Levels of mortality of the South African aged population using the method of extinct generations[1]

Takwanisa Machemedze and Rob Dorrington
Centre for Actuarial Research, University of Cape Town
Private Bag, Rondebosch 7700, Cape Town, South Africa
takwanisa@gmail.com, Rob.Dorrington@uct.ac.za
Tel:+27 (0)21 650 2467 Fax:+27 (0)21 689 7580

Abstract

This paper investigates the reasons for the levelling off of the mortality estimates at the oldest age groups and the possibility of estimating the level of the mortality rates at these ages.The research applies the method of extinct generations to estimate indirectly the population numbers at the oldest-old age groups (75 to 100+) using data on reported deaths alone, and hence, the mortality rates. After observing that the estimated mortality rates are levelling off with age at the advanced ages (age 90 to 100+) due to age exaggeration in both the deaths and the population, the Gompertz curve was fitted to the estimated mortality rates at age groups 75, 80 and 85. Our estimates are generally lower but close to the estimates derived by Dorrington et al.*, (2004) and the estimates from the United Nations Population Division (UNPD) and the US Census Bureau (USCB) population projections.*

Keywords: Old age mortality, extinct generations, age exaggeration, completeness, South Africa

Résumé

Cet article examine les raisons de la stabilisation des estimations de la mortalité des groupes d'âgede plus vieux et la possibilité d'estimer le niveau de taux de mortalité à ces âges. La recherche applique la méthode des générations éteintespour estimer indirectement les nombres de la population des groupes d'age de plus vieux (75 à 100+) en utilisant seuls les données sur lesdécèsrapportés et donc le taux de mortalité. Après avoir observé que le taux de mortalité estimés sont nivellés avec l'âge à des âges avancés (âge 90 à 100+) dû à l'exaggeration dans les décès ainsi que dans la poplation, la courbe de Gompertz était ajusté au taux de mortalité estimé aux groupes d'age 75, 80, 85. Nos estimations sont généralement plus faibles mais à proximités des estimations dérivées par Dorrington et al., (2004) et les estimations de la Division de la Population des Nations Unies (UNPD: United Nations Population Division) et le projection de populations du Bureau du recensement des États-Unis (USCB: US Census Bureau).

1. This paper is an extract from a Masters dissertation held by the Centre for Actuarial Research/University of Cape Town.

Introduction

Estimation of mortality at the oldest-age groups in African populations in general, and in the South African population in particular, is one of the areas that has not received much attention. This is because of a lack of vital registration data that are good enough to produce estimates. Apart from this, data that are available are usually subject to errors such as age exaggeration, age heaping, relative under count/over count of people and relative incompleteness of reporting of deaths by age (Jdanov *et al.*, 2008; Wilmoth, 1995). As a result of these errors, mortality estimates and life tables,where these have been estimated, usually have the advanced ages aggregated into open intervals at ages low enough for the errors to have, in aggregate, minimal effect (Horiuchi and Coale, 1982).

Alternatively, the United Nations Population Division (UNPD) and the United States Census Bureau (USCB) mortality rates, for example,are extrapolated at the oldest age groups for most countries. For example, in the case of South Africa, Dorrington *et al.*, (2004) extrapolated mortality rates at the advanced ages when estimating mortality in the period between the 1996 and 2001 censuses.

In developed countries where there are good vital registration systems, the method of extinct generations, first proposed by Vincent (1951), has been found to produce superior estimates of mortality at the advanced ages (Thatcher, 1992). The method of extinct generations uses information on reported deaths by age alone to esti mate the population size at some point in time in the past by single ages, and hence, the mortality rates.

This paper investigates the reasons for the levelling off of the mortality estimates at the older ages and the possibility of estimating the level of the mortality rates using data on reported deaths alone.

Literature review and theoretical framework

Like most other African countries, South Africa also suffers poor demographic data needed to estimate some of the demographic indicators. Deficiencies in the data available range from undercount of censuses, incomplete vital registration, age exaggeration, lack of details on variables such as ethnic group and inaccuracy of age, among others. Some of these flaws in the demographic data for most countries have led to the derivation of indirect methods for estimating mortality.

This study focuses on the mortality of people aged 75 and above where a number of methods have been proposed for estimating the mortality rates. The methods include the extrapolation of a parametric curve fitted to younger ages, using a relational function and a standard table, a model life table and the method of extinct generations.

