MORTALITY

Season of death and birth predict patterns of mortality in Burkina Faso

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Background Mortality in developing countries has multiple causes. Some of these causes are linked to climatic conditions that differ over the year. Data on season-specific mortality are sparse.

Methods We analysed longitudinal data from a population of ~35 000 individuals in Burkina Faso. During the observation period 1993–2001, a total number of 4098 deaths were recorded. The effect of season on mortality was investigated separately by age group as (i) date of death and (ii) date of birth. For (i), age-specific death rates by month of death were calculated. The relative effect of each month was assessed using the floating relative risk method and modelled continuously. For (ii), age-specific death rates by month of birth were calculated and the mean date of birth among deaths and survivors was compared.

Results Overall mortality was found to be consistently higher during the dry season (November to May). The pattern was seen in all age groups except in infants where a peak was seen around the end of the rainy season. In infants we found a strong association between high mortality and being born during the time period September to February. No effect was seen for the other age groups.

Conclusions The observed excess mortality in young children at or around the end of the rainy season can be explained by the effects of infectious diseases and, in particular, malaria during this time period. In contrast, the excess mortality seen in older children and adults during the early dry season remains largely unexplained although specific infectious diseases such as meningitis and pneumonia are possible main causes. The association between high infant mortality and being born at around the end of the rainy season is probably explained by most of the malaria deaths in areas of high transmission intensity occurring in the second half of infancy.

Keywords Africa, Burkina Faso, infant mortality, childhood mortality, adult mortality, malaria, rainy season, dry season, demographic surveillance

Introduction Mortality patterns in developing countries are usually characterized by high infant and childhood mortality and a specific distribution of causes of death.¹ However, any estimates of overall mortality are subject to error and bias because, especially for sub-Saharan Africa (SSA), mortality statistics covering the total population often lack reliability.² Therefore, statistics on mortality rates or number of dead persons are usually to be taken with caution.

Many countries in Africa are now undertaking steps towards providing a base for reliable information to support health policy and planning. An increasing number of demographic surveillance systems (DSS) are being established, mainly in rural areas (http://www.indepth-network.org/). These field sites continuously monitor vital events in populations living in well-defined geographical areas. In order to coordinate the activities of these sites, the INDEPTH network (International network of field sites with continuous demographic evaluation of populations and their health in...
developing countries) was established in 1998. The Nouna DSS, conducted in the research zone of the Centre de Recherche en Santé de Nouna (CRSN) in the Nouna Health District in north-western Burkina Faso, is a member of INDEPTH.

Relatively few publications report adult mortality patterns in African populations. Kaufmann et al. noted the scarcity of information on causes of death among adults in SSA. Although, little is known about the level and causes of adult mortality (15–59 years) in SSA, Kitange et al. reported that survivors of childhood in Tanzania show high rates of mortality throughout adult life. However, data on seasonal patterns are rarely available with the exception of a few studies in West Africa, mainly on childhood mortality. In recent years, there has been an interest in the effects of season of birth on mortality. Previous findings from Gambia that young adults (mean age 25) born in the rainy season had higher mortality rates support the thesis that being born in the rainy season and shortly after is a risk. But recently, Moore et al. and Simondon et al. found that season of birth is not associated with risk of early adult death in Bangladesh and Senegal, respectively, and Jaffar et al. found no marked difference in the death rate between children (<5 years) born in the rainy season and those born in the dry season in The Gambia.

Kynast-Wolf et al. analysed the Nouna DSS data for the period 1993–98. The population and age distribution and the mortality rates reflect a typical pattern in rural Africa: high childhood mortality. Mortality patterns of adults and older people were also described by Sankoh et al. Risk factors for childhood mortality in this population have been investigated by Becher et al.

We present here, our findings on seasonal mortality patterns from a rural population in north-western Burkina Faso surveyed over the period 1993–2001. The objectives of this study were to analyse (i) the overall and age-specific effects of season on mortality and (ii) the effects of month of birth on overall and age-specific mortality.

Materials and methods

Study area and the DSS data

The CRSN is located in the Nouna Health District in north-western Burkina Faso, West Africa, a country with an estimated population of ~12 million, 80% of which live in rural areas.

