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# Mortality patterns, 1993–98, in a rural area of Burkina Faso, West Africa, based on the Nouna demographic surveillance system

**G. Kynast-Wolf[1], O. A. Sankoh[1], A. Gbangou[2], B. Kouyaté[2] and H. Becher[1]**

1 *Department of Tropical Hygiene and Public Health, University of Heidelberg Medical School, Heidelberg, Germany*
2 *Centre de Recherche en Santé de Nouna, Nouna, Burkina Faso, West Africa*

**Summary** The Nouna demographic surveillance system database was analysed for the period 1993–98. Basic demographic parameters, age-specific and age-standardized mortality rates were calculated and a seasonal variation in mortality was analysed. Poisson regression was used to model the calculated mortality rates and to investigate the seasonal mortality pattern. Both the population distribution by age and the mortality rates reflect a typical pattern of population structures and total mortality in rural Africa as a whole: high childhood mortality and a young population (about 60% are up to age 25; about 10% above age 64). We identified a significant seasonal pattern with highest mortality rates in February. Demographic surveillance systems in Africa provide a viable method for the collection of reliable data on vital events in rural Africa and should therefore be established and supported.

**keywords** demographic surveillance, Poisson regression, sub-Saharan Africa, total mortality

**correspondence** Prof. H. Becher, Department of Tropical Hygiene and Public Health, University of Heidelberg Medical School, Im Neuenheimer Feld 324, 69120 Heidelberg, Germany.
E-mail: heiko.becher@urz.uni-heidelberg.de

## Introduction

In 1978, African delegates joined the representatives of other nations in endorsing the Alma Ata Declaration, which committed all governments to the common goal of achieving 'Health for all' by the year 2000. A major task of epidemiologists is to assess to what extent this ambitious target has been realized.

Good descriptive epidemiological data are required, and the difficult task of collecting and presenting them was started in a rather heterogeneous way in Africa. A comprehensive volume on mortality and morbidity data in sub-Saharan Africa (Feachem & Jamison 1991) highlighted achievements in the 1980s and shortcomings in terms of lack of data for a large number of countries. During the 1990s, the white spots on mortality maps gradually became smaller, but most estimates of overall mortality are subject to error and bias – especially for sub-Saharan Africa – as reliable mortality statistics covering the total population hardly exist (Cooper *et al.* 1998). Consequently, many countries in Africa are now taking steps towards providing a reliable information base to support health development. An increasing number of field sites operating demographic surveillance systems (DSS) is being established in rural areas to continuously monitor geographically defined populations. To coordinate the activities of the sites, an International Network of Field Sites with Continuous Demographic Evaluation of Populations and THeir Health in Developing Countries (INDEPTH; see http://www.indepth-network.org for the vision and goals of the network as well as its current activities) was established in Dar es Salaam, Tanzania, in 1998. Many DSS sites in Africa collaborate with international research institutions. For example, the Nouna DSS in Burkina Faso, on which this study is based, collaborates with the Department of Tropical Hygiene and Public Health at the University of Heidelberg in Germany.

Sankoh *et al.* (2001) analyse a subset of the Nouna DSS data by concentrating on the clustering of children under five in the study area. They use a space and space–time scan statistic proposed by Kulldorff (1997) to identify clusters and test for their statistical significance. The paper reports several statistically significant clusters of higher childhood mortality rates comprising different sets of villages; one specific village was consistently identified in the study population, indicating non-random distribution of childhood mortality. The authors conclude that their 'study may be regarded as a first step in prioritizing areas for follow-up public health efforts'.

In another study, Würthwein *et al.* (2001) discuss the measurement of the local burden of disease (BOD) with respect to years of life lost (YLL) using the same DSS population. The DSS data exhibit the same qualitative BOD pattern as the Global Burden of Disease Study (GBDS) although with different ranking of the diseases. Würthwein *et al.* recommend that 'local health policy should be based on local BOD measurement, rather than on extrapolations that might not represent the true BOD structure by cause'.

Unlike the aforementioned studies, this paper attempts a descriptive statistical analysis of data from the Nouna DSS in order to get a general picture of total mortality in the study area for the observation period, 1993–98. Various statistical methods used to analyse total mortality (i.e. mortality without reference to specific cause) are presented. We briefly describe the study population, discuss the statistical method used, present basic demographic parameters including age-specific and age-standardized mortality rates and discuss the results of an analysis of seasonal variation in mortality in the study area for the observation period.

