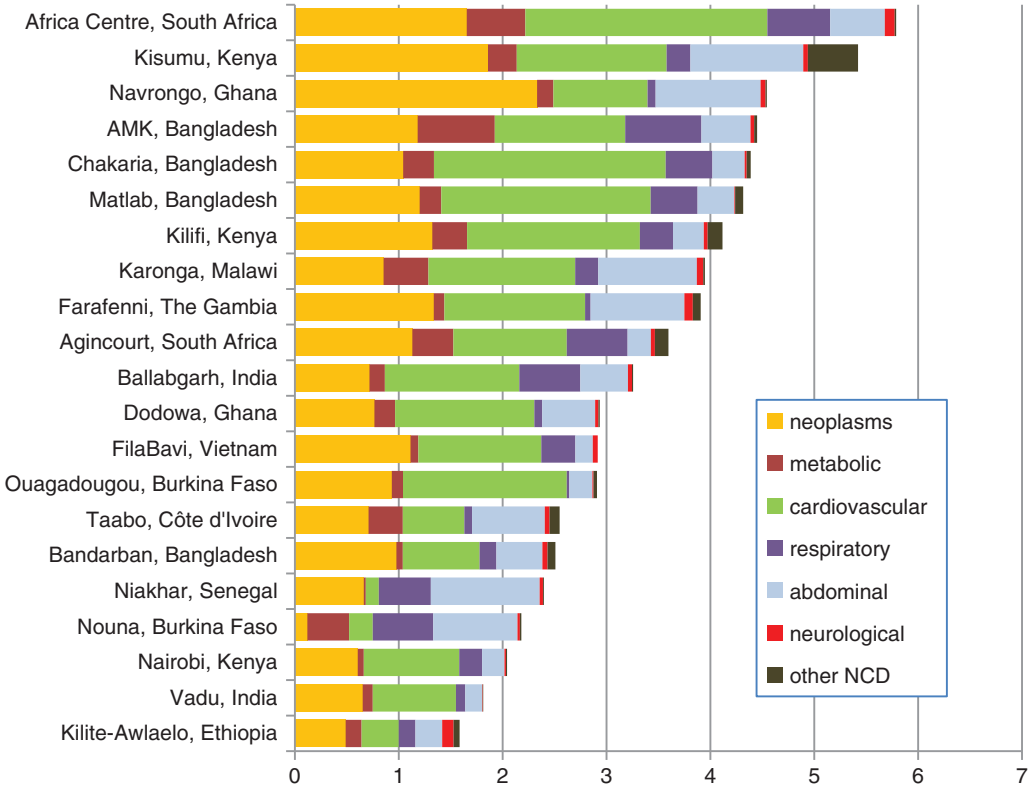


*Fig. 2.* Age–sex–time standardised mortality rates per 1,000 person-years among adults (15 years and over) in 21 INDEPTH HDSS sites in Africa and Asia, by sub-category of non-communicable diseases causing death (according to WHO 2012 VA cause of death chapters).

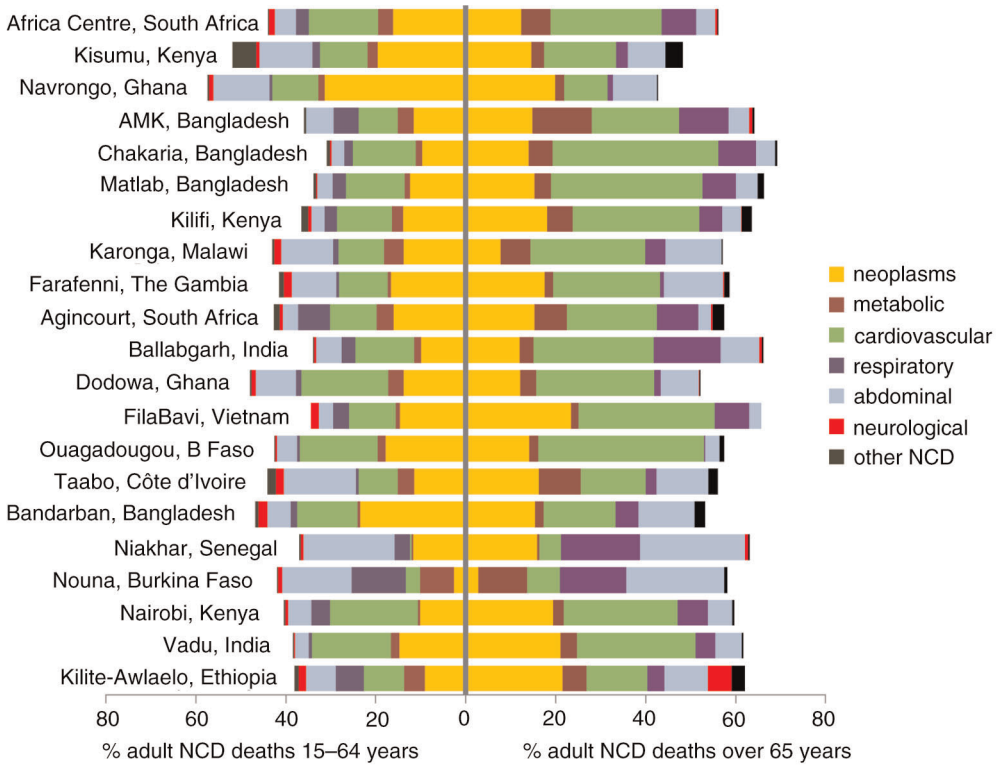


*Fig. 3.* Age–sex–time standardised percentages of adult NCD deaths for the 15–64 and over 65 year age groups by site and cause category.

