INDEPTH Mortality Clustering Supplement

Spatial and temporal clustering of mortality in Digkale HDSS in rural northern South Africa

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Background: Mortality data are frequently presented at the overall population level, possibly obscuring small-scale variations over time and space and between different population sub-groups.
Objective: Analysis of mortality data from the Dikgale Health and Demographic Surveillance System, in rural South Africa, over the period 1996–2007, to identify local clustering of mortality among the eight villages in the observed population.
Design: Mortality data and person-time of observation were collected annually in an open-cohort population of approximately 8,000 people over 12 years. Poisson regression modelling and space–time clustering analyses were used to identify possible clustering of mortality.
Results: Similar patterns of mortality clustering emerged from Poisson regression and space–time clustering analyses after allowing for age and sex. There was no appreciable clustering of mortality among children under 15 years of age nor in adults 50 years and over. For adults aged 15–49 years, there were substantial clustering effects both in time and in space, with mortality increasing during the period observed and particularly so in some locations, which were nearer to local conurbations. Mortality was relatively lower in the vicinity of the local health centre.
Conclusions: Although cause-specific mortality data were not available, the rise in mortality in the 15–49-year age group over time and in areas closer to conurbations strongly suggests that the clustering observed was due to the development of HIV/AIDS-related mortality, as seen similarly elsewhere in South Africa. The HIV/AIDS services offered by the local health centre may have contributed to lower relative mortality around that location.

Keywords: *South Africa*; *Dikgale*; *mortality*; *clustering*; *HIV/AIDS*

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Mortality results are frequently collated and presented on an overall basis for relatively large populations, even for entire countries. This may conceal important small-scale variations in time and space, as well as between various population sub-groups. Detailed mortality data such as are typically available within demographic surveillance systems contain a wealth of detail that may be overlooked in overall analyses, but may contain valuable public health information.

The Dikgale Health and Demographic Surveillance System (HDSS) is located in a rural area of South Africa's northernmost province, Limpopo. The HDSS is 45 km to the east of the provincial city of Polokwane. Fig. 1 shows the location of Limpopo Province within South Africa and of Dikgale District within the Province. According to the South Africa Community Survey of 2007, Limpopo province accounted for approximately 5.2 million of the 48.5 million national population (1). Dikgale HDSS was initiated in 1996, and throughout the period covered in the following analyses, up to the end of 2007, the surveillance covered a very stable overall population of 8,000 living in a cluster of eight rural villages, as mapped in Fig. 2. The site lies approximately 1,300 m above sea level, on South Africa's high veldt. The two larger villages, Madiga and Mantheding, are laid out on a grid of streets and are relatively densely populated

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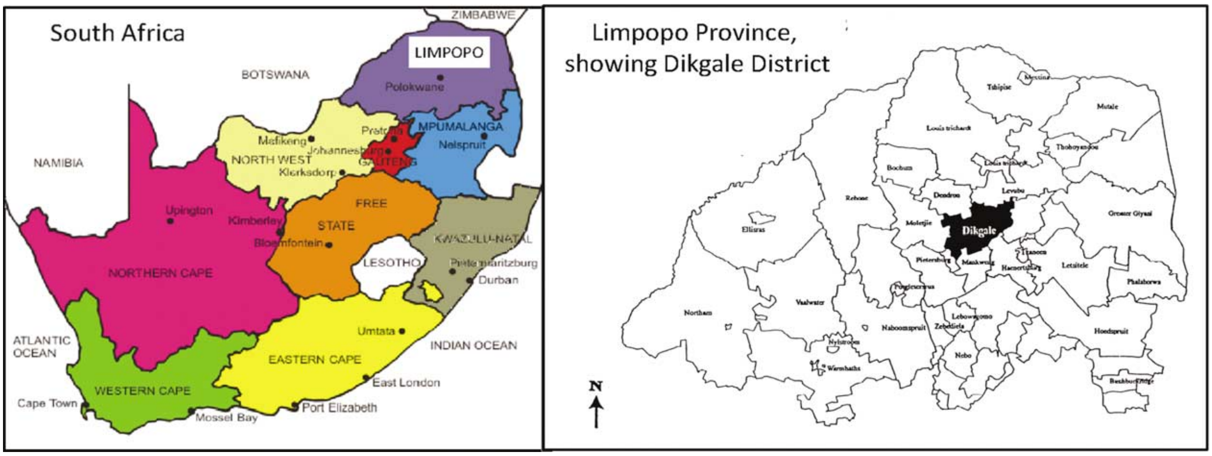

Fig. 1. Maps of South Africa and Limpopo Province.

compared to the six smaller villages, in which compounds are arranged more randomly. Although small amounts of crops are grown around houses in the villages, the land between the villages are the areas that are more systematically farmed. The villages are connected by a network of untarred roads. The main road to the west of the HDSS area provides public transport to nearby Mankweng town, where there is a major government hospital and other urban facilities. At the centre of the HDSS area, a clinic provides basic out-patient services, including counselling, testing and treatment for HIV/AIDS, and offers free treatment to children under 6 years of age, pregnant women and the elderly.