The Nouna study area is a dry orchard savannah populated almost exclusively by subsistence farmers and cattle keepers. The region has a sahelian climate with a mean annual rainfall of 796 mm (range 483–1083) over the past five decades. The region has a sahelian climate with a mean annual rainfall of 796 mm (range 483–1083) over the past five decades. The period November to May is the dry season while the period November to May is the dry season. Malaria is holoendemic but highly seasonal and has been demonstrated to be the main cause of morbidity and mortality in young children in the study area. Health services in the area comprise the District Hospital in Nouna town and four rural health centres in the surrounding villages.

The DSS of the CRSN has collected data from 39 villages surrounding Nouna town, since it was established in 1992. The DSS area has been augmented recently, but in this paper only data from these 39 villages are considered. The village populations range from 120 to about 2350 persons.

Vital events registration (VER) system started in 1992 after an initial census. The VERs were carried out by visits of trained interviewers to each village, who asked key informants whether any vital events had occurred since their previous visit. Two control censuses were carried out in 1994 and 1998. VER interviews are undertaken every 3 months: specific interviewers visit each household and ask about members previously registered or presently living in the household. The system is able to identify new vital events. Registered variables include births, deaths and migration with respective data. For some individuals, in particular in the early years of the DSS, only year of birth or year of death was available. These individuals were excluded or specially considered during the respective analyses (see Results section).

Statistical methods

Mortality by month of death

Poisson regression was used for absolute and relative mortality rate estimation and for modelling mortality by month on a continuous scale. For this analysis, we assumed a constant mortality rate over the observation period 1993–2001. This appears sufficiently true with an age-adjusted mortality of 14.6/1000 in 1993 and 14.0/1000 in 2001. Detailed data are available. The analyses were done adjusted by sex and age group (<1 year, 1–4, 5–14, 15–59, and 60+ years). Some analyses were done separately by age group. The sequence of analysis was as follows:

(i) Monthly mortality rates were estimated using the model

\[
\ln[D_j/MM_j] = \beta_1 \times \text{sex} + \beta_2 \times \text{age} + \beta_3 \times \text{month} \quad (I)
\]

Monthly death rates per K individuals (K = 1000) were estimated by age group using \(D_j\) as the number of deaths in age group \(i = 1, 2, \ldots, 5\), and month \(j = 1, \ldots, 12\), and likewise \(MM_j\) as the mid-month population in age group \(i\) and month \(j\). Rates were multiplied by 12 to allow comparison to yearly rates. All rates were scaled by an age-specific factor \(c = \text{(total deaths/deaths with known exact date of death)}\) to account for missing information on day of death. This procedure is valid under the assumption that the month of death is missing at random.

(ii) The mean mortality rates (adjusted for sex and age) were estimated by

\[
\ln[D_j/MM_j] = \beta_0 + \beta_1 \times \text{sex} + \beta_2 \times \text{age} \quad (II)
\]

To assess the relative effect of each month on mortality we used the floating absolute risk method. The relative effect is defined as the difference \(\beta_3(I) \times 6\) of the monthly effect of model (I) and the overall effect of model (II).

(iii) To get a continuous description of the seasonal effect we fitted a sine function of the form \(g(\text{month}) = \sin[(\text{month} + k) \times \pi/6]\), where \(k\) can take the value 1, 2, 3, 4, 5, 6 (assuming a period of 12 months) resulting in the following model

\[
\ln[D_j/MM_j] = \beta_1 \times \text{sex} + \beta_2 \times \text{age} + \beta_3 \times g(\text{month}) \quad (III)
\]
To investigate whether the monthly mortality rates differ between age groups, we investigated the above mentioned age groups separately in a similar fashion as described in (i)–(iii). Poisson regression analyses were carried out using the SAS-procedure PROC GENMOD.

### Month of birth and mortality

For calculating monthly death rates by date of birth, we had to exclude individuals with inaccurate date of birth or missing age. Age-specific death rates (ASDR) by month of birth are calculated as follows:

\[
\text{ASDR}_{ij} = \frac{D_{ij}}{\text{PY}_{ij}} \times K,
\]

where \(D_{ij}\) is the number of deaths per month of birth per age group \(i = 1, 2, \ldots, 5\) (0 ≤ 1, 1–4, 5–14, 15–59, 60+) and month \(j = 1, \ldots, 12\), and \(\text{PY}_{ij}\) are the corresponding person years in age group \(i\) of individuals born in month \(j\) within the observation period 1993–2001, and \(K\) is chosen to be 1000.

