 International Journal of Epidemiology 2001;**30**:485–492

Clustering of childhood mortality in rural Burkina Faso

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Background Childhood mortality is a major public health problem in sub-Saharan Africa. For the implementation of efficient public health systems, knowledge of the spatial distribution of mortality is required.

Methods Data from a demographic surveillance research project were analysed which comprised information obtained for about 30 000 individuals from 39 villages in northwest Burkina Faso (West Africa) in the period 1993–1998. Total childhood mortality rates were calculated and the geographical distribution of total childhood mortality was investigated. In addition, data from a cohort of 686 children sampled from 16/39 of the villages followed up during a randomized controlled trial in 1999 were also used to validate the results from the surveillance data. A spatial scan statistic was used to test for clusters of total childhood mortality in both space and time.

Results Several statistically significant clusters of higher childhood mortality rates comprising different sets of villages were identified; one specific village was consistently identified in both study populations indicating non-random distribution of childhood mortality. Potential risk factors which were available in the database (ethnicity, religion, distance to nearest health centre) did not explain the spatial pattern.

Conclusion The findings indicate non-random clustering of total childhood mortality in the study area. The study may be regarded as a first step in prioritizing areas for follow-up public health efforts.

Keywords Childhood mortality, clustering, demographic surveillance, spatio-temporal analysis

Accepted 15 February 2001

In the developing world, morbidity and mortality continue to show a pattern characterized by high childhood mortality, mainly due to infectious diseases. The World Health Organization[1] states that 'despite the extraordinary advances of the 20th century, a significant component of the burden of illness globally still remains attributable to infectious diseases …' It therefore states the need to develop more effective health systems as one of the challenges to be addressed in order to improve the world's health. 'The goal must be to create health systems that can: improve health status; reduce health inequalities; enhance responsiveness to legitimate expectations; increase efficiency; protect individuals, families and communities from financial loss; and enhance fairness in the financing and delivery of health care'.

Until now, there is no routine registration of births and deaths in most of the developing world. Information on basic demographic measures often stems from demographic surveillance systems (DSS). Usually, these systems are based on initial census of a population of limited size, often in the order of some ten thousands of individuals, followed by an active follow-up in which births, deaths, in- and out-migration are recorded. Active follow-up consists of information from specific community informants or regular house-to-house visits to the respective population at which events in the period since the preceding visit are obtained.

The development and evaluation of effective programmes to reduce the burden of disease requires a detailed knowledge of disease or mortality distribution and causal pathways. This knowledge could be derived from analytical epidemiological

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studies that use as a platform large-scale health surveys and the above described demographic surveillance systems (DSS) in which causal relationships between risk factors and diseases or mortality are investigated. Benzler and Sauerborn[2] recommend that in cases where general population-wide intervention programmes are too expensive to implement, it is necessary to limit such programmes to high risk units where certain adverse health effects are more likely to occur. Therefore, investigating whether the distribution of adverse health outcomes in a population are either random or not should be an important primary objective before starting a programme for primary and secondary prevention of infectious diseases. It is necessary to determine whether there are clusters where adverse health outcomes seem to aggregate. If this is the case, there is need to identify the causes of such clustering, to enable local health personnel to identify them by means of simplified scores, and to develop specific health care strategies targeted at these clusters.

Statistical methodology to identify disease clusters is under constant development. A general review of clustering methods is provided by Hertz-Picciotto[3] and examples of specific applications are given by Hjalmars *et al.*,[4] Britton,[5] Kulldorff *et al.*[6] and Kulldorff.[7] In this paper we employ the Kulldorff spatial scan statistic[8] for the identification of and testing for clusters of childhood mortality.

The paper is organized as follows: First, we describe the main characteristics of the DSS population on which most of the analyses are based. We then describe the study population from a controlled trial[9] which turned out to be useful for supporting the findings and give an outline of the statistical methods used. Following the results we discuss our findings in the light of immediate and future impact on public health and their possible limitations.

Study populations

Geographical description

The study area is within the rural province of Kossi in northwest Burkina Faso with the town of Nouna as its administrative headquarters (Figure 1). Burkina Faso is a landlocked country in West Africa with an estimated gross domestic product (GDP) per capita purchasing power parity of $1000 (CIA[10]), and an estimated cumulative mortality rate up to age 5 years of 182 for males and 172 for females (World Health Report[11]). The population is about 11 million (1997), with 56% children under 15 years, and an annual population growth rate of 2.6%. The country is predominantly rural; about 80% of the population live in rural areas. The rural provinces have an inadequate health delivery system compared to the urban areas.

