Extended abstract for PAA 2017

Estimating cause-specific mortality in Madagascar: a comparison of the Global Burden of Disease Study 2013 with registration data from the capital city

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***Objective**: Due to incomplete death registration in Madagascar, trends in cause-specific mortality are known from epidemiological models such as the Global Burden of Disease Study 2013 (GBD 2013). The external validity of such model-based estimates is difficult to establish, however, since all possible data are usually included. In Madagascar, the GBD 2013 study used death registration data from Antananarivo but only for the period 1984-1995. Using death records up to 2014, we aim to describe trends in mortality by age and sex and compare the distribution of causes of death observed in death records with GBD 2013.*

***Methods**: Information on the sex of the deceased, date of birth and death and underlying cause of death were transcribed from death registers. Causes of death were converted in GBD cause categories. The completeness of the registration of deaths was assessed using indirect demographic techniques.*

***Findings**: The completeness of the registration of deaths is higher than 90% in Antananarivo. The proportion of deaths attributed to "garbage codes" amounts to 19.4% when considering codes for symptoms, signs and ill-defined conditions, deaths from injuries whose intent is not determined, and ill-defined cardiovascular diseases and neoplasms. Significant differences are observed between the distributions of deaths by cause in the GBD 2013 estimates and death registers referring to the capital city.*

***Conclusions**: Death registration in Antananarivo, and possibly other African cities, is a low-cost and untapped data source which can help to refine disease burden estimates.*

Keywords: mortality, causes of death, Antananarivo, Madagascar, death records, vital registration, sub-Saharan Africa, burden of disease

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1. Background

Timely and reliable evidence on the leading causes of death is critical to develop public health policies and monitor health progress. However, globally, civil registration and vital statistics (CRVS) systems are still deficient as only one third of all deaths are registered worldwide [1]. In Madagascar, despite being established in the late nineteenth century, the CRVS system is still inoperative at the national level[4]. The completeness of the death registration has probably never exceeded 60%. Over the period 1965-1967, almost half of male deaths and more than a third of female deaths were not registered [2]. In the 1970s, the national statistical office (INSTAT) ceased to publish estimates based on registration data. Levels and trends in mortality are estimated from large-scale surveys such as Demographic and Health Surveys (DHS), since the last population census was conducted in 1993. Statistics on causes of death available to the National Health Information System are obtained from reports of health facilities, but these statistics cannot be considered representative of the general population.

Global estimates of cause-specific mortality are regularly developed by UN agencies and academic groups to overcome this lack of data. In recent years, the Global Burden of Disease Study (GBD) has emerged as a source of reference for global health estimates [3]. The GBD study is an unprecedented exercise of epidemiological modeling to quantify the global burden of disease and loss of life attributable to leading causes of death. GBD gathers together a wide range of data, including surveys, censuses, and death records. For countries where the registration of deaths remains incomplete, the World Health Organization now largely resorts to GBD estimates[5].

In Madagascar, the empirical basis on causes of death is limited. For mortality levels, two probabilities of death are used as anchor points in the GBD 2013: the mortality of children below age 5 ($_5q_0$) and that of adults between the ages 15 and 60 ($_{45}q_{15}$). Trends in child mortality are mostly reconstituted from full birth histories collected in DHS. Trends in adult mortality are derived from data collected in the same surveys on the survival of adult siblings. The 1993 census is also considered to estimate mortality from reports on recent household deaths. A three-step process is used to combine various empirical observations and produce smooth mortality trends and uncertainty intervals. A regression model first associates the probabilities $_5q_0$ and $_{45}q_{15}$ with average income per person, mean years of education among adults and crude death rate due to HIV/AIDS. A spatiotemporal regression is used to smooth the residuals of this first stage model, borrowing information between periods and between countries within the same region. The results of this second phase serve as starting points for a Gaussian regression process to derive final estimates. Complete life tables are generated from the probabilities $_5q_0$ and $_{45}q_{15}$ combined with typical age patterns of mortality (mainly from neighboring countries).

To model causes of death in Madagascar, the GBD 2013 study uses published estimates referring to the capital city during the period 1984-1995, based on death registration [4]. These estimates are completed with other epidemiological studies related to the prevalence of hepatitis A, B and C, meningitis, and rotavirus diarrhea. Police records, results from the National Program for the Fight Against Malaria and data from DHS (for pregnancy-related mortality) are also taken into account. However, GBD 2013

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4 Source: United Nations Statistics Division, Coverage of Birth and Death Registration [internet]; 2016 [cited 2016 Sept 29]. Available from: http://unstats.un.org/unsd/demographic/CRVS/CR_coverage.htm.