The Pedi ethnic group and language is dominant in the area. A large proportion of the HDSS population are migrant workers, either on long- or short-term bases. They mainly work as either farm labourers in commercial agriculture or as domestic workers in nearby centres of population and tourist areas, with some away on an extended basis in the mining sector. Unemployment within the HDSS population is high, despite typically high rates of literacy and education. There is no organised waste disposal in the area and most households have pit latrines. The demographic characteristics and mortality patterns in the community from 1996 to 2003 have been described previously (2), suggesting a rather stable pattern of mortality during that period. Other studies have shown appreciable signs of an increasing burden of non-communicable disease in this population (3). Owing to the relatively small size of the HDSS site, there has been no attempt to document and characterise cause of death patterns, but all deaths have been registered during annual follow-up visits to all households in the site.

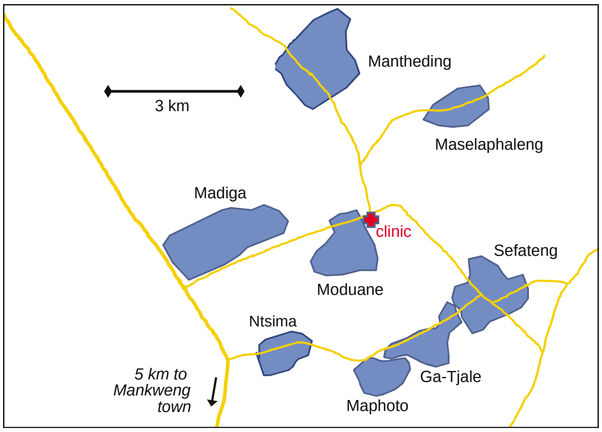

Fig. 2. Map of the Dikgale Health and Demographic Surveillance System area.

The aim of this paper is to characterise mortality patterns in this population over the 12-year period up to the end of 2007, and to see whether the application of space–time clustering analysis can offer additional insights into these patterns compared with overall analyses and regression modelling.

Methods

Following an initial process of mapping and censusing the HDSS area in 1995, there have been annual surveillance visits to all households. During these visit rounds, births, deaths and migration events have been documented, and, periodically, other background factors such as socioeconomic status have also been recorded (2). Households have been located in terms of latitude and longitude using GPS receivers. The Dikgale HDSS is a member of the Indepth Network (http://www.indepth-network.org) (4) and, apart from being smaller than other member sites, has followed the same general principles of population surveillance as other sites. Because of the relatively small size of the overall site, temporal analyses have been restricted to 4-year periods (1996–1999, 2000–2003 and 2004–2007) in order to have reasonable amounts of data in each category. The HDSS data have been managed in a customised Microsoft Access relational database system, from which the relevant data for the following analyses were extracted. Microsoft FoxPro was used to manage the data for analyses.

Descriptive and multivariate Poisson regression analyses were carried out using Stata 10, and space–time clustering analyses used the specialised SaTScan™ 8.0 software (http://www.satscan.org) (5), which reads data directly from FoxPro files. SaTScan™ allows purely spatial analyses, space–time analyses that can also include purely temporal clusters, and can allow for important background factors as covariates. For these analyses, a discrete Poisson-based model was used in which events at particular times and places were analysed against person-time observed in the same times and places.

The Dikgale HDSS activities received ethical approval from the Ethics Committee of the University of the North (subsequently University of Limpopo) in 1995 and the Department of Health and Welfare, Limpopo Province.

Results

The basic patterns of mortality by village, period (1996–1999, 2000–2003 and 2004–2007), age group (under 5 years, 5–14 years, 15–49 years, 50–64 years and 65+ years) and sex are shown in Table 1. The overall mortality amounted to 797 deaths over 96,194 person-years observed, a crude rate of 8.2 per 1,000 person-years. Numbers of deaths and person-time observed are shown for each category, leading to estimates of crude mortality and rate ratios with respect to reference categories. Moduane, a medium-sized and centrally located village, was chosen as the reference community; in the initial period (1996–1999), males and adults aged 15–49 years were reference categories for other parameters. Rate ratios adjusted over village, period, sex and age group were calculated using a Poisson multivariate regression model in which individual person-time was used as the exposure variable, the results of which are shown in the final column of Table 1.