and over 65-year age groups by site, using the same cause categories as Fig. 2, to illustrate the magnitude of the burden of premature NCD mortality. The overall bar for each site represents 100% of NCD deaths, split by cause categories and age group. Consequently, bars relating to higher life expectancy countries, with higher proportions of older people, tend to be shifted further to the right. Slightly more than half of the overall adult NCD deaths occurred in the over-65 age group, to the right; deaths shown to the left of the axis might be considered as 'premature'. Sites are shown in decreasing order of overall adult NCD mortality rate, the same as in Fig. 2, for ease of comparison.

Table 2 shows cause-specific rates at each site for the various categories of neoplasms specified in the WHO 2012 VA standard, separately for the under- and over-65 year age groups, and by sex, for the period 2006–2012.

Table 3 shows cause-specific rates at each site for other selected categories of NCDs specified in the WHO 2012 VA standard, separately for the under- and over-65 year age groups, and by sex, for the period 2006–2012.

Because some of the sites reporting the highest rates of NCD mortality were also those with the greatest burden of HIV/AIDS-related mortality (as explored from the same dataset in a separate paper (35)), in Fig. 4 we present, separately for the 15–64 and over-65 year age groups, the correlations between NCD and HIV/AIDS mortality rates, showing points for each site and least absolute deviations regression lines for both age groups. In both age categories, correlations are significant ($p < 0.005$; $R^2 = 0.40$ and 0.37, respectively) and suggest that in high HIV settings, around half of the mortality attributed to NCDs may well be associated with HIV. This was also reflected in falling NCD mortality rates among younger adults at most African sites between the 2000–05 and 2006–12 periods (Table 1), as HIV/AIDS-related mortality reduced sharply (35).

## Discussion

This study reports NCD mortality patterns for a large number of adults across a wide range of settings in Africa and Asia. Being part of the overall INDEPTH cause-specific mortality study (8), these rates for NCDs constitute a component of complete mortality surveillance in each site, as distinct from studies only considering NCDs. The age–sex–time standardised results presented here enable comparisons to be made between sites allowing for the dynamics of age–sex population profiles in different places.

Although proportions of NCD mortality were generally higher in Asian sites (Fig. 1), rates of NCD mortality were more consistent across African and Asian sites. This observation is driven less by NCD-specific factors than by demographic transition. Many populations in Asia are experiencing marked increases in mid-life survival, and



Citation: Glob Health Action 2014, **7**: 25365 - http://dx.doi.org/10.3402/gha.v7.25365

*Table 2.* Cause-specific adult mortality rates for neoplasms (according to WHO 2012 VA cause categories), by site, age group, and sex for 2006–2012