5 Source: World Health Organization, Department of Health Statistics and Information Systems, WHO methods and data sources for country-level causes of death 2000-2012 [internet]; May 2016 [cited 2016 Sept 29]. Available from: http://www.who.int/healthinfo/global_burden_disease/GlobalCOD_method_2000_2012.pdf?ua=1

estimates for Madagascar in the recent period are largely model-driven[6]. According to an approach called *Cause of Death Ensemble modelling* (Codem), several series of statistical models are used to predict the distribution by cause of death [5]. Nearly a hundred of covariates – referring to the national level - are involved in these models, such as the frequency of alcohol consumption, the average body mass index, the use of contraceptives, etc.

Data on causes of death used for modeling may come from sub-national levels, but the demographic and background characteristics of the area are not systematically taken into account. When civil registration data are available but incomplete, the assumption is that the distribution by cause of death observed among the reported deaths is comparable to that of unreported deaths. Indeed, the GBD 2013 did not consider that the sub-national vital registration data from Antananarivo were biased in a way that can be anticipated and adjusted.

In this paper, we use death registers from Antananarivo up to 2014, assess their quality, and derive estimates which are compared with GBD 2013 estimates. We first describe the death registration process in the capital city and evaluate the performance of the system. Mortality rates by age and sex are presented for Antananarivo and compared with national estimates from the GBD 2013. The comparison is extended to the distribution of causes of death. We conclude by emphasizing the potential of the continuous recording of deaths in major urban centers in Madagascar and other cities in Africa.

2. Data and methods

2.1. Data

The *Municipal Office of Hygiene* (BMH) of Antananarivo was created in 1916 and placed under the supervision of the mayor to offer free consultations, conduct immunization campaigns, manage prophylaxis against malaria and isolate patients with highly infectious diseases. Since 1921, the BMH is also in charge of the verification of all home deaths. Historically, this verification of deaths was part of prevention measures against the plague, and included liver and lung punctures. Today, ten doctors are responsible to meet a relative of the deceased, and establish the cause of death based on information provided by family and available medical documents. For deaths that occur in hospitals (about 40% of all deaths since 1976), relatives present the death certificate from the hospital to the BMH. All deaths are recorded in the same register. The registration office then issues a burial permit. Deaths need to be reported within a period of maximum twelve days. Over 80% of deaths reported to the BMH took place on the same day or the day before.

Records contain the following items: (1) registration number, (2) full name of the deceased, (3) date of birth, (3) gender, (5) date and time of death, (6) date and time of reporting of death, (7) address of the deceased, (8) date and place of burial, (9) place of death (name of the hospital, home or street), (10) diagnosis of the cause of death (or in the case of some deaths in the hospital, ICD code), (11) address and name of the declarant and relationship with the deceased. From the address of the deceased, non-residents in the capital are excluded from the analysis. For the six districts of Antananarivo-Renivohitra (about 1 million inhabitants in 2009), the database contains about 300 000 deaths for the period 1976-2014, including 235 000 residents and 80 000 deaths of children under age 15.

[6] All data sources are listed in the supplemental material to the GBD 2013 main paper: http://www.thelancet.com/journals/lancet/article/PIIS0140-6736(14)61682-2/supplemental

2.2. Evaluating the performance of the registration system

To assess the performance of the registration system, we use six dimensions of a synthetic index called *Vital Statistics Performance Index* [6]: (1) quality of cause of death reporting, (2) quality of age and sex reporting, (3) internal consistency, (4) completeness of death registration, (5) level of cause-specific detail, (6) data availability and timeliness. We slightly adapt the indicators for these six dimensions.

Quality of cause of death reporting. All causes of death recorded in the Malagasy capital were coded using the 9th revision of the ICD. These causes were then redistributed in the different categories of causes included in the GBD[7]. The GBD study has stressed the need to redistribute uninformative, so-called garbage codes to adequate codes. This includes not only causes identified as "undefined" in the specific ICD chapters, but also deaths attributed to causes which should not be considered as initial causes [7]. For example, respiratory failure and pulmonary embolism should not be considered as initial causes of death; they have an underlying cause that precipitated the chain of events leading to the death. As part of the GBD, different algorithms are used for garbage code redistribution (based on expert opinions, statistical models and simpler proportional redistribution). However, these algorithms have not been distributed in the public domain, which limits comparability of GBD estimates. The list of ICD9 codes redistributed within the GBD 2013 is public, however [3]. The WHO estimates[8] and older versions of the GBD [8], are based on a shorter list of *garbage codes,* which includes four categories: (1) ill-defined causes coded 780-799 in ICD9, (2) undetermined injuries, whether intentional or not (codes E980-989), (3) ill-defined cancers (ICD9 codes 195 and 199) and (4) ill-defined cardiovascular diseases (ICD9 codes 427.1, 427.4, 427.5, 428, 429.0, 429.1, 429.2, 429.9 and 440.9). To assess the quality of information on causes of death, we selected this shorter list, because established procedures exist to redistribute the deaths of each of these four categories (cfr. Appendix 1). As an indicator of quality, we simply calculate the percentage of deaths attributed to a code of this shortlist.

Quality of age and sex reporting: Phillips et al. (2014) use as an indicator the proportion of deaths for which the sex or age of death is unknown. Here we look at the share of deaths for which the age is known to the day and to the month.