## Materials and methods

### Study area and population

A comprehensive description of the study area and study population can be found elsewhere (Baltussen *et al.* 2000; Sankoh *et al.* 2001; Würthwein *et al.* 2001). Briefly, Nouna Health Research Center (Centre de Recherche en Santé de Nouna, CRSN) is located in the Nouna Health District in the northwest of Burkina Faso. With an area of 7464 km$^2$, Nouna Health District, which is identical to the administrative province of Kossi, has a population of 240 000 inhabitants and a population density of 32 inhabitants/km$^2$. It covers 16 basic health facilities referred to as *Centre de Santé et de Promotion Sociale* (CSPS), one district hospital, and one medical centre. The main ethnic groups in are Dafing, Bwaba, Mossi, Peulh and Samo. The Dioula language serves as *lingua franca*.

The predominantly rural study area includes the semi-urban town of Nouna. It is dry orchard savanna, populated almost exclusively by subsistence farmers and cattle keepers. The region has a sub-Sahelian climate with a mean annual rainfall of 796 mm (range 483–1083 over the past five decades). Although formal schools have existed in the area since 1935, most children do not attend them; many attend informal koranic schools. More than 70% of the population are illiterate.

The DSS of the CRSN has conducted regular population censuses since 1992. In 1992, the study population consisted of 26 626 individuals. By 1998, this number had risen to 31 782. During the study period of this paper (1993–98), the DSS covered 39 villages, the catchment area of three CSPS. In 2000, a new census enhanced the DSS, which now includes the semiurban town of Nouna and two additional villages, representing the catchment area of the district hospital in Nouna and four CSPS after a redistribution of responsibilities. The total population of the DSS is now about 55 000, and it further comprises a vital events registration (VER) system recording births, deaths, and in- and out-migration and routine verbal autopsy (VA) interviews to be able to analyse mortality data by cause of death (Chandramohan *et al.* 1998; Anker *et al.* 1999; Würthwein *et al.* 2001).

To ensure data reliability, quality control procedures were implemented at various stages of the survey during the field phase in Nouna. Generally, in all surveys of the CRSN, a random sample of 5–10% of the households was re-interviewed by a supervisor. During data entry, a system of systematical, mutual control was implemented and data entry routines contained a set of logical checks and consistency checks for many basic variables, e.g. sex, age and the period of residence in the study area. Multiple entries into the study area and individuals with missing values in the key variables were deleted from the database, or replaced by plausible values if possible.

### Statistical methods

In this section, we introduce relevant parameters used for the description of epidemiological and demographic surveillance data. Further details are given in dos Santos Silva (1999).

### Mortality rates

Crude death rates, age-specific death rates and age-standardized death rates for appropriate time intervals were calculated based on person-years (PYs) (dos Santos Silva 1999). A PY is the exact time an individual in the study area was under risk. These were exactly calculated for individuals staying in the study area for each year of the observation period using an SAS macro. Crude death rates were standardized by using the Segi world population (Segi 1960; Estève *et al.* 1994). Ninety-five per cent confidence intervals for crude and age-standardized death rates were calculated using the normal approximation.

### Poisson-regression model for mortality rates

Poisson regression was used to model the mortality rates (Breslow & Day 1987). We considered the following variables in the analysis: mortality rate as the dependent variable and the sex, age, calendar year and month as explanatory variables. The Poisson model was applied for the entire observation period, 1993–98, as follows.

To assess the effect of age, mortality rates were modelled as a continuous function of age. The method of fractional polynomials (Royston & Altman 1994) was used to identify the model which best describes the data. Other covariables taken are calendar year (as a categorical variable) and sex. The variable calendar year was considered to investigate a time trend.

To investigate whether mortality depends on the season of the year, monthly mortality rates were used. PYs and deaths over the total observation period were calculated for each month. A total of 702 observations were excluded from the analysis because of missing information. The resulting data were used to calculate the monthly age-specific death rates by sex. The null hypothesis was that the value of the mortality rates was independent of the month of the year. This was tested by first estimating the effect of the month as a categorical variable, and a simple function applied to get a continuous description of the effect. We used a sine function of the form

$$g(\text{month}) = \sin[(\text{month} + k) \times \pi/6], \qquad (1)$$

where $k$ can take the value 1, …, 6 (assuming a period of 12 months). For this analysis, we assumed a constant mortality rate over the observation period. A similar model but with calendar year as additional covariable was also fitted. The Poisson regression analysis was carried out using the SAS-procedure PROC GENMOD with a log-link function (SAS Institute 1997).