The parametric curves used to extrapolate the mortality rates include the logistic function and the Gompertz curve (Bongaarts, 2004; Preston *et al.*, 2001). An example of a relational function is the logit relation proposed by Brass (1968), which relates mortality of the population under study to that of some chosen standard population by a mathematical expression. The model life table gives empirical mortality rates based on empirical observations from a large population assumed to have reliable population and mortality data with the level determined by a simple index of the level of mortality in the study population (Coale *et al*., 1983; United Nations, 2002).

It is possible to use a combination of the various methods,as well. For example, according to Buettner (2002), the UNPD working group recommended a combination of the relational mortality standard proposed by Himes*et al*.,(1994), the old age term of the Heligman-Pollard mortality model (Heligman and Pollard, 1980) and the Coale-Kisker model (Coale and Kisker, 1990). In the case of South Africa, for example, some of the estimates of mortality rates which are available were produced by Dorrington *et al*.,(2004) who estimated the rates at the older age groups by fitting the Brass logit relational model using the Brass General Standard. The method of extinct generations, which is applied in this research, will be explained in more detail in the sections that follow.

Data and methods

Background on data

We use data from two censuses that were carried out in South Africa in 1996 and 2001, both with the night of 9-10 October as the reference date. According to post-enumeration surveys, the two censuses under-counted the national population by 10.7 per cent (Statistics South Africa, 1998) and 17.6 per cent (Statistics South Africa, 2004), respectively. The population data downloaded from the Statistics South Africa website (Statistics South Africa, 2009), have been corrected for these estimates of under enumeration.

The census questionnaires ask for dates of birth and ages in completed years of all people. In cases where the age and date of birth were inconsistent, the date of birth was preferred and was used to calculate the age, except for ages above 80 years where the reported age was given preference. When neither the age, nor the dates of birth were given, the enumerators had to estimate the age as accurately as possible, and in the few cases where this was not done or the age was over 120, ages were imputed.We also used data on registered deaths in South Africa for the years 1996 to 2007 inclusive. Death certificates are issued by the Department of Home Affairs (DHA) which then creates a death notification form that is eventually sent to Statistics South Africa (Stats SA) for processing (Statistics South Africa, 2008). The death notification form has information on the date of death, date of birth and age at last birthday of the deceased.

The death notification forms from the respective provinces are sometimes delayed in reaching the DHA, and hence, are not processed by Statistics South Africa as quickly as might be desired. This research used reported death statistics obtained from Statistics South Africa, and therefore, there is a chance that some deaths are still outstanding.

Dorrington *et al*.,(2004) used death distribution methods (Bennett and Horiuchi, 1981, 1984; Hill, 1987) to adjust for the incompleteness in the reported deaths.Their results showed that the completeness of reporting of deaths of adults of all ages over the period between the two censuses was

83.4 per cent and 84.5 per cent for males and females, respectively.

The data on deaths obtained from Statistics South Africa are given by sex and single ages for each year from 1997 to 2007. As the publicly available data are aggregated at the advanced ages, data on deaths by individual ages in the open interval were obtained directly from Statistics South Africa. Death statistics for the year 1996 were obtained from Statistics South Africa (2001). As a significant proportion (at least 20 per cent) of the registered deaths did not have the population group of the deceased recorded, it was not possible to apply this method to investigate mortality by population group.

For comparative purposes, the derived mortality rates (derived after applying the method of extinct generations) were compared with those estimated by Dorrington *et al.*, (2004) and those underlying various population projections, namely the UN Population Division (United Nations, 2007), the US Census Bureau (US Census Bureau, 2005) and ASSA (Actuarial Society of South Africa, 2005). The USCB does not publish the mortality rates underlying its projection, nor does it project the number of deaths, and as a result the census survivor ratio method of mortality estimation (United Nations, 2002) was applied to the midyear population projections to estimate mortality rates over the period between the 1996 and 2001 censuses at the advanced age groups. Mortality rates from the UNPD were obtained by dividing the estimates of deaths by the number of person-years lived over the period, while the ASSA model produces mortality rates as the output.