Space–time clustering analysis commenced with a spatial-only analysis over the whole time period using SaTScan™ 8.0, allowing high and low incidence clusters with a maximum cluster size of 50% of the overall population, in which the only statistically significant cluster was one covering Ntsima and Maphoto, with a relative risk of 1.74 ($p = 0.010$). Proceeding to space–time clustering, and taking the same methodological approach while also allowing temporal-only clusters across the whole area, the most likely cluster emerged as the period 2004–2007 over the whole area, with a relative risk of 1.33 ($p = 0.007$). The next cluster covered Madiga and Moduane during 1996–1999, with a relative risk of 0.71 ($p = 0.037$). The third and final significant cluster covered Ntsima, Maphoto, Ga-Tjale and Sefateng during 2004–2007, with a relative risk of 1.55 ($p = 0.040$).

Table 1. Mortality in Dikgale HDSS from 1996 to 2007 by village, period, sex and age group

Parameter	Level	Deaths/ person-years	Crude rate/1,000 person-years	Unadjusted rate ratio (95% CI)	Adjusted rate ratio[a] (95% CI)
Village	Moduane	77/10,004	7.7	Ref	Ref
	Mantheding	262/30,025	8.7	1.13 (0.88–1.46)	1.44 (1.12–1.86)[b]
	Maselaphaleng	20/1,868	10.7	1.39 (0.86–2.26)	1.30 (0.84–2.03)
	Madiga	266/36,145	7.4	0.96 (0.74–1.23)	1.18 (0.92–1.52)
	Ntsima	14/1,066	13.1	1.71 (0.97–3.01)	1.97 (1.12–3.45)[b]
	Maphoto	36/2,497	14.4	1.87 (1.27–2.77)[b]	1.68 (1.13–2.51)[b]
	Ga-Tjale	44/5,097	8.6	1.12 (0.78–1.62)	1.21 (0.83–1.75)
	Sefateng	78/9,490	8.2	1.07 (0.78–1.46)	1.13 (0.83–1.55)
Period	1996–1999	221/32,603	6.8	Ref	Ref
	2000–2003	261/31,881	8.2	1.21 (1.01–1.45)[b]	1.17 (0.98–1.40)
	2004–2007	315/31,709	9.9	1.47 (1.23–1.74)[b]	1.35 (1.14–1.60)[b]
Sex	Male	408/46,528	8.8	Ref	Ref
	Female	389/49,666	7.8	0.89 (0.78–1.03)	0.66 (0.57–0.76)[b]
Age group (years)	15–49	294/48,821	6.0	Ref	Ref
	<5	66/10,496	6.3	1.04 (0.80–1.36)	1.06 (0.81–1.38)
	5–14	13/23,104	0.6	0.09 (0.05–0.16)[b]	0.09 (0.05–0.16)[b]
	50–64	119/8,023	14.8	2.46 (2.00–3.05)[b]	2.53 (2.04–3.13)[b]
	65 and over	305/5,749	53.1	8.81 (7.54–10.3)[b]	9.71 (8.26–11.4)[b]

[a] Adjusted for village, period, sex and age group.

[b] Significantly different from reference level, $p < 0.05$.

However, since it was apparent from the Poisson regression model shown in Table 1 that age and sex had a significant confounding effect on mortality patterns by village and period (reflected in differences between corresponding adjusted and unadjusted rate ratios), we next decided to repeat the overall space–time clustering analyses with the addition of age and sex as covariates. A purely spatial analysis with age and sex as covariates yielded no significant clusters of mortality, but a space–time analysis (also allowing temporal-only clusters) identified Mantheding as the only significant cluster, with a relative risk of 1.43 during 2004–2007 ($p = 0.037$).

To explore, rather than adjust for, the effects of age on mortality, we proceeded to space–time clustering analyses within specific age groups. Owing to the relatively small overall dataset, we decided to consider the under-15, 15–49 and 50+ years bands as the three age groups for further analyses. This choice was partly informed by concerns in South Africa in general about rising HIV/AIDS-related mortality among young adults (5). Sex was retained as a covariate in these analyses, which used space–time clustering with purely temporal clusters being allowed. No significant clusters were found on this basis among either the under-15 or over-50 age groups. In the 15–49 year age group, the most likely cluster included the entire area during the period 2004–2007, with a relative risk of 1.76 ($p = 0.001$). A further three significant clusters were also identified. Madiga, Moduane and Ntsima constituted a low-risk cluster during 1996–1999 with a relative risk of 0.47 ($p = 0.004$). During 2004–2007, Mantheding represented a high-risk cluster (relative risk 1.71, $p = 0.031$) and the three villages of Maphoto, Ga-Tjale and Sefateng together comprised a high-risk cluster with a relative risk of 1.92 ($p = 0.05$). These findings are summarised in Fig. 3.