## Results

### Basic demographic parameters

Table 1 shows the population distribution by age and sex at two specific time points, 31 December 1993 and 31 December 1998. The age distribution for both males and females is similar. More than 60% of the population is below 25 years of age. From 1992 to 1998, the population of both sexes rose steadily from 26 626 to 31 782 persons. This is an increase of 19.4%, with a mean yearly population growth rate of 3.0%.

For the entire observation period, 1993–98, the Nouna DSS data set comprised a total of 41 915 individuals

**Table 1** Population distribution for the Nouna DSS at the end of 1993 and 1998

| | 31 December 1993 | | | | 31 December 1998 | | | |
|---|---|---|---|---|---|---|---|---|
| | Males | | Females | | Males | | Females | |
| Age group | *n* | % | *n* | % | *n* | % | *n* | % |
| <1 | 549 | 3.9 | 489 | 3.6 | 661 | 4.1 | 675 | 4.3 |
| 1–4 | 2094 | 15.0 | 2024 | 14.8 | 2360 | 14.7 | 2236 | 14.3 |
| 5–9 | 2366 | 16.9 | 2276 | 16.6 | 2578 | 16.0 | 2385 | 15.2 |
| 10–14 | 1868 | 13.4 | 1632 | 11.9 | 2309 | 14.3 | 2108 | 13.4 |
| 15–19 | 1517 | 10.9 | 1419 | 10.4 | 1666 | 10.4 | 1457 | 9.3 |
| 20–24 | 1035 | 7.4 | 983 | 7.2 | 1278 | 7.9 | 1256 | 8.0 |
| 25–29 | 838 | 6.0 | 880 | 6.4 | 978 | 6.1 | 970 | 6.2 |
| 30–34 | 784 | 5.6 | 769 | 5.6 | 783 | 4.9 | 872 | 5.6 |
| 35–39 | 567 | 4.1 | 617 | 4.5 | 780 | 4.8 | 766 | 4.9 |
| 40–44 | 470 | 3.4 | 523 | 3.8 | 542 | 3.4 | 605 | 3.9 |
| 45–49 | 433 | 3.1 | 478 | 3.5 | 476 | 3.0 | 528 | 3.4 |
| 50–54 | 354 | 2.5 | 434 | 3.2 | 432 | 2.7 | 459 | 2.9 |
| 55–59 | 284 | 2.0 | 310 | 2.3 | 353 | 2.2 | 425 | 2.7 |
| 60–64 | 295 | 2.1 | 322 | 2.4 | 273 | 1.7 | 272 | 1.7 |
| 65–69 | 219 | 1.6 | 216 | 1.6 | 258 | 1.6 | 285 | 1.8 |
| 70–74 | 146 | 1.0 | 168 | 1.2 | 175 | 1.1 | 171 | 1.1 |
| 75–79 | 82 | 0.6 | 86 | 0.6 | 104 | 0.6 | 116 | 0.7 |
| 80–84 | 54 | 0.4 | 60 | 0.4 | 51 | 0.3 | 55 | 0.4 |
| 85+ | 21 | 0.2 | 15 | 0.1 | 39 | 0.2 | 45 | 0.3 |
| Total | 13 976 | 100 | 13 701 | 100 | 16 096 | 100 | 15 686 | 100 |

(20 432 males, 21 483 females, i.e. a male/female ratio of 0.95). A total of 135 individuals with missing sex or age were excluded from the data set. A total of 4886 individuals immigrated into the study area and 5640 individuals emigrated. The PYs of emigrating people were calculated up to the date of emigration. In the end the 41 915 individuals included in the analysis contributed collectively to 174 445 PYs (88 464 for males and 85 981 for females). The overall mean follow-up time is 4.1 with median 5.0 (range 0–6) years. On average 1355 births were registered per year. The distribution of PYs in the age groups is as follows: 18.3% fall in the age group 0–4 years, 40.0% in the age group 5–19, 37.7% in the age group 20–64 and 4.0% in the age group 65+.