Quality of data

A previous study has already assessed the quality of data of the South African aged population for signs of digit preference and age exaggeration in both the reported deaths and the published population numbers (Machemedze, 2009). Heaping in the reported deaths, which is likely to cause kinks in the mortality patterns by age, was assessed using probabilities of deaths (Jdanov *et al.*, 2008; Kannisto, 1988). Machemedze (2009) showed that there was heaping at certain years of birth as opposed to the usual heaping at age last birthday. The years of birth which were preferred were 1910, 1914, 1918, 1920 and 1930. This is probably due to periods of mass registration, where people made reference to certain years which are easy to remember and give as the years of their birth. The years 1910, 1920 and 1930 are probably easy to give because they are multiples of ten, whereas 1914 and 1918 are historical years associated with the period of the First World War. The same pattern of heaping of years of birth was also observed in the published population numbers. However, these were not material to estimating the level of mortality rates.

Machemedze (2009) compared the reported deaths with those simulated by the ASSA model and the results are similar with signs of age exaggeration in the reported deaths at the advanced ages (age 85 and above). He also applied the Synthetic Extinct Generations (SEG) method and the results show patterns which suggest that there is either age exaggeration in the population, or the completeness of reporting of deaths is falling with age, or both.

Methods

Direct estimates of old age mortality (*D/P*) derived using vital registration statistics and the census population are too low relative to estimates from other sources as shown in Figure 2. This may be the result of either falling completeness in the reporting of deaths with age, or possible age exaggeration in the population numbers, or both. Applying the Synthetic Extinct Generations (SEG) method (Bennett and Horiuchi, 1981, 1984) to correct for the incompleteness in the reporting of deaths only raised the level but leaves the rates still levelling with age at the advanced age groups.

In order to improve estimates of the population numbers in the oldest age groups, Vincent (1951) proposed a method which makes use of reported deaths alone to estimate the numbers alive at these ages at a given point in time. The method is based on the fact that cumulating deaths of a given age cohort from a point in time to its extinction gives, if all deaths are reported accurately, the size of the cohort at that point in time. An example is that of estimating the population at the beginning of year γ aged χ last birthday $P(\chi, \gamma)$ which can be estimated as follows:

$$P(\chi,\gamma)= \frac{1}{2}[D(x,y)+D(x+1,y)]+\frac{1}{2}[D(\chi+1,\gamma+1)+D(\chi+2,\gamma+1)]+\ldots$$

where $D(\chi, \gamma)$ are the reported deaths at age χ last birthday throughout year γ. The splitting of deaths is done because most individuals are age last birthday at two possible ages within a year and, as a result, the deaths are split between the two affected cohorts (Kannisto, 1988).

The method is applicable in countries where there are accurate statistics by age and with the population closed to international migration, at least at the advanced ages. The migration assumption has generally been accepted to hold since the population at the advanced ages is less likely to be mobile (Bourbeau and Lebel, 2000). The original derivation of the method of extinct generations required that the cohort to be estimated become extinct first before an estimate of the population is derived. While this is theoretically true, it is usually inconvenient to have to wait for the extinction of the cohort in question before being able to apply the method. As a result, assumptions are made in order to estimate the small surviving population. This modification to the method is known as the "almost extinct generations method" (Andreev, 2004; Jdanov *et al.*, 2008; Jdanov *et al.*, 2005). Thatcher*et al.*, (2002) noted that even Vincent and his assistant sometimes had to estimate future deaths at some of the younger ages. One of the approaches to estimating the surviving population is the use of survival ratios (Jdanov *et al.*, 2005; Rosenwaike, 1981; Thatcher *et al.*, 2002). The surviving population is then estimated by extrapolating the survival ratios observed for earlier cohorts to deaths recorded to date. The population was then estimated at the middle of each of the years 1996 and 2001. The mid-year population estimates were also interpolated to estimate the population as at the date of the 1996 and 2001 censuses.

Mortality rates over the period between the two censuses were estimated as the ratio of the reported deaths over the period to the estimate of the number of person-years lived in that period on the assumption that the completeness of reporting of deaths is constant by age for the age groups 75 up to 100+.