| | Oral neoplasms | | | | Digestive neoplasms | | | | Respiratory neoplasms | | | | Breast neoplasms | | Reproductive neoplasms | | | | Other neoplasms | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sex | Males | | Females | | Males | | Females | | Males | | Females | | Females | | Males | | Females | | Males | | Females | |
| Age (years) | <65 | 65+ | <65 | 65+ | <65 | 65+ | <65 | 65+ | <65 | 65+ | <65 | 65+ | <65 | 65+ | <65 | 65+ | <65 | 65+ | <65 | 65+ | <65 | 65+ |
| Bangladesh: Matlab | 0.01 | | 0.01 | 0.04 | 0.45 | 3.84 | 0.23 | 2.35 | 0.38 | 5.41 | 0.12 | 2.80 | 0.03 | 0.06 | 0.03 | 0.56 | 0.05 | 1.34 | 0.19 | 1.95 | 0.05 | 1.89 |
| Bangladesh: Bandarban | | | 0.02 | | 0.61 | 0.70 | 0.19 | 1.30 | 0.17 | 3.88 | | 1.97 | 0.06 | | 0.04 | | 0.14 | 1.40 | 0.24 | 0.71 | 0.05 | 0.77 |
| Bangladesh: Chakaria | | | | 0.2 | 0.16 | 1.82 | 0.08 | 1.38 | 0.16 | 4.47 | 0.15 | 2.36 | 0.02 | 0.37 | 0.00 | 0.69 | 0.02 | 1.01 | 0.30 | 2.55 | 0.18 | 1.72 |
| Bangladesh: AMK | | 0.19 | 0.01 | | 0.30 | 2.23 | 0.25 | 3.12 | 0.19 | 5.40 | 0.09 | 1.76 | 0.02 | | 0.01 | 0.42 | 0.04 | 1.02 | 0.11 | 1.46 | 0.04 | 1.55 |
| Burkina Faso: Nouna | | | | | 0.03 | 0.35 | 0.01 | 0.11 | 0.02 | | | | | | | | 0.00 | 0.23 | | | | |
| Burkina Faso: Ouagadougou | 0.01 | | 0.01 | | 0.20 | 3.85 | 0.15 | 0.64 | 0.19 | 2.55 | 0.11 | 1.69 | 0.04 | | 0.05 | 0.76 | 0.07 | 0.52 | 0.08 | 0.72 | 0.01 | 0.31 |
| Cote d'Ivoire: Taabo | 0.07 | 1.55 | | | 0.23 | 1.52 | 0.05 | 1.69 | 0.01 | 0.37 | 0.03 | | 0.03 | 0.14 | | 1.14 | 0.06 | | 0.08 | 2.21 | | 1.25 |
| Ethiopia: Kilite Awlaelo | | | | | 0.04 | 0.80 | 0.07 | 1.27 | 0.08 | 1.88 | 0.05 | 1.27 | | | | 0.41 | 0.03 | 0.44 | 0.05 | 0.87 | | 1.43 |
| The Gambia: Farafenni | | 0.52 | | | 0.32 | 2.59 | 0.15 | 1.52 | 0.03 | 1.40 | 0.03 | 1.03 | 0.08 | | 0.02 | 0.99 | 0.06 | | 0.14 | 2.51 | 0.06 | 1.84 |
| Ghana: Navrongo | 0.04 | 0.38 | 0.03 | 0.09 | 1.57 | 9.51 | 0.89 | 5.25 | 0.29 | 3.78 | 0.11 | 1.38 | 0.14 | 0.34 | 0.13 | 1.08 | 0.15 | 1.80 | 0.05 | 0.33 | 0.01 | 0.29 |
| Ghana: Dodowa | | 0.03 | 0.01 | | 0.32 | 3.37 | 0.25 | 1.99 | 0.02 | 0.56 | 0.04 | 0.53 | 0.05 | 0.16 | 0.02 | 0.2 | 0.05 | 0.48 | 0.03 | 1.18 | 0.05 | 0.84 |
| India: Ballabgarh | 0.01 | 0.08 | 0.01 | 0.26 | 0.27 | 2.82 | 0.19 | 2.13 | 0.05 | 1.16 | 0.03 | 0.80 | | 0.12 | 0.06 | 2.06 | 0.03 | 1.13 | 0.05 | 0.31 | 0.04 | 0.30 |
| India: Vadu | 0.01 | 0.47 | | | 0.27 | 5.95 | 0.10 | 1.17 | 0.04 | 1.80 | 0.05 | 1.08 | 0.06 | | 0.02 | 0.07 | 0.07 | 1.43 | 0.02 | | | 0.19 |
| Kenya: Kilifi | | 0.45 | 0.01 | | 0.17 | 2.85 | 0.12 | 0.94 | 0.29 | 4.02 | 0.14 | 2.36 | 0.01 | | 0.01 | 1.02 | 0.05 | 0.55 | 0.14 | 3.16 | 0.07 | 1.27 |
| Kenya: Kisumu | 0.03 | 0.06 | 0.02 | 0.10 | 0.39 | 3.33 | 0.31 | 2.01 | 0.36 | 5.11 | 0.27 | 3.19 | 0.04 | 0.07 | 0.01 | 0.34 | 0.08 | 0.55 | 0.46 | 3.47 | 0.19 | 3.31 |
| Kenya: Nairobi | | 0.14 | 0.01 | | 0.07 | 0.86 | 0.02 | 1.48 | 0.07 | 4.41 | 0.06 | 2.80 | 0.01 | 0.45 | 0.01 | | 0.04 | 1.71 | 0.06 | 0.84 | 0.01 | 0.44 |
| Malawi: Karonga | | | 0.01 | | 0.22 | 2.56 | 0.20 | 1.12 | | 0.25 | 0.01 | 0.08 | 0.03 | 0.21 | 0.02 | 0.55 | 0.17 | 1.27 | 0.02 | | 0.01 | |
| Senegal: Niakhar | | | | | 0.09 | 0.55 | 0.07 | 0.19 | | 0.14 | 0.06 | 0.13 | 0.01 | | | 0.24 | 0.01 | 0.82 | 0.25 | 4.59 | 0.02 | 2.02 |
| South Africa: Agincourt | 0.01 | | 0.01 | 0.09 | 0.24 | 1.29 | 0.17 | 2.69 | 0.26 | 2.70 | 0.19 | 2.68 | 0.08 | 0.13 | 0.02 | 0.24 | 0.15 | 0.68 | 0.12 | 0.99 | 0.07 | 1.69 |
| South Africa: Africa Centre | 0.03 | 0.05 | 0.02 | 0.07 | 0.38 | 1.88 | 0.18 | 0.86 | 0.34 | 5.42 | 0.20 | 1.62 | 0.06 | 0.27 | 0.04 | 1.31 | 0.23 | 1.47 | 0.18 | 2.31 | 0.07 | 1.03 |
| Vietnam: FilaBavi | | | 0.01 | | 0.24 | 2.85 | 0.17 | 1.37 | 0.38 | 8.61 | 0.06 | 2.74 | 0.01 | | 0.03 | 0.50 | 0.04 | 1.06 | 0.20 | 3.50 | 0.08 | 1.60 |