Figure 1 shows the age pyramid of the population of Nouna DSS for 1993–98 based on the average PYs of each age group by sex over the years 1993–98. The pyramid looks typical for sub-Saharan Africa: many young and few old people.

### Overall mortality

A total of 1274 male and 1217 female deaths were recorded during the observation period 1993–98. Taking into account the 174 903 PYs (including the few persons with unknown ages), a crude death rate of 14.4/1000 for males and 14.1/1000 for females was calculated. The under-five mortality rate (U5MR) is 33.6/1000 for the same period. Male and female crude death rates are similar over the observation period.

The annual PYs, deaths and crude death rates (Kynast-Wolf *et al.* 2001) show that the highest crude death rates were observed in 1994 and 1995, with a peak in 1994 for females (16.6/1000) and in 1995 for males (15.6/1000). They were standardized using the Segi world population to get the age-standardized death rates shown in the tables. In most cases, crude death rates are slightly lower than age-specific death rates.

Figure 2a,b illustrates age-specific death rates of males and females for two calendar periods (1993–95, 1996–98). Death rates among infants and children under 5 are high: about 40% (for males often well over 40% but slightly under 40% for the last two years 1997 and 1998) of all deaths per year. Infant death rates are higher in males than in females. About 20% of the deaths occur at ages above 65. For these age groups, however, the mortality rates differ substantially by year, possibly because of the small numbers of individuals in these age groups that invariably yield large random variations between years.

Table 2 shows the crude and age-standardized death rates by sex for both calendar periods. The age-standardized