Results

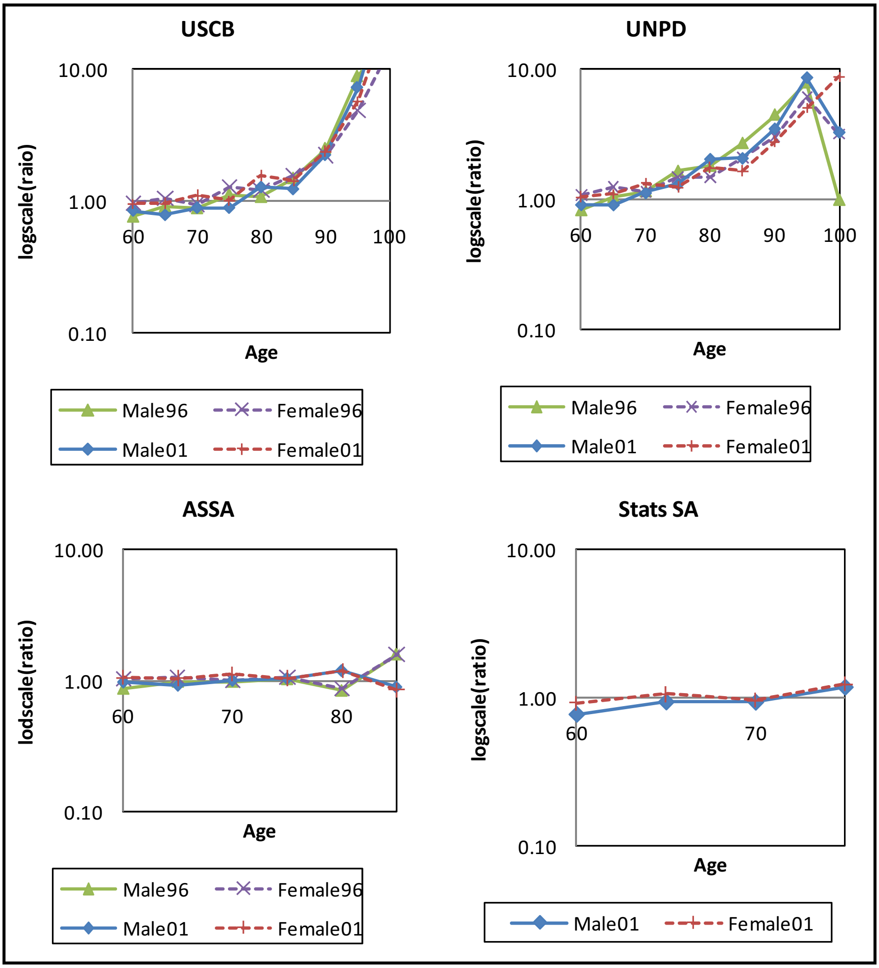

Figure 1 Ratio of census to estimates from various sources by age and sex: 1996 and 2001

In order to decide on the age range of interest, we first compared differences in the respective population numbers. Therefore, the various official estimates of the South African mid-year population were interpolated to estimate the population as at the census dates and compared with the census numbers as shown in Figure 1 above.

One can see from the above figures that the excess of the census population over the population estimated from the various sources generally increases with age. By inspection, the census population becomes excessively higher relative to the USCB and UNPD population estimates from age 75 and above. A comparison with the ASSA population estimates shows that the discrepancies start from age 80 and above. There are no significant differences in the comparison with mid-year estimates from Stats SA, at least not for the age groups where the estimates are available (estimates available up to age groups 80 and above). The ratios suggest that ASSA estimates are more consistent with the census population. The estimates from USCB and UNPD are lower than the counted population at ages as low as 75 which suggest that the two sources of estimates are probably over estimating the South African old age mortality. If the ASSA estimates of the population are correct, then either the difference between the ASSA estimates and the census/survey population is because the population was over counted from age 80 and above or because there is age exaggeration. Following these observations, it was decided to re-estimate the population numbers from age 75.

Next, the estimates of mortality rates derived from the census data and registered deaths (*D/P*) were compared with estimates obtained after adjusting for the completeness of reporting of deaths (D adjusted/P), the estimates derived by Dorrington *et al.*, (2004) (DMT) and the estimates derived from the UNPD and USCB population projections as shown in Figure 2 below.

From Figure 2, one can see that the direct estimates level off with age as a result of falling completeness with age and/or age exaggeration. Correcting the estimates by adjusting for the completeness independent of age merely raises the level throughout.

The method of extinct generations was then applied to estimate the mid-year population and the estimates of the population as at the date of both the 1996 and 2001 censuses interpolated from these estimates. These census date estimates are compared with the census estimates as shown in Table 1 below. In each of the two census years, extinct generation estimates were adjusted for general under-registration on the assumption that all exaggeration was confined to the 75+ age range.