Discussion

Both the Poisson regression modelling and SaTScan™ space–time clustering analyses of mortality in the Dikgale HDSS revealed some important heterogeneities within the relatively small population covered by the site. In contrast to previous analyses of earlier mortality in this site (2), the onset of increasing mortality among younger adults is now clearly seen, as noted earlier in other settings such as the Agincourt HDSS (6). Although cause-specific mortality data are not available for Dikgale, it is not reasonable in this setting to draw any other conclusion than that HIV/AIDS-related mortality is responsible for these changes (7).

This HDSS is also characterised by some long-standing variations in age-sex profiles between adjacent villages, possibly due to varying patterns of migration, retirement and other factors. Although the factors behind this may not be clear, it is evident from both the Poisson and clustering approaches that including age and sex as covariates has an important effect when comparing mortality patterns between villages. Therefore, we would place relatively more emphasis on the adjusted rate ratios from the Poisson model and from the clustering analyses including covariates when interpreting mortality differences in space and time.

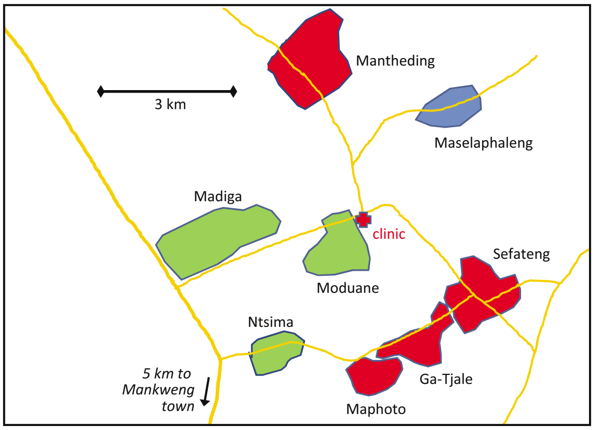

Fig. 3. Space–time clustering of mortality among adults aged 15–49 years between 1996 and 2007 in Dikgale HDSS. The villages of Madiga, Moduane and Ntsima formed a low-risk mortality cluster (green) (relative risk 0.47) during 1996–1999; Mantheding comprised a high-risk cluster (red) (relative risk 1.71) during 2004–2007, and during the same period the high-risk cluster (red) of Maphoto, Ga-Tjale and Sefateng had a relative risk of 1.92. In addition, the entire area had an increased risk of 1.76 during 2004–2007 compared with earlier periods.

In this relatively small dataset, a by-village approach to Poisson regression modelling and spatial clustering using village as the spatial unit are rather similar. Mantheding emerged as the major high-risk area in the overall space–time analyses using both methods. The two smaller villages, Ntsima and Maphoto, had significantly higher mortality rates in the overall Poisson analysis, but did not reach statistical significance as a cluster in the SaTScan™ analysis. Because of the rather small size of the Dikgale site, we restricted our analyses over time to three defined 4-year periods rather than dividing the data into years. Since there were only 13 deaths in the 5–14 year age group, we used under 15 years as the basis for childhood clustering analyses.

The lack of significant age-specific clustering other than in the 15–49 year age group shows that most of the dynamics and heterogeneity in mortality within this population are related to changes in this age group. The significant clusters emerging from the analysis within the 15–49-year age group clearly show a picture of rapidly increasing mortality (the significantly higher overall risk in the final period) compounded with localised high risks in the northern and southern extremes of the area, also during the final period. It is interesting to note that Mantheding is relatively closer to the larger villages of

Ga-Mokgopo and Ga-Dikgale, which lie beyond the north-east of the HDSS area, while the high-risk southern cluster of Maphoto, Ga-Tjale and Sefateng villages are closer to the urban centre of Mankweng. Whether these observations reflect urban to rural patterns of HIV transmission remains a matter of speculation. At the same time, the central area of the HDSS, where HIV counselling, testing and treatment services are available through the local clinic, seems to have been less severely affected by increasing adult mortality, though again it is impossible to relate cause and effect (8).

Compared with similar analyses from other Indepth HDSS locations (9, 10), this study is somewhat compromised by the relatively small size of the Dikgale site. We have managed this to some extent by taking time in 4-year periods rather than analysing individual years. Despite this limitation, we have identified heterogeneities in mortality that are both significant in statistical terms and make sense in public health terms within the wider context of South Africa. Although both the Poisson and clustering approaches are basically tackling similar issues and arriving at broadly similar conclusions, the identification of specific space–time clusters at significantly high or low risk of mortality is an intuitively attractive approach that can be easily understood. Taking a geographical approach to mortality patterns is an important component in overall understanding and in potentially targeting public health intervention strategies.

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Conflict of interest and funding

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