Internal consistency: We calculate the proportion of deaths where the underlying cause is inconsistent with the age at death and/or sex of the deceased, using the list established by Phillips et al. (2014). A death of a child under age 15 cannot be associated with some types of neoplasms (e.g. lung or larynx), and a woman cannot die from prostate cancer. Deaths incompatible because of the age at death were reclassified as *garbage code*. For inconsistencies with the sex of the deceased, the sex was corrected, considering that this is due to an entry error.

Completeness of death registration: We use two death distribution methods: the generalized growth balance method (GGB*)*, and synthetic extinct generation method (SEG) [9, 10]. These two methods are applied based on the age distribution of the population registered in 1975 and 1993, and the age distribution of deaths between the two censuses. They provide an estimate of the completeness of

[7] The correspondence table refers to the GBD 2010 Study and is available on: http://www.healthdata.org/sites/default/files/files/data_for_download/2012/IHME_GBD2010_CauseListandICD.pdf

[8] Sc: http://www.who.int/healthinfo/global_burden_disease/GlobalCOD_method_2000_2012.pdf?ua=1

registration of deaths over this period[9]. These two methods are based on strict assumptions; (1) that the population is closed to migration, (2) that the completeness of reporting of the population and deaths are invariant by age (beyond a certain age), and (3) that there are not systematic age errors. In the absence of data to make adjustments, we assume that net migration in Antananarivo is null. Compared to other African capitals, Antananarivo is characterized by a low rate of growth (estimated at 4.7% per year over the period 1975 to 1995) and relatively constant immigration rates [11, 12]. The few available means to make sure that the assumptions underlying the GGB and SEG methods are verified are visual checks [13, 14].

Level of cause-specific detail: Phillips et al. (2014) calculate the percentage of causes considered in the GBD 2010 study (192 single causes) that are mentioned in the death registers. The GBD 2013 has 240 causes, but these refer to different levels, because the list of causes is hierarchical. Thus, a death coded as due to a "liver cancer caused by hepatitis c" is encoded as B.1.3.2 in the GBD classification, because it is included in the NCD group (B), neoplasms (B.1) and liver cancer (B.1.3). Here we calculate the proportion of cases of level 3 in the GBD classification which are mentioned in death records. In total, the list includes 141 single causes, but we eliminate 4 causes that have not, according to the GBD, caused any death in Madagascar between 1990 and 2013 (Chagas disease, yellow fever, trypanosomiasis and collective violence), and combine four types of cirrhosis (due to hepatitis B, C, alcohol and other causes) in one category.

Data availability and timeliness: Phillips et al. (2014) use a weighted smoothing algorithm that gives more weight to recent data over data produced intermittently or not updated recently. Here we simply note that data are continuously generated and readily available for analysis upon request.

1.1. Comparison of estimates from death registration with those of the GBD 2013

To compare death registration and GBD 2013 estimates, we calculate life tables for each year and compare the following probabilities of death: ${}_5q_0$, ${}_{10}q_5$, ${}_{35}q_{15}$, ${}_{20}q_{50}$. In the absence of a recent census, it is difficult to estimate the population at risk of dying. We fit a logistic curve on administrative accounts available since 1901, censuses of 1975 and 1993 and the provisional count conducted in 2009 as part of the preparation of the next census (since postponed for political reasons). The age structure is obtained by interpolating between the last two censuses and four DHS (1992, 1997, 2003-04 and 2008-09) using spline functions. We compare ranks of the leading causes of death in 1990 and 2013 after weighting death records to impose the same age structure as deaths estimated in the GBD.

[9] The GGB method also provides an estimate of the completeness of the registration of the *population in the second census compared to the first,* and we use this value to adjust the population numbers before applying the SEG method.

2. Results

2.1. Performance of the registration system

Quality of cause of death reporting. When using the complete list of codes considered *garbage* in the GBD, up to 47% of all deaths in registers from Antananarivo are attributed to a *garbage code*. The top 15 causes most frequently attributed to a *garbage code* are listed in Table 1. Together, these 15 cases represent 30.6% of deaths in the period 1976 to 2014. However, several *garbage codes*, such the code 436 (acute but ill-defined cerebrovascular disease) are not considered as such by the WHO (Table 1). By applying the shorter WHO list, the proportion of deaths requiring garbage code redistribution is reduced to 19.4%. This proportion varies considerably by age, from 6.5% in infants to 41% among adults who died at age 70 or above (Figure 1). It varies relatively little over time. The sudden rise in the second half of the 1980s in children can be attributed to an acute health crisis with a resurgence of malaria and malnutrition, which could have disrupted the organization of health services and overburden the registration office [15].