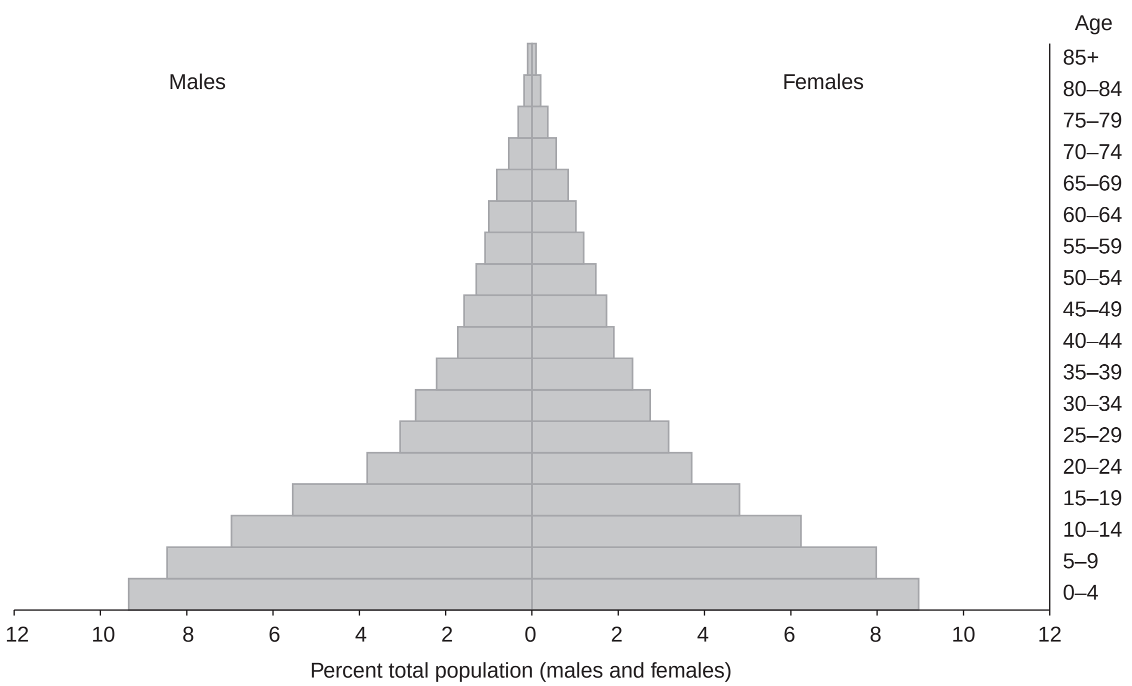


**Figure 1** Population pyramid of Nouna demographic surveillance system (DSS) (1993–98).

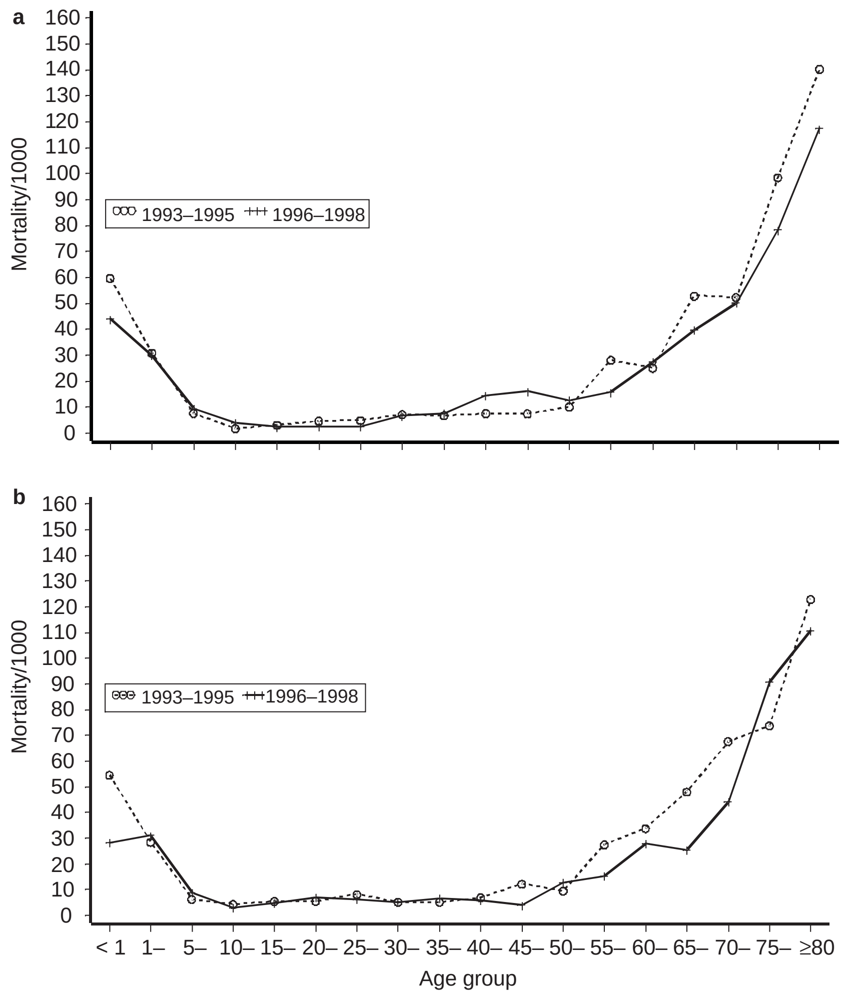


**Figure 2** Annual mortality by age for 1993–98: (a) males, Nouna DSS; (b) females, Nouna DSS.

death rate for females dropped from 16.7/1000, 95% CI (15.3, 18.2), in the first period (1993–95) to 13.6/1000, 95% CI (12.4, 14.8), in the second period (1996–98). Mortality for both male and female infants fell considerably (males: 59.8/1000 to 44.0/1000; females: 54.6/1000 to 28.4/1000). Childhood mortality (age 1–4) remained relatively unchanged in both periods. The rates for the succeeding seven age groups maintained a similar slowly decreasing pattern with increasing age for both males and females. We found a decreasing trend in mortality for the two periods 1993–95 and 1996–98 ($P = 0.04$).

The results of the Poisson regression show that the risk of mortality is not significantly associated with sex ($P = 0.46$). Hence, we omitted these variables from the model. Testing second-degree fractional polynomials, we found one which yielded the best fit for the data. The estimated regression coefficients led to the following function of the rate by age:

$$\mathrm{Rate}(\mathrm{age}) = \exp(-2.6565 + 0.0010 \times \mathrm{age}^2 - 0.6459 \times \sqrt{\mathrm{age}}). \quad (2)$$

The result is displayed in Figure 3. The fit is very good and shows the usual bathtub shape of rates.

## Seasonal variation in mortality

With the assumption that the two main seasons in Burkina Faso (rainy season June–October and dry season November–May) may have some effect on mortality, we investigated possible seasonal variability in the rates. We calculated the age-standardized death rates and crude death rates for each month by sex for the entire observation period (Kynast-Wolf *et al.* 2001); the latter are plotted in Figure 4 with 95% confidence intervals.