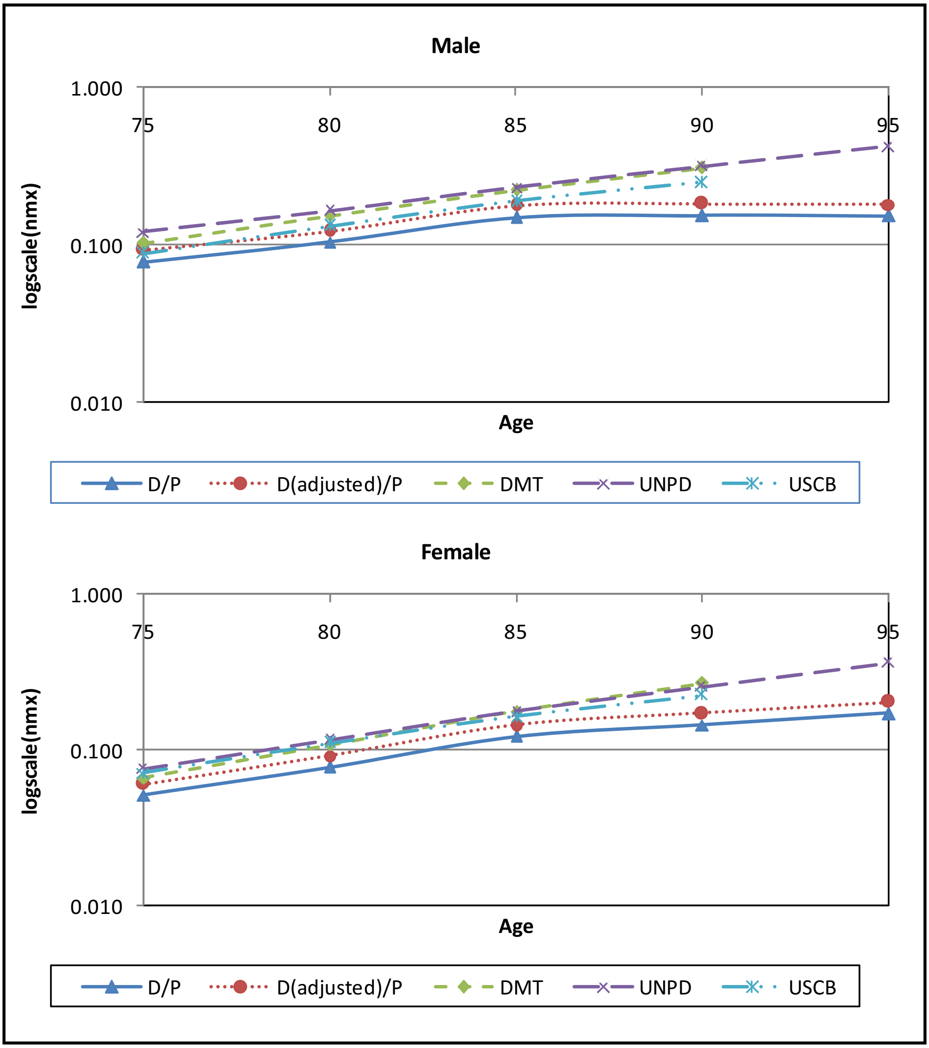

Figure 2 Mortality estimates by age group and sex over the period 1996-2001

The differences in the population numbers in Table 1 suggest that there was age exaggeration only above age 95 in both the 1996 and 2001 censuses. Thus, assuming that completeness of reporting of deaths is constant for all ages, it is possible to use the population derived from the extinct cohorts together with deaths at particular ages to estimate mortality rates directly. This would then eliminate the impact of age exaggeration in the population on the pattern of rates by age. These mortality estimates are shown in Figure 3 as *D / D* (sum).

Table 1 Census estimates and the population estimated using the method of extinct generation, by age and sex, 1996 and 2001 censuses

	Census		Method of Extinct Generations		Per cent deviation	
Age group	Male	Female	Male	Female	Male	Female
1996						
75-79	142, 013	235, 500	140, 423	239, 880	1.1	-1.8
80-84	62, 203	117, 123	64, 882	117, 473	-4.1	-0.3
85-89	28, 985	62, 313	29, 444	60, 390	-1.6	3.2
90-94	9, 944	23, 204	9, 340	21, 211	6.5	9.4
95-99	3, 949	7, 359	3, 216	7, 212	22.8	2.0
100+	496	1, 584	284	917	74.4	72.8
2001						
75-79	136, 353	231, 190	135, 405	233, 083	0.7	-0.8
80-84	90, 845	180, 097	85, 742	174, 655	6.0	3.1
85-89	28, 928	65, 303	33, 587	72, 772	-13.9	-10.3
90-94	11, 265	30, 448	13, 594	31, 333	-17.1	-2.8
95-99	4, 273	11, 171	3, 712	8, 075	15.1	38.3
100+	1, 636	4, 367	1, 261	2, 658	29.7	64.3

Note: The 1996 census numbers in Table 1 have been adjusted by a proportional reallocation of those with unspecified age.