To investigate the effect of month of birth as a predictor for mortality, we applied a method proposed by Le et al., where the day of birth is transformed to a continuous variable on the unit circle, represented by an angle \(\theta\), or a pair of coordinates \((x, y)\). Thus, January 1 is represented by \(\theta = 0^\circ\), February 1 by \(\theta = 30^\circ\), etc. A mean date of birth of a group of individuals is obtained by calculating the arithmetic mean of all pairs \((x_i, y_i)\) separately for \(x\) and \(y\) and projecting the resulting point to the unit circle with \(\left(\frac{x}{r}, \frac{y}{r}\right)\) where \(r = \sqrt{x^2 + y^2}\).

We compared mean birth dates of infant deaths to all other individuals who survived infancy in the observation period. The variation of these means was assessed with bootstrap methods, using 1000 bootstrap samples from each group. Each sample provides a bootstrap mean for date of birth among deaths and among survivors. We projected the bootstrap means to the unit circle. This yields empirical bootstrap distribution functions for both groups, and 95% CIs using the uncorrected percentile method as the 2.5 and 97.5% quantiles.

### Results

#### Basic demographic parameters

The population size rose steadily from 28,315 persons in 1993 to 35,549 persons in 2001 with an average yearly population increase of 2.9%.

A total number of 4112 deaths were recorded during the observation period January 1, 1993 to December 31, 2001, of which 11 with missing age and 3 with missing sex were excluded, so that the analyses include 4098 deaths. Crude mortality rates were 14.5/1000 (95% CI 14.1–15.0) for the overall population, 51.3/1000 (95% CI 47.5–55.4) for infants, and 29.9/1000 (95% CI 28.2–31) for children aged 1–4 years. The under five mortality rate is 34.9/1000 (95% CI 33.3–36.5).

#### Seasonal mortality based on date of death

For 872 (21.3%) of 4098 persons who died during the observation period the year of death, but not the month of death, was recorded.

The overall (adjusted according to the procedure given in Methods section) death rates for each month for the entire observation period are shown in Figure 1 with 95% CI. It shows a clear seasonal trend with high overall mortality rates in the months of November to May and low overall mortality rates in the months of June to October.

The identified seasonal pattern was then modelled using Poisson regression. The best fit of the model was obtained for

![Figure 1](image_url)
the parameter value $k = 1.4$. This corresponds to a minimum of mortality rates on August 18 and a maximum on February 18. The results indicate a highly significant effect ($P < 0.001$) of the month on mortality in the study area. The first curve of Figure 2 illustrates the rate ratios (RR) for each month using the sine function estimated as:

$$
\log \text{RR}_{\text{month}}(\theta) = 0.22 \times \sin[(\text{month} + 1.4) \times \pi / 6].
$$

The monthly age-specific death rates are shown in Table 1. Although based on smaller numbers, seasonal effects were observed in all five age groups and were reasonably consistent over the period of observation. The patterns of mortality rates of youths, adults and old-aged people are similar to the overall pattern with a significant mortality peak in the cold dry season. The pattern for infants differs from the pattern in the older age groups with higher mortality rates at the end of the year, from August to December. The pattern for children aged 1–4 to that of infants show higher rates from November to February.

The results from modelling a sine function using Poisson regression support a highly significant ($P < 0.001$) seasonal variation of mortality in the study area in all age groups. Table 2 summarizes the functions describing the best fit of the RRs and the corresponding dates of minimum and maximum rates.

Figure 2 illustrates the RRs for each month using the floating absolute risk method and the sine function describing the RRs depending on month for the five age groups and overall.
Seasonal mortality by date of birth
Seasonal variation in mortality depending on month of birth by age groups
This analysis requires accurate dates of birth, so that 1345 (33% of 4098) individuals, for whom only the year of birth was known, had to be excluded. Figure 3 shows the number of monthly births, which displays a more or less regular peak towards the end of the year.