*Table 3.* Cause-specific adult mortality rates for selected NCDs (according to WHO 2012 VA cause categories), by site, age group, and sex for 2006–2012

| | Diabetes mellitus | | | | Acute cardiac disease | | | | Stroke | | | | Other cardiac disease | | | | Chronic obstructive pulmonary disease | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sex | Males | | Females | | Males | | Females | | Males | | Females | | Males | | Females | | Males | | Females | |
| Age (years) | <65 | 65+ | <65 | 65+ | <65 | 65+ | <65 | 65+ | <65 | 65+ | <65 | 65+ | <65 | 65+ | <65 | 65+ | <65 | 65+ | <65 | 65+ |
| Bangladesh: Matlab | 0.04 | 0.91 | 0.03 | 1.71 | 0.30 | 2.07 | 0.05 | 0.47 | 0.60 | 14.14 | 0.39 | 17.03 | 0.27 | 4.74 | 0.10 | 3.44 | 0.13 | 2.92 | 0.03 | 1.71 |
| Bangladesh: Bandarban | | | | | 0.35 | 3.75 | | 0.33 | 0.15 | 3.15 | 0.16 | 2.69 | 0.06 | 0.35 | 0.13 | 0.73 | | 0.71 | 0.04 | 2.64 |
| Bangladesh: Chakaria | 0.10 | 5.19 | 0.19 | 7.13 | 0.06 | 2.98 | 0.03 | 1.39 | 0.27 | 5.12 | 0.24 | 6.00 | 0.10 | 3.28 | 0.10 | 2.93 | 0.11 | 5.04 | 0.21 | 4.95 |
| Bangladesh: AMK | 0.09 | 2.61 | 0.08 | 2.26 | 0.40 | 2.31 | 0.06 | 1.55 | 0.43 | 14.38 | 0.31 | 16.82 | 0.35 | 6.98 | 0.22 | 5.06 | 0.09 | 5.63 | 0.06 | 2.65 |
| Burkina Faso: Nouna | 0.07 | 1.76 | 0.12 | 2.22 | | 0.10 | 0.01 | | 0.04 | 2.26 | 0.03 | 0.27 | | 0.08 | | 0.41 | 0.25 | 2.06 | 0.09 | 1.35 |
| Burkina Faso: Ouagadougou | 0.03 | 0.26 | 0.03 | | 0.15 | 2.86 | 0.05 | 1.25 | 0.29 | 11.66 | 0.21 | 6.54 | 0.06 | 5.89 | 0.06 | 0.22 | | | | |
| Cote d'Ivoire: Taabo | | 0.51 | 0.07 | 1.12 | 0.02 | | 0.03 | | 0.10 | 2.87 | 0.09 | | 0.07 | 5.63 | 0.11 | 0.53 | 0.03 | 1.49 | | |
| Ethiopia: Kilite Awlaelo | 0.03 | 0.53 | 0.03 | 0.40 | 0.03 | 0.49 | 0.01 | 0.18 | 0.06 | 1.81 | 0.08 | 1.18 | 0.07 | 1.16 | 0.06 | 0.57 | 0.09 | 0.41 | 0.02 | 0.61 |
| The Gambia: Farafenni | | 0.27 | 0.03 | | 0.14 | 0.34 | 0.02 | 0.43 | 0.10 | 6.36 | 0.31 | 7.12 | 0.06 | 1.94 | 0.05 | 0.45 | 0.02 | 0.92 | | |
| Ghana: Navrongo | 0.08 | 1.15 | 0.07 | 0.66 | 0.37 | 2.64 | 0.09 | 0.93 | 0.26 | 2.60 | 0.15 | 1.88 | 0.16 | 2.05 | 0.14 | 1.41 | 0.03 | 0.76 | 0.02 | 0.54 |
| Ghana: Dodowa | 0.04 | 0.78 | 0.01 | 0.39 | 0.24 | 4.30 | 0.17 | 2.60 | 0.27 | 4.93 | 0.30 | 5.09 | 0.06 | 1.48 | 0.09 | 1.34 | 0.01 | 0.10 | | 0.08 |
| India: Ballabgarh | 0.05 | 1.67 | 0.05 | 0.81 | 0.22 | 4.38 | 0.20 | 1.63 | 0.26 | 7.78 | 0.13 | 5.38 | 0.12 | 3.96 | 0.07 | 2.12 | 0.09 | 8.54 | 0.09 | 4.39 |
| India: Vadu | 0.01 | 0.24 | 0.02 | | 0.08 | 1.64 | 0.08 | 1.02 | 0.14 | 4.12 | 0.18 | 5.43 | 0.07 | 1.41 | 0.15 | 1.17 | 0.01 | 1.19 | | 0.74 |
| Kenya: Kilifi | 0.04 | 1.91 | 0.02 | 0.73 | 0.03 | 0.92 | 0.02 | 0.29 | 0.29 | 7.00 | 0.24 | 7.16 | 0.15 | 5.94 | 0.14 | 3.84 | 0.05 | 1.92 | 0.03 | 1.25 |
| Kenya: Kisumu | 0.05 | 2.04 | 0.02 | 0.56 | 0.05 | 0.85 | 0.03 | 0.49 | 0.13 | 1.27 | 0.10 | 2.18 | 0.39 | 8.84 | 0.38 | 7.97 | 0.07 | 1.89 | 0.03 | 1.64 |
| Kenya: Nairobi | 0.01 | | 0.00 | 0.44 | 0.10 | 1.16 | 0.04 | 1.58 | 0.04 | 0.50 | 0.03 | 1.81 | 0.27 | 5.61 | 0.27 | 6.25 | 0.03 | 1.23 | 0.00 | 1.39 |
| Malawi: Karonga | 0.02 | 1.97 | 0.08 | 0.58 | 0.08 | 1.06 | | 0.83 | 0.22 | 6.41 | 0.23 | 7.12 | 0.04 | 2.80 | 0.04 | 2.76 | | 1.47 | 0.01 | 1.72 |
| Senegal: Niakhar | | | | | | 0.60 | | 0.38 | | 1.13 | | 0.59 | | 0.14 | 0.02 | 0.20 | 0.09 | 5.15 | 0.03 | 4.03 |
| South Africa: Agincourt | 0.14 | 1.83 | 0.12 | 6.57 | 0.07 | 0.29 | 0.04 | 0.60 | 0.25 | 2.53 | 0.24 | 11.42 | 0.17 | 2.15 | 0.19 | 8.77 | 0.22 | 1.69 | 0.11 | 4.71 |
| South Africa: Africa Centre | 0.18 | 4.22 | 0.25 | 4.20 | 0.12 | 0.75 | 0.06 | 0.34 | 0.23 | 6.36 | 0.26 | 6.58 | 0.33 | 8.82 | 0.47 | 9.79 | 0.06 | 4.14 | 0.08 | 4.09 |
| Vietnam: FilaBavi | 0.02 | 0.36 | | 0.28 | 0.06 | 1.40 | 0.02 | 0.42 | 0.23 | 8.27 | 0.12 | 10.04 | 0.32 | 5.00 | 0.14 | 2.83 | 0.02 | 1.11 | | 0.69 |