The data and their illustration in Figure 4 show a distinct pattern. For males and females, the mortality rates

**Table 2** Person-years, crude and age-standardized death rates by calendar period

| | Males | | Females | |
|---|---|---|---|---|
| | 1993–95 | 1996–98 | 1993–95 | 1996–98 |
| Person-years | 42 547 | 46 076 | 41 567 | 44 713 |
| Crude death rate (SE) | 14.7 (0.59) | 14.1 (0.55) | 15.0 (0.60) | 13.3 (0.55) |
| 95% CI | 13.5–15.9 | 13.0–15.2 | 13.8–16.2 | 12.2–14.4 |
| Age standardized* death rate (SE) | 15.8 (0.72) | 15.2 (0.68) | 16.7 (0.74) | 13.6 (0.62) |
| 95% CI | 14.4–17.2 | 13.9–16.5 | 15.3–18.2 | 12.4–14.8 |

*Standardization according to the Segi world population.

were high in the months of November until May and relatively low in the months of June until October. There was a peak in the month of September. We assumed that this pattern could have been affected by the data of the first age group (<1 year), but when we excluded infants from the data and repeated the analysis, this did not affect the seasonal pattern. We also investigated age groups (1–4, 5–19, 20–64, 65+) separately (data not shown), and a similar seasonal trend was observed in all although because of smaller numbers the effects were not as clear as for the total group.

The identified seasonal pattern was then modelled using Poisson regression. The function describing the rate ratio (RR) depending on months was estimated as:

$$\log \mathrm{RR}(\mathrm{month}) = 0.31 \times \sin[(\mathrm{month} + k) \times \pi/6]. \quad (3)$$

The best fit of the model was got when the constant $k$ was taken as 1. The results indicate a highly significant ($P < 0.001$) monthly effect on mortality in the study area with the highest mortality observed in February and the lowest in July and August. Figure 5 illustrates the RRs for each month using the sine function (1).

## Discussion

Descriptive epidemiological studies play an important role in medical research: information on mortality patterns is needed for the evaluation of health politics, identification of health hazards, planning of public health activities, and for many other issues. Such studies are very valuable especially where few epidemiological and demographic data exist. This study contributes to knowledge on general mortality in Burkina Faso and confirms the relevance of DSS as a viable means for collecting valid data on Africa's rural populations. As many such systems are established, new sets of valid data on Africa's populations will replace the 'guesstimates' which have so far been characteristic of international publications on Africa's rural populations.

The population is ascertained by field workers who visit households and collect the data. Newborns who die within the first days of life may not always be recorded (Kouyaté, personal communication), and infant mortality may therefore be slightly underestimated. Another study is underway to estimate the magnitude of this possible bias.