The results in Figure 3 show that mortality rates estimated using estimates of the population derived by the method of extinct generations are generally slightly above the estimates derived using the census population. Even if the mortality estimates derived using the extinct cohort estimate of the population still level off with age, they are closer to the estimates from the other sources. Thus, while the method of extinct generations corrects for at least some of the impact of age exaggeration, the rates still appear to level off too rapidly.

Discussion and conclusions

This paper investigated the reasons for the levelling off of the mortality estimates at the older ages and the possibility of estimating the level of the mortality rates at these ages in South Africa. The method of extinct generations, which indirectly estimate the population numbers at the advanced ages in order to reduce the impact of the errors in the reported data, was used to estimate the population aged 75 up to 100+ as at the census dates in 1996 and 2001.

Before re-estimating the census population, we first compared the census numbers with estimates from various sources and the results suggest that the UNPD and the USCB are under estimating the population at the advanced ages.

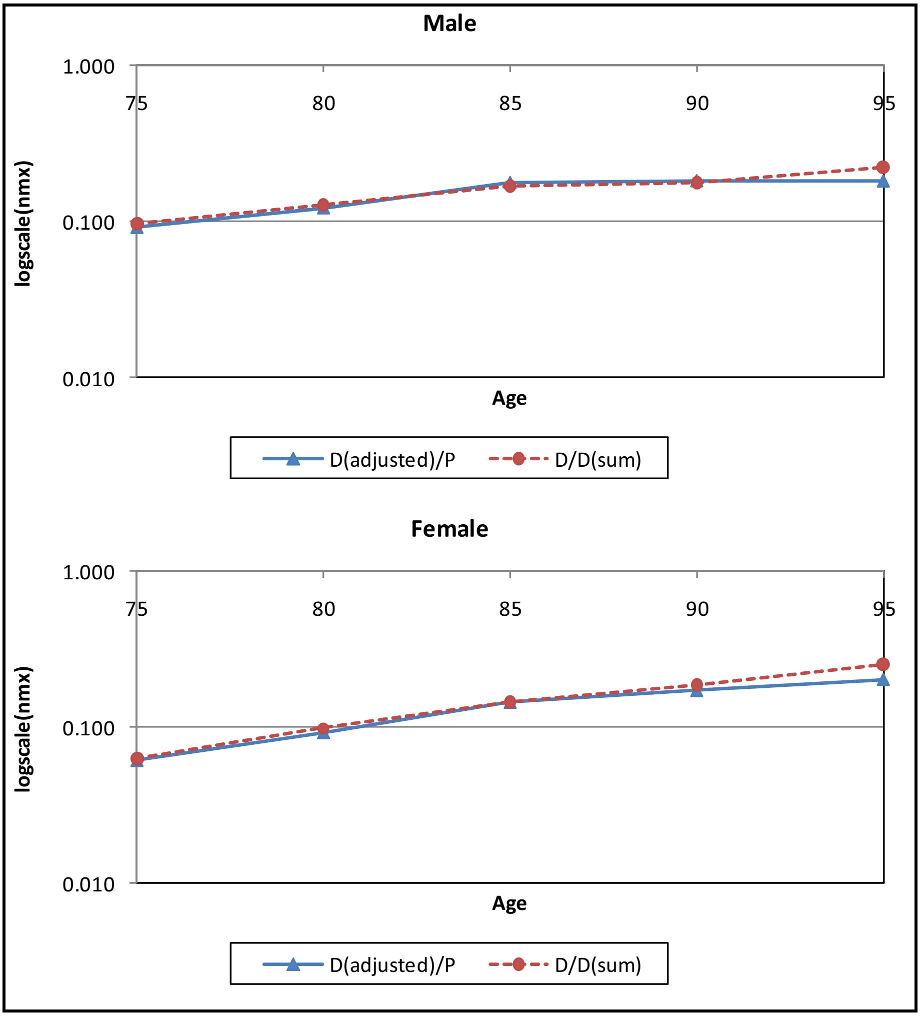

Figure 3 Mortality estimates by age group and sex over the period 1996-2001

The mortality rates estimated using the census data and the reported deaths were observed to be too low relative to the estimates of others (Dorrington *et al.*, 2004) and estimates underlying the UNPD and the USCB population projections. However, even after adjusting the deaths for an overall level of incompleteness, the estimated mortality rates level off with advancing age at the oldest ages. The empirical estimates could be wrong for the following reasons: (a) completeness of reporting of deaths relative to the population may fall with age, (b) age exaggeration may be greater in the census than for deaths, (c) there may be age exaggeration in both the registered deaths and the census population and (d) the population may have been over counted at the advanced ages. In order to decide which of these is likely to be the explanation, we need to interpret the results more thoroughly.