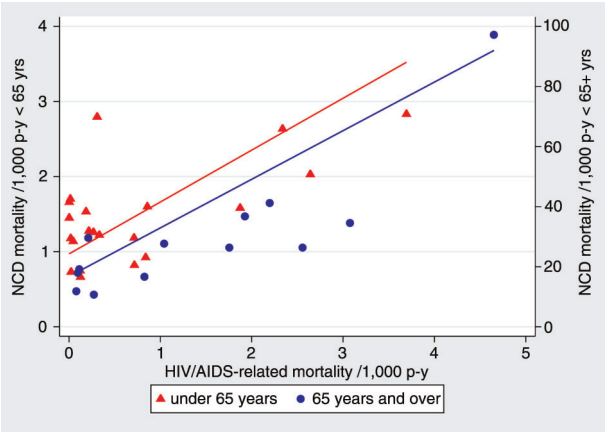


*Fig. 4.* Age–sex–time standardised NCD mortality for 15–64 and over-65 year age groups in relation to age–sex–time standardised HIV/AIDS-related mortality in the same populations, all per 1,000 person-years.

consequently life expectancy, which lead to historically low levels of crude mortality. Thus, according to UN Population estimates, many Asian countries currently record much lower crude mortality rates than their European and American counterparts, having reduced infection-related mortality but not having yet accumulated substantial population proportions of older people (36). As populations gain larger numbers of older people, there will be increasing numbers of NCD-related deaths, even if rates remain the same.

Because not all sites operated population surveillance for the same time period, we have limited evidence on the time trends in NCD mortality rates (Table 1). However, in the sites where trends could be seen, there was little clear evidence of NCD mortality rates increasing over time. As expected for NCD mortality, rates increased very markedly with age; however, the relatively small population proportions of people over 65 years in most of these sites means that the high mortality rates observed in that age group do not yet translate into large numbers of deaths.

Figure 2 shows that cancers and cardiovascular diseases were the major components of NCD mortality in almost all sites. Similar proportions of most causes were seen across most sites; a notable exception was the lack of cancer-related mortality at the Nouna, Burkina Faso, site, which is possibly a consequence of items missing from the VA instrument in use there. Some cancer deaths at Nouna were probably misclassified into the relatively high rates of respiratory and abdominal NCDs at that site. This is an example of some of the difficulties that may occur as a result of harmonising VA data collected at many sites, over different time periods, using a variety of antecedents to the WHO 2012 standard (37). This is discussed further in the introductory paper (8) but there are no simple solutions.

Table 2 shows a breakdown of cancer-related mortality rates. As one of few long-established national cancer registries in sub-Saharan Africa, the Gambian cancer registry has reported incidence rates for various cancers over more than 20 years, partly with the aim of tracking possible reductions in liver cancer incidence following the pilot introduction of hepatitis B vaccination in the 1980s (38). Although incidence and mortality rates are not directly comparable, there are similar age–sex patterns in the Gambian incidence rates and the mortality rates reported here, particularly for several of the West African sites. In eastern and southern Africa, cancer mortality rates may also be influenced by high HIV rates (39). Respiratory cancer mortality as reported here showed higher rates for men in most sites over both age groups, which probably reflects gendered norms around smoking as a risk factor. Appreciable rates of 'other neoplasms' were recorded from many sites, which may partly reflect a lack of specific information about cancers recalled in VA interviews, or a lack of specific items in some historic VA instruments.

Table 3 shows, in the same format as Table 2, mortality rates for diabetes, cardiovascular disease, and chronic obstructive pulmonary disease. These categories were major contributors to NCD mortality across many sites, although the relative magnitude of these categories of mortality varied between sites. Some sites were using VA instruments designed before NCDs were considered to be major causes of death in the populations concerned. It is likely that the quality of NCD cause assignment achievable by InterVA-4 will increase as primary VA data collected according to the complete WHO 2012 VA specification become more widely available. Nevertheless, the overall consistency observed across these varied sites in many respects suggests that historical inter-site variations did not have a major influence on the overall pattern of NCD mortality findings.