For infants, mortality rates showed a significant heterogeneity by month of birth, with highest rates for the months September, October and December. For all other age groups, the mortality pattern by month of birth appears randomly distributed (Table 3).

Seasonal variation of mortality by month of birth for infants
Detailed analyses were performed for 611 of all 638 infants who died during the observation period. 11 556 individuals who survived infancy in the same period were included as a comparison group.

Table 1 Monthly age-specific death rates per 1000 per year (MASDR) by age group and month of death, rural Burkina Faso, 1993–2001

<table>
<thead>
<tr>
<th>Age classes</th>
<th>MASDR</th>
<th>95% CI</th>
<th>MASDR</th>
<th>95% CI</th>
<th>MASDR</th>
<th>95% CI</th>
<th>MASDR</th>
<th>95% CI</th>
<th>MASDR</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infants (&lt;1)</td>
<td>Jan</td>
<td>49.6</td>
<td>37.6–65.3</td>
<td>Feb</td>
<td>40.4</td>
<td>29.8–54.8</td>
<td>Mar</td>
<td>45.9</td>
<td>34.5–61.0</td>
<td>Apr</td>
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</table>

CI Confidence interval (adjusted for individuals with missing month of death, see text).

Table 2 Continuous modeling of seasonality patterns of month of death by age group, rural Burkina Faso, 1993–2001

<table>
<thead>
<tr>
<th>Age group</th>
<th>log RR(month)</th>
<th>P-value</th>
<th>Minimum date</th>
<th>Maximum date</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1</td>
<td>0.18 × sin[(month + 4.2) × π/6]</td>
<td>0.0018</td>
<td>26 May</td>
<td>24 November</td>
</tr>
<tr>
<td>1–4</td>
<td>0.21 × sin[(month + 2.6) × π/6]</td>
<td>&lt;0.0001</td>
<td>13 July</td>
<td>12 January</td>
</tr>
<tr>
<td>5–14</td>
<td>0.51 × sin[(month + 0.3) × π/6]</td>
<td>&lt;0.0001</td>
<td>21 September</td>
<td>23 March</td>
</tr>
<tr>
<td>15–59</td>
<td>0.21 × sin[(month + 0.5) × π/6]</td>
<td>&lt;0.0001</td>
<td>15 September</td>
<td>17 March</td>
</tr>
<tr>
<td>60+</td>
<td>0.38 × sin[(month + 1.0) × π/6]</td>
<td>&lt;0.0001</td>
<td>31 August</td>
<td>1 March</td>
</tr>
</tbody>
</table>

Figure 3 Percentage of births by month, rural Burkina Faso, 1993–2001
The mean day of birth of deceased children was October 24 (95% CI: October 6–November 15), and it was November 25 (95% CI: November 12–December 9) for survivors. The difference between both means is statistically significant ($P < 0.001$). Figure 4 shows both means, surrounded by the ‘clouds’ of bootstrap samples used to compute CIs. Both means are clearly distinct from the null value, which indicates that the distribution of date of birth is not random over the year.

Discussion

This study demonstrates a strong association between mortality and season in a rural area of Burkina Faso. Based on the analysis of a large number of deaths over a period of 9 years, overall mortality was found to be consistently higher during the dry season compared with the rainy season. When looking more specifically at the dynamics of mortality by age group, the overall pattern with a mortality peak in the early dry season was observed in all age groups except in infants. In infants, highest mortality rates were around the end of the rainy season. Children aged 1–4 years showed an intermediate pattern with highest mortality rates also around the end of the rainy season but in addition also during the early dry season. Moreover, in infants we found a strong association between high mortality and being born during the time period September to February.