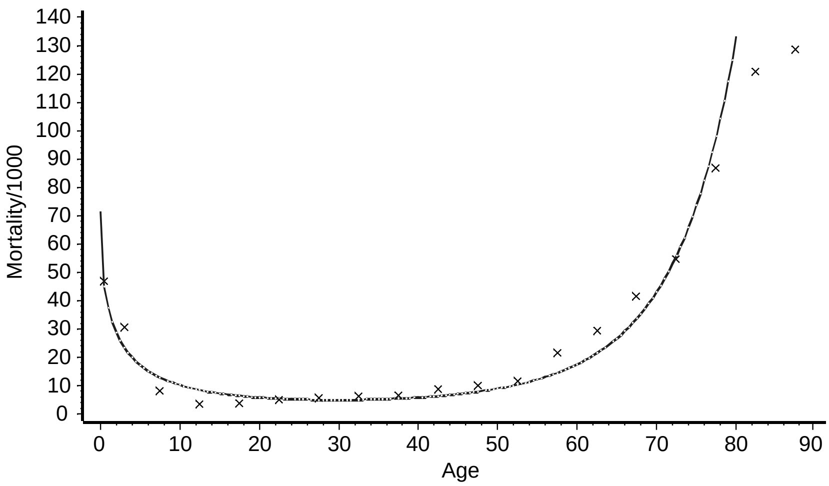


**Figure 3** Mortality rates by age, continuous and categorical, males and females, DSS population, Nouna DSS, 1993–98.

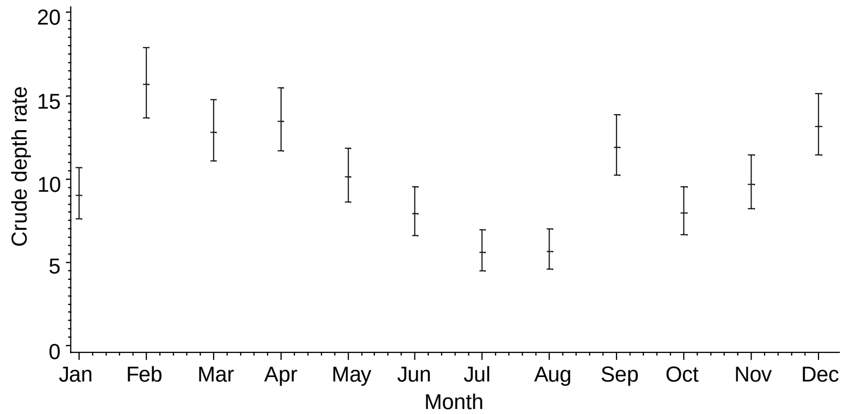


**Figure 4** Crude death rates by months for the years 1993–98 (males and females combined).

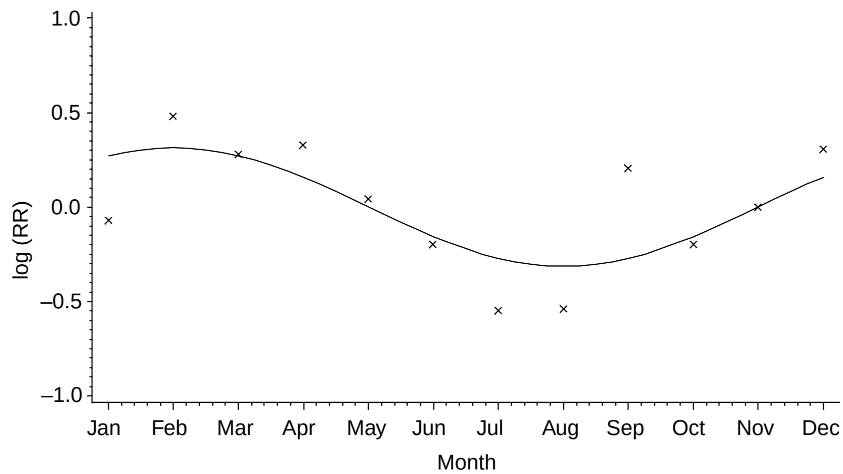


**Figure 5** Seasonal-dependent rate ratios using a Poisson model adjusted for sex and age.

We used the Segi world population to standardize calculated crude death rates because most published rates are based on it and thus the results of this paper can be compared directly with previously published work. For developing countries in particular and in the absence of a standard population for Africa, the Segi population is a good choice because its artificial distribution is similar to that found in developing countries. As a result, calculated crude and standardized rates are rather similar. The WHO has recently introduced a new standard to replace it to take into account the increasing life expectancy in the last decades in most countries. However, the age structure of this new population differs from those in the countries in sub-Saharan Africa.

Poisson regression modelling was a useful means to describe mortality rates from DSS. It provides a convenient and intuitively appealing method to graphically illustrate mortality patterns. Appropriate software for its implementation is readily available.

High childhood mortality continues to be a disturbing feature of public health in many developing countries. However, in Nouna infant mortality decreased over the observation period, which was confirmed by Sankoh *et al.* (2001). This promising sign needs to be verified in the next few years. Mortality rates for the age groups 5–14 and 15–64 did not change; those for people above 64 showed a decline, but the numbers are too small to allow firm conclusions. Remarkably, males and females in Nouna showed a very similar mortality pattern across all age groups.

As reported in the results, a highly significant seasonal effect on mortality was identified. Our observation of high mortality rates in the dry season contrasts with a previous study in The Gambia (Jaffar *et al.* 1997) which reports high mortality rates in the rainy season. The reasons for this difference are still unclear. A cause-specific analysis in further investigations may bring some light to this finding. This paper has considered all-cause mortality. To determine the cause of mortality, VA are used in the Nouna DSS. This method is useful for a number of diseases, even infectious ones (Garenne *et al.* 2000). Cause-specific mortality will be reported in forthcoming publications.

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