Table 1: Top 15 ICD 9 codes considered « garbage » in the mortality database of Antananarivo

Rank	ICD 9	% of deaths	Code description	Listed as *garbage code* by the WHO
1	436	6.54	Acute but ill-defined cerebrovascular disease	No
2	428.9	5.25	Heart failure unspecified	Yes
3	485	2.86	Bronchopneumonia, organism unspecified	No
4	486	2.83	Pneumonia, organism unspecified	No
5	799.9	2.44	Other unknown and unspecified cause of mortality	Yes
6	797	2.34	Senility	Yes
7	785.5	1.55	Shock without mention of trauma (symptoms involving cardiovascular system)	Yes
8	586	1.06	Renal failure, unspecified	No
9	428	0.93	Congestive heart failure unspecified	Yes
10	799.1	0.86	Respiratory arrest	Yes
11	38.9	0.86	Septicemia	No
12	578.9	0.85	Hemorrhage of gastrointestinal tract	No
13	429.9	0.79	Heart disease, unspecified	Yes
14	276.5	0.76	Dehydration	No
15	428.1	0.71	Left heart failure	Yes
	Total=	30.6 %		

Quality of information about the age and sex: The year of birth and death is known for more than 99.5% of all deaths since 1976. However, the accuracy of dates of birth and death vary over time. In 1976, the age at death was known up to the day in 57% of cases. This proportion dropped to 40% in 1981, due to the health crisis, then increased gradually to 85% in 2001. In the most recent years, it is possible to calculate the age at death up to the day for over 99% of deaths.

Internal consistency of data: In 99.3% of deaths, the GBD category of causes of death is consistent with the age of the deceased and the sex (after redistributing garbage codes). In 0.4% of cases, deaths occurred at too young an age for the cause that has been assigned. This is particularly the case of deaths among infants and classified as due to chronic obstructive pulmonary disease, originally coded in ICD 9 as bronchitis (490, 491.8).

Figure 1: Proportions of garbage codes by age group when using the WHO short list

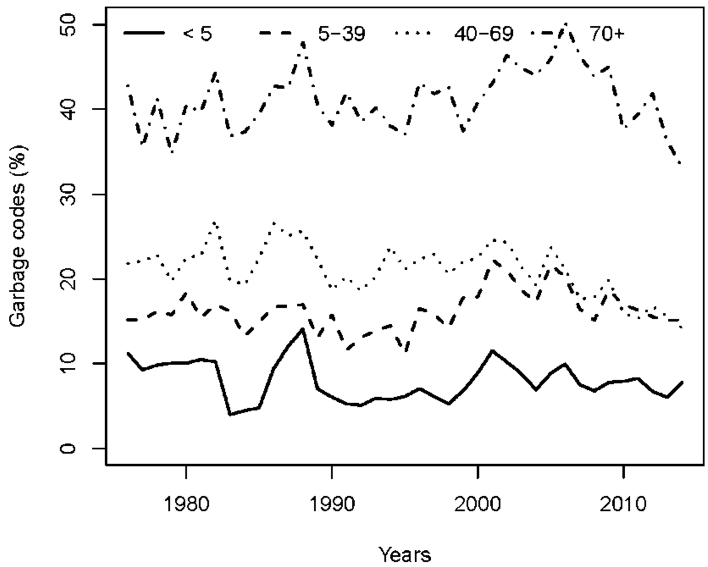
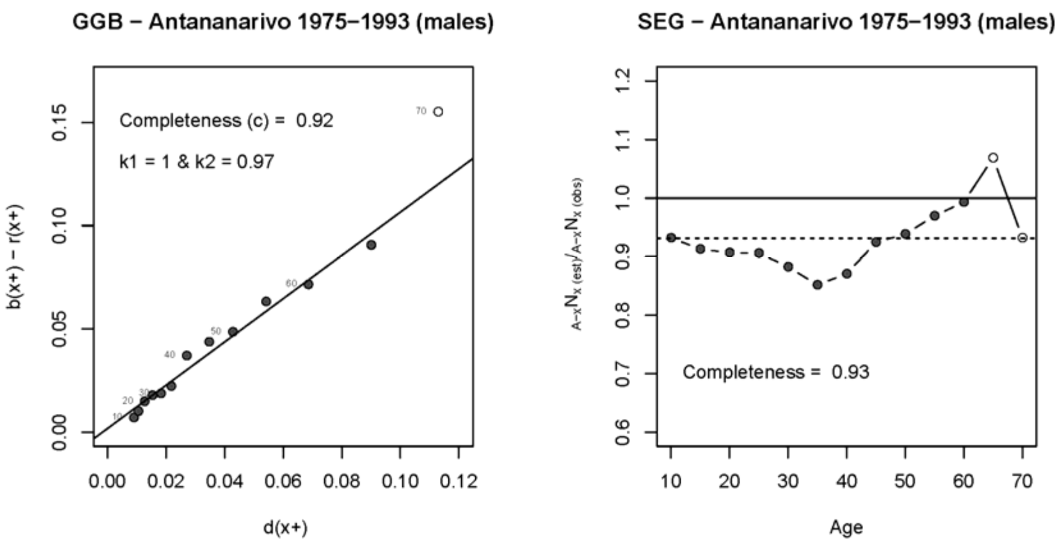