The population at these age groups (75 to 100+) was estimated using the method of extinct generations and compared with the census estimates as at the 1996 and 2001 census. The estimates derived from the deaths were generally lower than the census estimates which suggest that the censuses may have over counted or exaggerated the ages of the population to some extent,or that the reporting of deaths is generally incomplete relative to the census estimates. The over count of the population or age exaggeration in the population is confined to the oldest age groups, i.e., 95+ in both 1996 and 2001 which rule out (b) and (d) at the lower ages. It was also observed that the discrepancy between the population estimates from the method of extinct generations and the census numbers increases with age and this shows that accuracy of the population estimates falls with age at the advanced ages.

On the assumption that the completeness of reporting of deaths is constant by age at the advanced ages, mortality rates were estimated using the new derived population estimates and the reported deaths. We would expect these new estimates to produce correct rates if completeness of reporting of deaths is constant with respective to age. Surprisingly, the rates still level off with age, suggesting a general increase in completeness of reporting of deaths with age (which rules out (a))[2]. In addition, even if the estimates still level off with age, they are better than the standard estimates since they are higher and closer to the estimates from the other sources.

The conclusion is that much of the effect in the mortality rates is due to a general exaggeration of age of both deaths and the population (in fact, simulation suggest that the observed rates are best recreated by assuming a falling in completeness with age from around retirement age mixed with increasing age exaggeration, particularly in the last two age groups (95 and 100+)). These patterns in the reporting of ages can probably be attributed to the rural/ urban and the racial composition of the population at the advanced ages which change quite rapidly with age.

There is an increase in the proportion of the White population surviving to the advanced ages and also, not independently, the urban population. The death statistics from these population groups are more completely reported relative to the other groups. Therefore, it is possible that the completeness of reporting of deaths may have been falling around the retirement ages when people migrate to rural areas and then increasing again at the advanced ages because of the population composition.

In order to avoid the effects of the age exaggeration observed, it is suggested that a Gompertz curve be fitted to mortality estimates (D/D(sum)) at age groups 75, 80 and 85,giving final estimates of mortality shown in Table 2.

2. When the completeness of reporting of deaths increases with age, the estimated population at the advanced ages becomes less complete relative to the deaths.

Table 2 Mortality rates (nmx) by age group and sex over the period 1996-2001

Age group	Male	Female
75	0.09793	0.06375
80	0.12958	0.09695
85	0.17145	0.14745
90	0.22686	0.22425
95	0.30016	0.34106
100+	0.39716	0.51871

The estimates of mortality presented in Table 2 are generally lower but close to the estimates from the other sources.

Acknowledgements

I would like to thank the Hewlett Foundation and the University of Cape Town (Postgraduate Funding Office) for their financial assistance which facilitated my studies.

References

Actuarial Society of South Africa. 2005. *Aids Demographic Model 2003*. Cape Town: Actuarial Society of South Africa. *www.actuarialsociety.org.za*

Andreev, K.F. 2004. "A Method for Estimating Size of Population Aged 90 and over with Application to the 2000 U.S. Census Data", *Demographic Research* **11**(9):235-262.

Bennett, N.G. and Horiuchi, S. 1981. "Estimating the Completeness of Death Registration in a Closed Population", *Population Index* **47**(2):207-221.

Bennett, N.G. and Horiuchi, S. 1984. "Mortality Estimation from Registered Deaths in Less Developed Countries", *Demography* **21**(2):217-233.

Bongaarts, J. 2004. *Long Range Trends in Adult Mortality: Models and Projection Methods*.Policy Research Division Working Paper No. 192. Population Council.

Bourbeau, R. and Lebel, A. 2000. "Mortality Statistics for the Oldest-Old: An Evaluation of Canadian Data", *Demographic Research* **2**(2)

Brass, W. 1968. *The Demography of Tropical Africa.* Princeton, New Jersey: Princeton University Press.