With an area of 7464.44 km^2, Kossi province has a population of 240 000 and a population density of 32 inhabitants per square kilometre. Of the population, 50.16% are female and 49.84% male. In all, 18.7% of the population are projected to be children aged 0–5 years in 2000.

The DSS population

The DSS in rural Burkina Faso comprises the entire population of 39 villages with approximately 30 000 people and approximately 4800 households within the province of Kossi. The villages are in the catchment area of three dispensaries with attached maternity clinics staffed by a nurse and a midwife. In 1992, the first census was carried out. A control census was held in 1993, and a further complete census was held in 1998. Since 1992 Vital Events Registrations (VEE) have been carried out through the visits of trained interviewers to each village. These interviewers ask three key informants if any deaths, births or in- and out-migration have occurred in the preceding month since the previous visit.[12] In the VEE, births, deaths and migrations were recorded with the cause of death determined by verbal autopsy according to the method of Anker *et al.*[13] The database for this paper included a follow-up of the population until 31 December 1998.

Randomized controlled trial cohort

In June 1999, a cohort of 686 children aged 6–31 months in a subsample of the DSS study villages was enrolled for a randomized placebo-controlled trial on zinc supplementation in which a possible effect on frequency of malaria episodes was investigated.[9] Children for the study were recruited from 16 out of 39 study villages (blocks of 30 and 60 children randomly sampled from small and big villages respectively), and prospectively followed up for a period of 6 months through daily household visits. Information on deaths was recorded during this trial. The data of this study are used here for the purpose of validating the results from the DSS database.

Statistical methods

Mortality ratios for the DSS data

We calculated the childhood death rates (DR) by village i, $i = 1,\ldots,39$ for years j, $j = 1993,\ldots,1998$ using $DR_{ij} = \frac{d_{ij}}{n_{ij}}$ where n_{ij} denotes the midyear population of children aged 0–4 years in village i at year j, and d_{ij} the corresponding observed number of deaths. In order to identify villages in which the death rate was significantly above average, an exact 95% CI for each rate was based on the Poisson distribution of the observed number of deaths.[14] A rate was considered significantly above average if the overall rate of the respective year was below the lower value of the confidence interval of the village rate, a procedure commonly used in descriptive epidemiology.[15] An overall temporal trend in rates was analysed by applying a Poisson regression model of the form $d_{ij} = \log(n_{ij}) + \mu + \beta \,.\, j$ where $i = 1,\ldots,39$, $j = 1993, 1994,\ldots,1998$ and tested for $H_o : \beta = 0$[16] using the software package EGRET.[17]

Method to investigate disease clustering

As briefly outlined in the introduction, several methods for disease cluster analysis have been suggested. We chose the Kulldorff spatial scan statistic[8] in which the spatial distribution of the population is taken into consideration as follows.

A circular window is imposed on a map by the spatial scan statistic and it allows the centre of the circle to move across the study region. For any given position of the centre, the radius of the circle changes continuously so that it can take any value between zero and some upper limit. The circle is therefore able to include different sets of neighbouring villages. A village is captured if it lies in the circle.

The method creates a set containing an infinite number of distinct circles. Each of these circles could contain a different set of neighbouring villages and each of the circles is a potential cluster of childhood mortality in the Kossi study area. For each circle, the spatial scan statistic calculates the likelihood of observing the observed number of cases inside and outside the circle. The circle with the maximum likelihood is defined as the most likely cluster, implying that it is least likely to have occurred by chance. For each circle, the method tests the null hypothesis against the alternative hypothesis that there is at least one circle for which the underlying risk of mortality is higher inside the circle as compared to outside. Generally, the method tests the null hypothesis that the risk of children dying is the same in all villages in the study area.

Let N be the total number of deaths in the study area, n the observed number of deaths within the circle, and λ the expected number of deaths in the circle under the null hypothesis. Let the number of deaths in each village follow a Poisson distribution. Hence the likelihood ratio for a specific circle is therefore proportional to

$$\frac{L_A(D)}{L_0} \propto \left(\frac{n}{\lambda}\right)^n \left(\frac{N-n}{N-\lambda}\right)^{N-n} I(n > \lambda), \qquad (1)$$

where $L_A(D)$ is the likelihood under the alternative hypothesis that there is a cluster of elevated annual mortality rates in age group 0–4 in a specific circle D, L_0 is the likelihood under the null hypothesis, and I is an indicator function that is equal to 1 when the circle has more deaths than expected under the null hypothesis, and 0 otherwise. Maximizing (1) over all circles results in the one that constitutes the most likely mortality cluster. The test statistic is

$$\max_D \frac{L_A(D)}{L_0} \qquad (2)$$

Kulldorff[8] has derived the likelihood ratio test and provided the properties of the test statistic. We have used SaTScan 2.1[18] to perform the calculations. The P-value of the statistic is obtained through Monte Carlo hypothesis testing, where the null hypothesis of no clusters is rejected at an α level of 0.05 exactly if the simulated P-value is $\leqslant 0.05$ for the most likely cluster. The program gives the most likely cluster with the corresponding P-value. If other clusters not overlapping with the most likely cluster are identified, these are also given by the program with their corresponding P-values. We applied this method both to the DSS population (each year separately) and to the zinc study population.