There are not much data available on the influence of season on mortality rates in SSA. In two studies from The Gambia, high infant and childhood mortality rates were clearly associated with the time around the end of the rainy season. This is similar to our findings and supports other results from SSA on malaria, being the major causes of observed excess mortality during and around the end of the rainy season. Malaria has thus been shown to be the greatest contributor to childhood morbidity and mortality in both The Gambia and in Burkina Faso. However, owing to differences in malaria endemicity the results from The Gambia, which is a mesoendemic area, are not directly comparable with the results from Burkina Faso, which is a holoendemic area. The observed high mortality in children aged 1–4 years during the cold dry season in our study may be explained by a higher prevalence of other infections such as pneumonia, measles and meningitis in these months. As vaccination coverage is high in Burkina Faso and the region and as measles is only rarely seen in these days in the study area, this disease is not likely to play a major role. In contrast, meningitis is well known to greatly contribute to childhood mortality in Burkina Faso, which belongs to the African meningitis belt. In these areas, regular meningitis outbreaks during the dry seasons are probably explained by a low absolute humidity and the dusty harmattan wind, which damages the local mucosal defences. However, we believe that the mortality peak in 1- to 4-year old children in February, which is the end of the cold dry season, is mainly explained by pneumonia known to be the major cause of mortality in young children in developing

Figure 4 Mean date of birth for infants who died during infancy compared with those surviving their first year of life, rural Burkina Faso, 1993–2001
Table 3. Person Years (PY), age-specific death rates per 1000 (ASDR) by age group and month of birth, rural Burkina Faso, 1993–2001

<table>
<thead>
<tr>
<th>Age classes</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PY</td>
<td>ASDR</td>
<td>CI</td>
<td>PY</td>
<td>ASDR</td>
<td>CI</td>
<td>PY</td>
<td>ASDR</td>
<td>CI</td>
<td>PY</td>
<td>ASDR</td>
</tr>
<tr>
<td>Infants(&lt;1)</td>
<td>883</td>
<td>51.0</td>
<td>36.1–65.9</td>
<td>883</td>
<td>52.7</td>
<td>37.8–67.6</td>
<td>883</td>
<td>51.7</td>
<td>36.5–65.9</td>
<td>883</td>
<td>51.7</td>
</tr>
<tr>
<td>Children(1–4)</td>
<td>2715</td>
<td>35.0</td>
<td>28.0–42.0</td>
<td>2715</td>
<td>35.0</td>
<td>28.0–42.0</td>
<td>2715</td>
<td>35.0</td>
<td>28.0–42.0</td>
<td>2715</td>
<td>35.0</td>
</tr>
<tr>
<td>Young age(5–14)</td>
<td>4531</td>
<td>7.7</td>
<td>5.1–10.2</td>
<td>4531</td>
<td>7.7</td>
<td>5.1–10.2</td>
<td>4531</td>
<td>7.7</td>
<td>5.1–10.2</td>
<td>4531</td>
<td>7.7</td>
</tr>
<tr>
<td>Adults(15–59)</td>
<td>3927</td>
<td>7.1</td>
<td>4.5–9.8</td>
<td>3927</td>
<td>7.1</td>
<td>4.5–9.8</td>
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<td>4.5–9.8</td>
<td>3927</td>
<td>7.1</td>
</tr>
<tr>
<td>Old age(&gt;60)</td>
<td>3757</td>
<td>6.6</td>
<td>4.6–8.6</td>
<td>3757</td>
<td>6.6</td>
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<td>6.6</td>
<td>4.6–8.6</td>
<td>3757</td>
<td>6.6</td>
</tr>
</tbody>
</table>

PY, person years; CI, confidence interval.

The observed infant and childhood excess mortality from August until December in our study is thus mainly to be explained by the effects of malaria around the end of the rainy season, and in adults is needed and malaria control measures in areas of high transmission intensity should focus more on very young children.
Acknowledgements

This work was supported by the collaborative research grant ‘SFB 544’ of the German Research Foundation (DFG). The authors would like to thank the field staff in Nouna/Burkina Faso and Gabriele Stieglbauer for effective data management.

KEY MESSAGES

- The mortality pattern of a population of 35 000 individuals under demographic surveillance in rural Burkina Faso was analysed with respect to season of birth and death.
- Overall mortality shows a seasonal peak in the dry season for all age groups except infants where a peak was found at the end of the rainy season.
- Date of birth had no effect on mortality except for infants with higher rates for those born in September, October and December.
- Malaria is likely to be the cause of the observed patterns in infants.

References

Commentary: Patterns in mortality governed by the seasons

Sophie E Moore

It has long been recognized that seasonal patterns exist in mortality rates with, for example, northern hemisphere countries observing a marked excess of deaths during the colder winter months.1,2 Many causes for this winter excess...