Figure 2: Diagnostics plots of the GGB and SEG method for male deaths between 1975 and 1993



Completeness of death registration: Figure 2 shows, for men, the two diagnostic plots for the GGB and SEG methods. In the case of the GGB, the estimate of completeness is 92% (the same value is obtained for women). The population appears underestimated by 3% in the 1993 census, as compared to the 1975 census (7% in women). With the SEG method, we obtain a very close estimate of completeness, 93% for both sexes. There is some irregularity in the estimates of the completeness by age, but the consistency of the estimates by sex and between the two methods reinforces the idea that registration of adult deaths is higher than 90% in the capital. Consequently, we adjust deaths based on an estimate of the completeness of 92.5% for both sexes.

Level of cause-specific detail: 130 of the 134 causes of the third level of the GBD list considered for Madagascar are mentioned in the records of the capital. The only causes that are not included are dengue fever, late maternal deaths or maternal deaths aggravated by HIV/AIDS, iodine deficiency and exposure to the forces of nature or disasters.

2.2. Comparison of estimates from death records with GBD 2013

Trends in child mortality (for both sexes) and life expectancy (by gender) from register data are compared to GBD 2013 in Figure 3. It should be kept in the mind that mortality levels obtained from death records refer only to the capital, while the GBD estimates refer to the whole country. The lowest child mortality rates estimated for Antananarivo are expected, since the city has a more favorable health and economic development. By contrast, it is difficult to explain why women in the capital would benefit from higher life expectancies since 1990 than estimated for the country, while estimates for men are almost identical. Furthermore, trends in life expectancies highlight the importance of death records, as these clearly demonstrate the health crisis in the 1980s. A resurgence of infectious diseases, respiratory, and nutritional deficiencies resulted in a drop in life expectancy of 13 years for men (8 years for women) in the capital [15].

Figure 3: Trends in child mortality and life expectancy at birth in Antananarivo according to death registration data and GBD 2013.

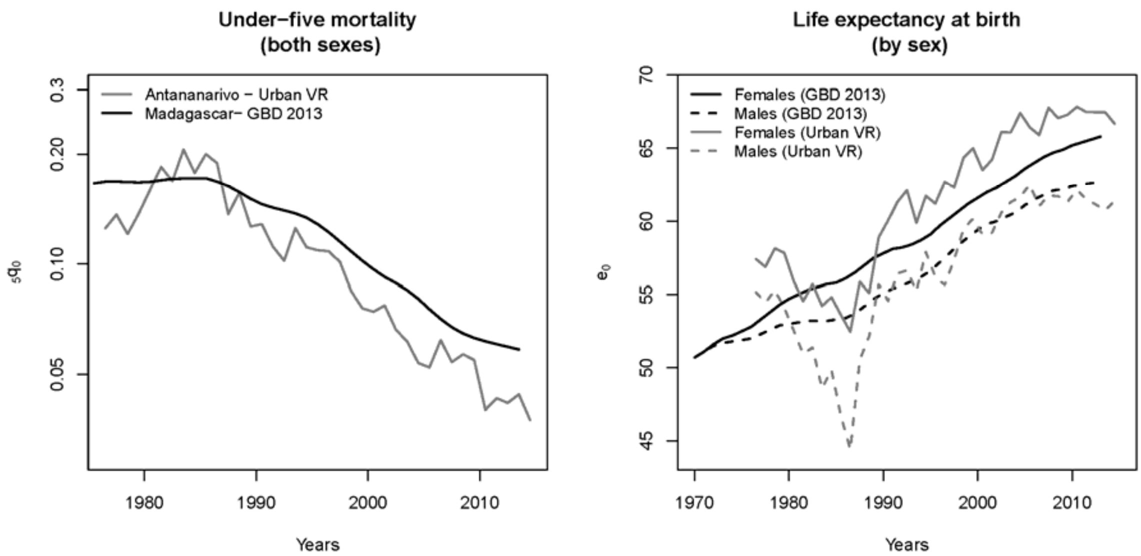


Table 2 presents the main indices of mortality by sex, according to the GBD and urban vital registration, for 1990 and 2013[10]. Child mortality is higher according to GBD for both sexes and both periods, while the mortality of men between 15 and 70 years is lower in both years, according to registration data. In women, adult mortality levels from registers are higher than GBD 2013 estimates in 1990 but the differences vary by age in 2013. Among 5- to 14-year-olds, mortality is always slightly lower according to death records. Overall, according to registration data, women have benefited more from the decline in mortality than men over the period 1990 and 2013, but this is not apparent in model-based estimates.