The importance of separating NCD mortality into premature and less-avoidable groupings by age is clearly illustrated in Fig. 3. Due consideration must be given to both NCD mortality rates as well as numbers of NCD deaths in considering how disease burdens may be changing. Here, we have somewhat arbitrarily taken 65 years as the cut-off for considering premature mortality, because that fitted with the WHO 2012 VA age groups used in this dataset. In addition, many of the countries represented here have life expectancies at birth in the range of 60 to 70 years, and so 65 years may represent a reasonable dichotomy in terms of 'prematurity'. In the global context, 70 years might be a more reasonable cut-off (40). As yet, none of the countries represented here has a top-heavy population pyramid, with the consequence that there is a reasonably even balance in proportions of NCD deaths occurring before and after 65 years of age, despite high NCD rates among older people. However, it is to be expected, as time passes, that there

will be a gradual rightward shift in the pattern shown in Fig. 3, unless increased NCD risk factor exposures at younger ages also increase NCD mortality rates among the under-65 age group. Nevertheless, the appreciable number of NCD deaths recorded among the under-65 age group must also reflect a considerable burden of chronic disease morbidity in that otherwise productive age group. To the contrary, modelling results suggest that it could be possible to achieve significant global reductions in premature (under-70 years) NCD deaths if relevant risk factors were appropriately managed (40); however, the extent to which those risk factors are likely to be effectively managed in the countries reported here remains an important question.

The contribution of diabetes to the overall picture of NCD mortality in these populations was relatively small compared to cancers and cardiovascular diseases. Whether this reflects situations where risk factors are not yet translating into mortality rates, or whether VA methods led to some misclassification of diabetes mortality into, for example, cardiovascular deaths is uncertain.

The correlations between HIV-related mortality and NCD mortality across the whole adult age range, as shown in Fig. 4, show how important it is to take a holistic view of cause-specific mortality across entire populations. The increased NCD mortality rates in higher HIV mortality populations here are consistent with previous work that analysed causes of death by HIV status (39). This is clearly an important factor to bear in mind when comparing patterns of NCD mortality across sites with varying HIV epidemiology. The ICD-10 system tries to classify almost all deaths in HIV-positive people under the B2 categories related to HIV (41). In reality, however, particularly if HIV status is not known and for final illnesses that are not indicative of HIV/AIDS, it is very likely (by any means of cause of death assignment) that a proportion of deaths among HIV-positive people will be attributed to NCDs. This is likely to be an increasing issue as higher proportions of HIV-positive people receive effective antiretroviral treatment.

## Conclusions

Against a background of considerable concern about the magnitude of the global NCD mortality burden, these population-based findings provide useful geographic examples of the state of adult NCD mortality across a range of locations in Africa and Asia, standardised for ease of comparison. The importance of distinguishing between premature NCD mortality and the inevitably high rates of NCDs that occur late in life is clear from these data. These findings also provide a useful baseline from which to track future trends in NCD mortality, using the same standardised methods. It is also evident that, in areas of high HIV endemicity, NCD mortality rates have to be seen as possibly including some HIV-related deaths, in cases where no clear evidence of HIV status was available.

## Acknowledgements

We are grateful to all the residents of INDEPTH HDSS sites who have contributed personal information to this mortality dataset, to the field staff who undertook so many verbal autopsy interviews, and the data management staff who handled the data at every participating site. INDEPTH thanks all the site scientists who participated in bringing this work together, and who variously participated in analysis workshops in Ghana, Belgium, Thailand, and the United Kingdom. The INDEPTH Network is grateful for core funding from Sida, the Wellcome Trust, and the William & Flora Hewlett Foundation. The Umeå Centre for Global Health Research is core funded by Forte, the Swedish Research Council for Health, Working Life and Welfare (grant 2006-1512). PB's residency at the University of the Witwatersrand Rural Knowledge Hub to analyse and draft these results was supported by the European Community Marie Curie Actions IPHTRE project (no. 295168). icddr,b is thankful to the Governments of Australia, Bangladesh, Canada, Sweden and the UK for providing core/unrestricted support. The Ouagadougou site thanks the Wellcome Trust for its financial support to the Ouagadougou HDSS (grant number WT081993MA). The Kilite Awlaelo HDSS is supported by the US Centers for Disease Control and Prevention (CDC) and the Ethiopian Public Health Association (EPHA), in accordance with the EPHA-CDC Cooperative Agreement No.5U22/PS022179_10 and Mekelle University, though these findings do not necessarily represent the funders' official views. The Farafenni site is supported by the UK Medical Research Council. The Vadu site is thankful for the core continued funding support from KEM Hospital Research Centre since 2004. The Kilifi site is supported through core support to the KEMRI-Wellcome Trust Major Overseas Programme from the Wellcome Trust. TNW is supported by a Senior Fellowship (091758) and CN through a Strategic Award (084538) from the Wellcome Trust. This paper is published with permission from the Director of KEMRI. The Kisumu site wishes to convey its gratitude for the contribution of the late Dr. Kubaje Adazu to the development of KEMRI/CDC HDSS, which was implemented and continues to be supported through a cooperative agreement between KEMRI and CDC. The Nairobi Urban Health and Demographic Surveillance System (NUHDSS), Kenya, since its inception has received support from the Rockefeller Foundation (USA), the Wellcome Trust (UK), the William and Flora Hewlett Foundation (USA), Comic Relief (UK), the Swedish International Development Cooperation Agency (SIDA) and the Bill and Melinda Gates Foundation (USA). The Agincourt site thanks the School of Public Health and Faculty of Health Sciences, University of the Witwatersrand, and the Medical Research Council, South Africa, for having provided vital support since inception of the Agincourt HDSS. Core funding has been provided by the Wellcome Trust, UK (Grants 058893/Z/99/A; 069683/Z/02/Z; 085477/Z/08/Z) with contributions from the National Institute on Aging (NIA) of the NIH, William and Flora Hewlett Foundation, and Andrew W Mellon Foundation, USA.