Buettner, T. 2002. "Approaches and experiences in projecting mortality patterns for the oldest-old ", *North American Actuarial Journal* **6**(3):14-29.

Coale, A.J., Demeny, P. and Vaughan, B. 1983. *Regional Model Life Tables and Stable Populations.* New York, N.Y./ London: England Academic Press.

Coale, A.J. and Kisker, E.E. 1990. "Defects on Data on Old-Age Mortality in the United States: New Procedures for Calculating Schedules and Life Tables at the Higher Ages", *Asian and Pacific Population Forum* **4**:1-31.

Dorrington, R.E., Moultrie, T.A. and Timaeus, I.M. 2004. *Estimation of mortality using the South African census 2001 data*.Cape Town:

Centre for Actuarial Research: University of Cape Town.

Heligman, L. and Pollard, J.H. 1980. "The Age-Pattern of Mortality", *Journal of the Institute of Actuaries* **107**:49-75

Hill, K.H. 1987. "Estimating census and death registration completeness", *Asian and Pacific Population Forum* **1**(3):8-13.

Himes, C.L., Preston, S.H. and Condran, G.A. 1994. "A Relational Model of Mortality at Older Ages in Low Mortality Countries", *Population Studies* **48**(2):269-291.

Horiuchi, S. and Coale, A.J. 1982. "A Simple Equation for Estimating the Expectation of Life at Old Ages", *Population Studies* **36**(2):317-326.

Jdanov, D.A., Jasilionis, D., Soroko, E.L., Rau, R. and Vaupel, J.W. 2008. *Beyond the Kannisto-Thatcher Database on Old Age Mortality: An Assessment of Data Quality at Advanced Ages. MPIDR Working Paper WP 2008-013.*

Jdanov, D.A., Scholz, R.D. and Shkolnikov, V.M. 2005. "Official population statistics and the Human Mortality Database estimates of populations aged 80+ in Germany and nine other European countries", *Demographic Research* **13**(4):335-362.

Kannisto, V. 1988. "On the Survival of Centenarians and the Span of Life", *Population Studies* **42**(3):389-406.

Machemedze, T. 2009. "Old age mortality in South Africa." Unpublished MPhil thesis, Cape Town: University of Cape Town.

Preston, S.H., Heuveline, P. and Guillot, M. 2001. *Demography: Measuring and Modelling Population Processes.* Oxford: Blackwell.

Rosenwaike, I. 1981. "A Note on New Estimates of the Mortality of the Extreme Aged", *Demography* **18**(2):257-266.

Statistics South Africa. 1998. *The people of South Africa : population census 1996 , calculating the undercount in Census 96 /Statistics South Africa*.Pretoria: Statistics South Africa, 1998.

Statistics South Africa. 2001. *Recorded deaths, 1996*.Pretoria: Statistics South Africa, 2000.

Statistics South Africa. 2004. *Census 2001: Post-enumeration survey: Results and methodology*.Pretoria: Statistics South Africa, 2004.

Statistics South Africa. 2008. *Mortality and causes of death in South Africa, 2006: Findings from death notification*.Pretoria: Statistics South Africa, 2008.

Statistics South Africa. 2009. Interactive data. *http://www.statssa.gov.za/*. Accessed 4 February 2009

Thatcher, R. 1992. "Trends in Numbers and Mortality at High Ages in England and Wales", *Population Studies* **46**(3):411-426.

Thatcher, R., Kannisto, V. and Andreev, K. 2002. "The Survivor Ratio Method for Estimating Numbers at High Ages", *Demographic Research* **6**():1-18.

United Nations. 2002. *Methods for estimating adult mortality.* ESA/P/WP.175.New York: United Nations Population Division.

United Nations. 2007. World Population Prospects: The 2006 Revision Population Database. New York:Department of Economic and Social Affairs. *http://esa.un.org/unpp/*.

Accessed 26 February 2009

US Census Bureau. 2005. International Database. Washington DC: International Programs Center. http:// www.census.gov/ipc/www/idb/country/sfportal.html. Accessed 26 February 2009

Vincent, P. 1951. "La Mortalité des Vieillards", *Population* **6**(2):181-204.

Wilmoth, J.R. 1995. "Are Mortality Rates Falling at Extremely High Ages: An Investigation Based on a Model Proposed by Coale and Kisker", *Population Studies* **49**(2):281-295.