Table 2: Levels of mortality by age, sex, time and data source (Antananarivo, Madagascar)

	1990				2013			
	Males		Females		Males		Females	
	GBD	VR	GBD	VR	GBD	VR	GBD	VR
${}_{5}q_{0}$	0.153	0.126	0.138	0.113	0.063	0.050	0.054	0.034
${}_{10}q_{5}$	0.022	0.018	0.020	0.016	0.010	0.008	0.008	0.007
${}_{35}q_{15}$	0.174	0.179	0.151	0.128	0.155	0.198	0.114	0.126
${}_{20}q_{50}$	0.421	0.456	0.360	0.311	0.393	0.446	0.347	0.307
e_0	55.1	55.6	57.8	60.1	62.7	60.1	65.8	67.5

The ranking of the top 20 causes of death in 1990 is presented in Figure 4 for men (left) and women (right). The percentages of deaths assigned to specific causes are shown in column. It should be kept in mind that registration data are used in the GBD 2013 for the period 1984-1995, for broad categories of causes. Consequently, there should be a closer agreement between the two types of estimates in 1990, as compared to 2013.

For both sexes, the four leading causes of death according to GBD 2013 are among the top four causes of death according to the death records 1990. Cerebrovascular diseases cause a lower proportion of deaths according to death registration (5.9% against 10.3% according to GBD 2013 among men). Malaria ranks fifth in the hierarchy of causes registered by the doctors, and ranks sixth in GBD 2013 estimates. There are larger discrepancies when considering less common causes of death. Ischemic heart disease and other cardiovascular diseases are more common according to registers. Several causes are included in the list of the top 20 causes according to GBD although they represent less than one percent of death records. This is the case for both sexes of sexually transmitted diseases (other than AIDS), iron deficiency anemia, road accidents, and chronic obstructive pulmonary disease. Measles, which represents 3.7% of male deaths and 4.3% of female deaths according to the GBD causes less than 1% of male deaths and 1.2% of female deaths in the registers. Conversely, some causes are associated with a relatively high proportion of deaths according to the death records without appearing in the top 20 causes in the GBD. This is the case of chronic kidney disease, alcohol use disorders (among men), endocrine, metabolic, blood and immune disorders, peptic ulcer disease (among men), and diabetes mellitus, among others.

[10] Estimates based on registration data were obtained by taking an average over the years 1989 to 1991 for 1990, and 2012 to 2014 for 2013.

Figure 4: Comparison of the ranking of causes of deaths according to death registers from Antananarivo and the GBD 2013, for 1990