## Conflict of interest and funding

The authors have not received any funding or benefits from industry or elsewhere to conduct this study.

## References

1. World Health Organization (2011). Global status report on non-communicable diseases 2010. Geneva: WHO.

2. Beaglehole R, Bonita R, Horton R, Adams C, Alleyne G, Asaria P, et al. Priority actions for the non-communicable disease crisis. Lancet 2011; 377: 1438–47.
3. Santosa A, Wall S, Fottrell E, Högberg U, Byass P. The development and experience of epidemiological transition theory over four decades: a systematic review. Glob Health Action 2014; 7: 25374, http://dx.doi.org/10.3402/gha.v7.25374
4. World Health Organization (2012). Sixty-fifth World Health Assembly, second report of Committee A. A65/54, Geneva: WHO.
5. Dalal S, Beunza JJ, Volmink J, Adebamowo C, Bajunirwe F, Njelekela M, et al. Non-communicable diseases in sub-Saharan Africa: what we know now. Int J Epidemiol 2011; 40: 885–901.
6. Alleyne G, Binagwaho A, Haines A, Jahan S, Nugent R, Rojhani A. Embedding non-communicable diseases in the post-2015 development agenda. Lancet 2013; 381: 566–74.
7. Sankoh O, Byass P. The INDEPTH Network: filling vital gaps in global epidemiology. Int J Epidemiol 2012; 41: 579–88.
8. Streatfield PK, Khan WA, Bhuiya A, Alam N, Sié A, Soura AB, et al. Cause-specific mortality in Africa and Asia: evidence from INDEPTH Health and Demographic Surveillance System sites. Glob Health Action 2014; 7: 25362, http://dx.doi.org/10.3402/gha.v7.25362
9. INDEPTH Network. INDEPTH Network Cause-Specific Mortality - Release 2014. Oct 2014. Provided by the INDEPTH Network Data Repository. www.indepth-network.org. doi: 10.7796/INDEPTH.GH003.COD2014.v1.
10. Razzaque A, Nahar L, Akter Khanam M, Streatfield PK. Socio-demographic differentials of adult health indicators in Matlab, Bangladesh: self-rated health, health state, quality of life and disability level. Glob Health Action 2010; 3: 4618, http://dx.doi.org/10.3402/gha.v3i0.4618
11. INDEPTH Network. Bandarban HDSS. Available from: http://www.indepth-network.org/Profiles/Bandarban HDSS.pdf
12. Hanifi MA, Mamun AA, Paul A, Hasan SA, Hoque S, Sharmin S, et al. Profile: the Chakaria Health and Demographic Surveillance System. Int J Epidemiol 2012; 41: 667–75.
13. Lindeboom W, Das SC, Ashraf A. Health and Demographic Surveillance report 2009 – Abhoynagar and Mirsarai. Dhaka, Bangladesh; ICDDR,B; 2011.
14. Sié A, Louis VR, Gbangou A, Müller O, Niamba L, Stieglbauer G, et al. The Health and Demographic Surveillance System (HDSS) in Nouna, Burkina Faso, 1993–2007. Glob Health Action 2010; 3: 5284, http://dx.doi.org/10.3402/gha.v3i0.5284
15. Rossier C, Soura A, Baya B, Compaoré G, Dabiré B, Dos Santos S, et al. Profile: the Ouagadougou Health and Demographic Surveillance System. Int J Epidemiol 2012; 41: 658–66.
16. Kouadio MK, Righetti AA, Abé NN, Wegmüller R, Weiss MG, N'goran EK, et al. Local concepts of anemia-related illnesses and public health implications in the Taabo Health Demographic Surveillance System, Côte d'Ivoire. BMC Hematol 2013; 13: 5.
17. Weldearegawi B, Ashebir Y, Gebeye E, Gebregziabiher T, Yohannes M, Mussa S, et al. Emerging chronic non-communicable diseases in rural communities of Northern Ethiopia: evidence using population-based verbal autopsy method in Kilite Awlaelo surveillance site. Health Policy Plan 2013; 28: 891–8.
18. Oduro AR, Wak G, Azongo D, Debpuur C, Wontuo P, Kondayire F, et al. Profile: the Navrongo Health and Demographic Surveillance System. Int J Epidemiol 2012; 41: 968–76.
19. Gyapong M, Sarpong D, Awini E, Manyeh AK, Tei D, Odonkor G, et al. Profile: the Dodowa Health and Demographic Surveillance System. Int J Epidemiol 2013; 42: 1686–96.
20. Jasseh M, Webb EL, Jaffar S, Howie S, Townend J, Smith PG, et al. Reaching Millennium Development Goal 4 – the Gambia. Trop Med Int Health 2011; 16: 1314–25.
21. Ng N, Hakimi M, Santosa A, Byass P, Wilopo SA, Wall S. Is self-rated health an independent index for mortality among older people in Indonesia? PLoS One 2012; 7: e35308.