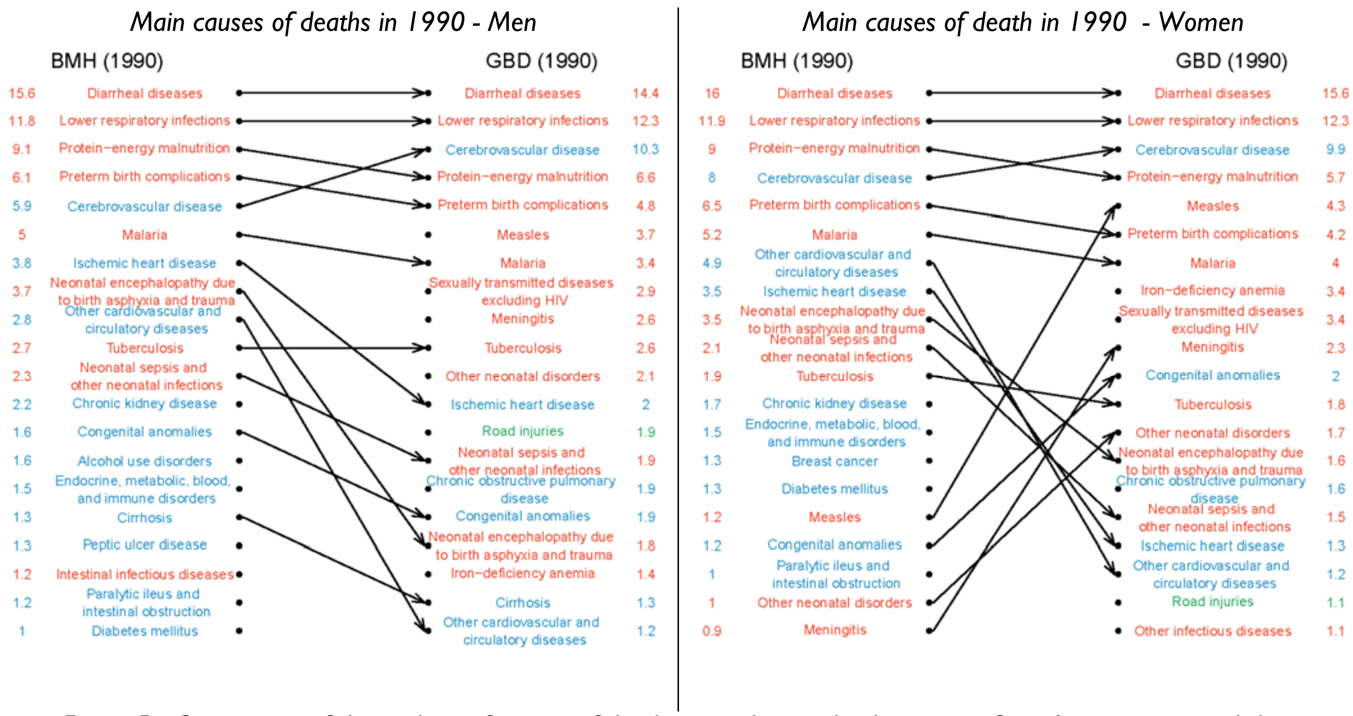
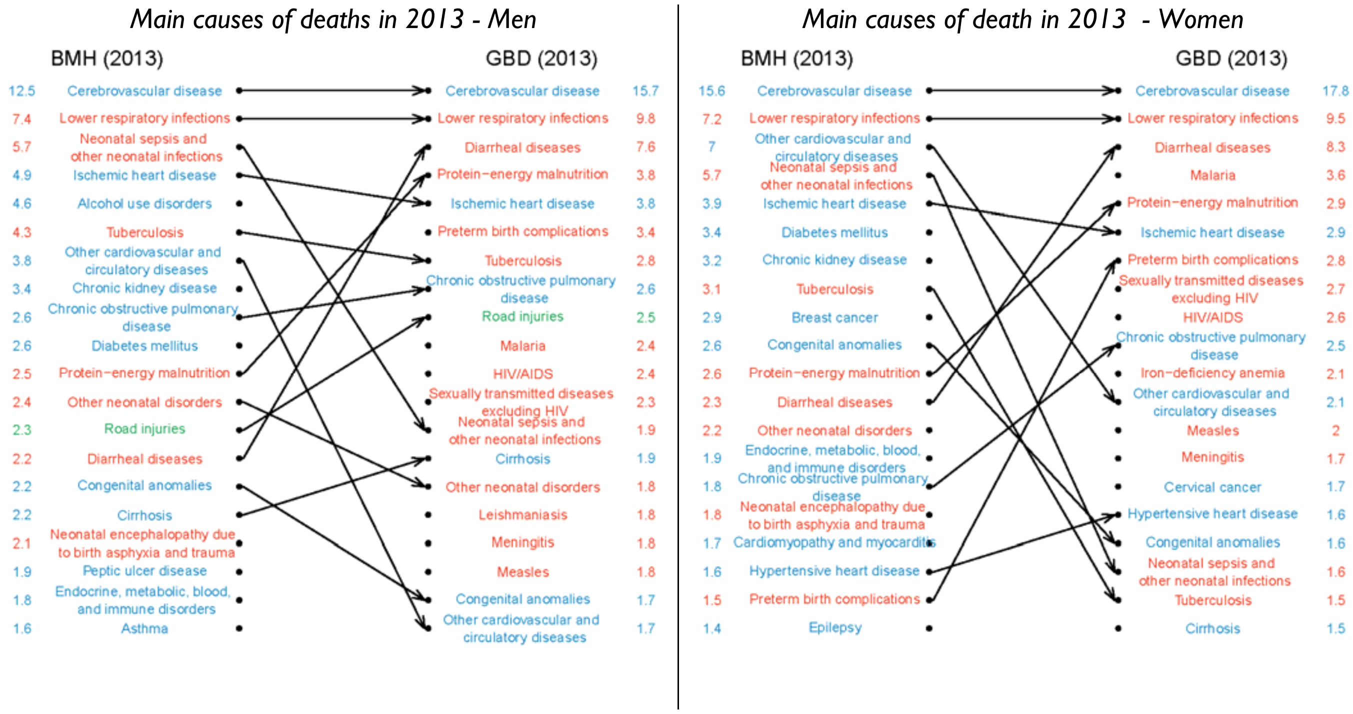


Figure 5 : Comparison of the ranking of causes of deaths according to death registers from Antananarivo and the GBD 2013, for 2013



Differences between the two types series are more pronounced in 2013, when the distribution of causes of death in models is mainly based on covariates, due to the dearth of empirical estimates for this period. Only the first two causes of death are the similar: cerebrovascular disease, and lower respiratory infections. For both sexes, neonatal sepsis and other neonatal infections are among the four leading causes of death according to deaths records, but they cause less than 2% of deaths according to the GBD. As a result of garbage code redistribution, unspecified cardiovascular and circulatory diseases also cause significantly more deaths than in models, especially among women. In addition, breast cancer (in women), alcohol-related disorders (in men), chronic kidney disease, diabetes mellitus and endocrine, metabolic, blood and immune disorders are in the list of the top 20 causes of death in the deaths records but not in the leading causes of death of the GBD 2013. Correspondingly, some communicable diseases are less important than expected in the GBD: in particular, diarrheal diseases cause less than 2.5% of deaths in the capital, against more than 7.5% according to the GBD.

3. Discussion

Civil registration systems in sub-Saharan Africa are regularly described as rudimentary or non-existent, because most assessments are conducted at the national level. In a recent assessment of civil registration systems, little progress was observed in death registration, especially in sub-Saharan Africa [1]. However, evaluations conducted at the national level should be pursued by detailed assessments in major cities, because some of them have put in place an efficient system of death registration. As early as the 1970s, several studies emphasized the good coverage of civil registration in some large African cities, where death certificates are required for issuing a burial permit. In Bamako (Mali), Fargues and Nassour (1988) estimate that the completeness of death registration above age 5 was 73% for men and 68% for women in the late 1970s [17]. In Libreville (Gabon), Antoine et al . (1976) analyze registration data for the period 1969 to 1972 and concluded that they are reliable enough to be used, even if it happens that burials take place without a burial permit [18]. In Abidjan, a study of the period 1973-1992 showed that death registration was complete for adults, but incomplete for children [19]. In Senegal, death registration is considered to be above 90% in the city of St. Louis as early as the 1980s [20]. In Antananarivo, we estimated here that the completeness of death reporting among adults was higher than 90%. There is no method to assess completeness of death registration among children, but in an earlier publication, we showed that child mortality rates estimated from registers were very close to that of DHS for the capital city [16]. Death records of these different cities, and potentially others, are therefore usueful data sources which are often carefully preserved but remain usually untapped.

Even if they remain imperfect, these local death registration systems can help to refine the modeling of mortality by cause, provided that the urban character of the data source is explicitly taken into account. In this study, we have highlighted important differences between estimates of the GBD 2013 and the Antananarivo death registers. Globally, non-communicable diseases are responsible in 2013 for more deaths in the death records (58% in men and 63% among women), compared with what the GBD predicts (44% in men and 46% among women). This difference may reflect a more rapid progression of the epidemiological transition in the capital, but the differences seen with specific causes, such as chronic kidney disease, alcohol use disorders (for men), and diabetes mellitus, point instead to the limits of a model based on a limited empirical basis in countries without vital registration. The comparison conducted here has two main limitations. First, registers provide high quality data on deaths, but the population at risk of dying is difficult to estimate in the absence of recent census. Mortality rates from the death registration could be biased if our population estimates are inaccurate. This should not affect, however, the distribution of deaths by causes. Second, deaths associated with garbage codes were redistributed by adopting an approach that differs from redistributions of algorithms used in the GBD. These should be made public to allow a more accurate comparison.

In Madagascar, municipal health offices are active in major urban centers outside of the capital city, but the completeness of death registration has never been estimated. There are significant differences in the structures and processes of these municipal health offices, but all offices tend to be in short supply of resources to store the registers and encode them in databases, and they often lack the resources needed to ensure that all home deaths are verified. Initiatives to expand the CRVS system in Madagascar should support these local structures. Feasibility surveys are also required to assess the potential of verbal autopsies for deaths that are reported to the offices but cannot be certified by a doctor.

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6. Ethical statement and competing interests

Ethical concerns regarding the free and informed consent of participants are not relevant here as the study participants are deceased persons. Ethical clearance was not sought as the dataset based on death registers is anonymous and contains no identifiable information of any study participant.

We declare that we have no competing interests.

7. Annex

The following table shows, for the different ICD 9 codes, the procedure used to redistribute the *garbage codes* in acceptable categories.

ICD 9	Redistributed to GBD Cause list	Share of *garbage codes* according to GBD list	Share of *garbage codes* according to WHO list
Before any redistribution		47.0%	19.4%
436 (Acute but ill-defined cerebrovascular disease)	B.2.3 - Cerebrovascular disease	40.4%	19.4%
485 (Bronchopneumonia, organism unspecified) and 486	A.2.3 - Lower respiratory infections	34.8%	19.4%

(Pneumonia, organism unspecified)			
427.1, 427.4, 427.5, 428, 429.0, 429.1, 429.2, 429.9, and 440.9: ill-defined CVD deaths.	Redistributed to B.2.2 (Ischemic heart disease) and B.2.10 (Other cardiovascular and circulato ry diseases) using the age-specific correction fa ctors for "High ill-defined coding countries", av ailable in [8].	26.8%	11.1%
ICD-9 codes 195–199 : ill-defined neoplasms	Redistributed pro rata across all cancer sites identified in GBD (except liver, pancreas, ovary, and trachea, bronchus, and lung) within each age group and sex.	26.5%	10.8%
ICD-9 Chapter XVI : Symptoms, signs and ill-defined conditions	Redistributed pro rata across all GBD causes (excluding injuries) within each age group, sex and decade of death.	16.3%	0.6%
ICD-9 codes E980-989: injuries undetermined whether accidentally or purposefully inflicted	Redistributed pro rata by age and sex to the GBD categories for intentional and unintentional injury.	15.9%	0%
All remaining ICD 9 codes considered as garbage in the GBD list	All ICD-9 codes reported in the registers were classified in 41 broad categories, following =[21]=[21]. Then the remaining ICD-9 considered as garbage have been redistributed pro rata by age, sex and year to acceptable GBD causes within each category.	0%	0%