22. Kant S, Misra P, Gupta S, Goswami K, Krishnan A, Nongkynrih B, et al. Profile: the Ballabgarh Health and Demographic Surveillance System (CRHSP-AIIMS). Int J Epidemiol 2013; 42: 758–68.
23. Hirve S, Juvekar S, Sambhudas S, Lele P, Blomstedt Y, Wall S, et al. Does self-rated health predict death in adults aged 50 years and above in India? Evidence from a rural population under Health and Demographic Surveillance. Int J Epidemiol 2012; 41: 1719–27.
24. Scott JA, Bauni E, Moisi JC, Ojal J, Gatakaa H, Nyundo C, et al. Profile: the Kilifi Health and Demographic Surveillance System (KHDSS). Int J Epidemiol 2012; 41: 650–7.
25. Odhiambo FO, Laserson KF, Sewe M, Hamel MJ, Feikin DR, Adazu K, et al. Profile: the KEMRI/CDC Health and Demographic Surveillance System – Western Kenya. Int J Epidemiol 2012; 41: 977–87.
26. Oti SO, Mutua M, Mgomella GS, Egondi T, Ezeh A, Kyobutungi C. HIV mortality in urban slums of Nairobi, Kenya 2003–2010: a period effect analysis. BMC Public Health 2013; 13: 588.
27. Crampin AC, Dube A, Mboma S, Price A, Chihana M, Jahn A, et al. Profile: the Karonga Health and Demographic Surveillance System. Int J Epidemiol 2012; 41: 676–85.
28. Delaunay V, Douillot L, Diallo A, Dione D, Trape JF, Medianikov O, et al. Profile: the Niakhar Health and Demographic Surveillance System. Int J Epidemiol 2013; 42: 1002–11.
29. Kahn K, Collinson MA, Gómez-Olivé FX, Mokoena O, Twine R, Mee P, et al. Profile: Agincourt health and socio-demographic surveillance system. Int J Epidemiol 2012; 41: 988–1001.
30. Herbst AJ, Mafojane T, Newell ML. Verbal autopsy-based cause-specific mortality trends in rural KwaZulu-Natal, South Africa, 2000–2009. Popul Health Metr 2011; 9: 47.
31. Huong DL, Minh HV, Vos T, Janlert U, Van DD, Byass P. Burden of premature mortality in rural Vietnam from 1999–2003: analyses from a Demographic Surveillance Site. Popul Health Metr 2006; 4: 9.
32. Sankoh O, Sharrow D, Herbst K, Kabudula CW, Alam N, Kant S, et al. The INDEPTH standard population for low- and middle-income countries, 2013. Glob Health Action 2014; 7: 23286, http://dx.doi.org/10.3402/gha.v7.23286
33. Byass P, Chandramohan D, Clark SJ, D'Ambruoso L, Fottrell E, Graham WJ, et al. Strengthening standardised interpretation of verbal autopsy data: the new InterVA-4 tool. Glob Health Action 2012; 5: 19281, http://dx.doi.org/10.3402/gha.v5i0.19281
34. World Health Organization (2012). Verbal autopsy standards: the 2012 WHO Verbal Autopsy Instrument. Geneva: WHO.
35. Streatfield PK, Khan WA, Bhuiya A, Hanifi SMA, Alam N, Millogo O, et al. HIV/AIDS-related mortality in Africa and Asia: evidence from INDEPTH Health and Demographic Surveillance System sites. Glob Health Action 2014; 7: 25370, http://dx.doi.org/10.3402/gha.v7.25370
36. United Nations (2013). World population prospects: the 2012 revision. New York: United Nations.
37. Leitao J, Chandramohan D, Byass P, Jakob R, Bundhamcharoen K, Choprapawon C, et al. Revising the WHO verbal autopsy instrument to facilitate routine cause-of-death monitoring. Glob Health Action 2013; 6: 21518, http://dx.doi.org/10.3402/gha.v6i0.21518

38. Bah E, Carrieri MP, Hainaut P, Bah Y, Nyan O, Taal M. 20-Years of population-based cancer registration in hepatitis B and liver cancer prevention in the Gambia, West Africa. PLoS One 2013; 8: e75775.
39. Byass P, Calvert C, Miiro-Nakiyingi J, Lutalo T, Michael D, Crampin A, et al. InterVA-4 as a public health tool for measuring HIV/AIDS mortality: a validation study from five African countries. Glob Health Action 2013; 6: 22448, http://dx.doi.org/10.3402/gha.v6i0.22448
40. Kontis V, Mathers CD, Rehm J, Stevens GA, Shield KD, Bonita R, et al. Contribution of six risk factors to achieving the 25 × 25 noncommunicable disease mortality reduction target: a modelling study. Lancet 2014; 384: 427–37.
41. World Health Organization (2011). International Statistical Classification of Diseases and related health problems, 10th Revision. Volume 2: Instruction Manual. Geneva: WHO.