Kulldorff *et al.*[4] have extended the spatial scan statistic into a space-time scan statistic. In this case, the window imposed on the study area by the statistic is cylindrical with a circular geographical base and with height corresponding to time. The centre of the base is one of several possible centroids located throughout the study area and the height reflects any possible time interval. The cylindrical window is then moved in space and time. This was applied to the DSS data for the time window 1993–1998.

Results

The focus of this section is on the results from the DSS data. As noted earlier, the results from the randomized control cohort study are used here to validate the results from the DSS database.

The DSS population

Table 1 provides summary data for all 39 villages in the study area. The average yearly death rate (per 1000) for children under 5 for the 6-year period was 35. This corresponds to a cumulative rate up to age 5 years of $1-\exp(-5 \times 0.035) = 0.16$ which is close to the estimated country-wide rate reported by the WHO. There is a decline towards the end of the observation period. We investigated whether there is a trend in the rates. Using the full observation period, no significant trend was observed. However, considering the possibility of some underreporting of deaths in the first year (1993) of observation which may have resulted in the course of establishing the field procedures, we omitted the first year from the analysis and found a highly significant decreasing trend in mortality ($P < 0.001$).

Table 2 shows crude death rates (per 1000) per year for each of the 39 villages in Kossi province (ordered according to the population size in the villages).

We calculated the death rates (per 1000) per year for each of the 39 villages in Kossi province and the confidence intervals for the rates. We then checked whether or not these contained the overall average. In the second column of Table 2 are mean midyear populations of children under 5 years old. Although there was some variation in the number of children within a village over the years, the population between the villages differed up to a factor of about 15. The variation in rates in almost all the villages can mainly be attributed to chance. An exception is the village of Cissé which has rates significantly above average in the last three years of the observation period (1996–1998). The fact that these rates for Cissé appeared consistent for consecutive years gives a first hint that chance alone cannot explain these patterns. The following analysis further strengthens this point.

Space and space-time scan statistic results of the DSS population

Table 3 presents the results of the purely spatial analysis scanning for high rates using the Poisson model for 1993 to1998. No statistically significant cluster was identified for 1993. A statistically significant cluster ($P = 0.0051$) comprised of

Table 1 Total childhood mortality in the study area. (Summary data for all 39 villages.) Demographic surveillance systems study population

	1993	1994	1995	1996	1997	1998	Total (1993–1998)
Total no. of deaths	151	195	172	204	147	162	1031
Midyear population children <5	4720	4786	4899	4840	4895	5323	29 463
Death rate (per 1000)	35.0	44.7	38.6	46.2	32.8	33.5	35.0
95% CI[a]	29.91–40.11	38.94–50.38	33.37–43.87	40.38–51.94	27.96–37.66	28.78–38.16	32.89–37.09

[a] Based on normal approximation.

Table 2 Total childhood mortality in 39 villages in the Kossi province. Demographic surveillance systems study population

Name of village	Total no. of deaths	Mean population size[a]	Death Rate (per 1000) 1993	1994	1995	1996	1997	1998
Goni	86	405	52.6	36.8	43.3	43.8	12.2	24.2
Koro	73	319	36.7	41.3	41.0	56.8	19.5	26.0
Kemena	72	310	40.8	19.4	28.2	48.8	60.6	33.3
Toni	34	255	10.5	15.0	19.5	41.0	34.2	16.5
Kamadema	64	244	50.3	79.4	55.6	71.7	64.3	60.6
Bourasso	40	237	33.5	30.2	40.4	23.5	17.0	26.4
Solimana	47	230	37.2	63.1	39.5	31.0	13.5	60.4
Kodougou-B	32	194	5.0	20.4	19.3	58.2	17.4	40.6
Nokuy-Bobo	35	189	11.2	31.4	25.1	55.0	34.1	29.1
Ouette	31	166	6.6	85.5	55.9	5.8	23.7	15.5
Sobon	42	161	41.4	73.8	40.0	25.2	59.8	43.0
Seriba	42	150	68.8	50.0	45.8	50.7	20.0	43.5
Pa	40	141	22.2	44.8	58.4	53.7	35.7	6.6
Sikoro	18	137	14.6	15.2	6.6	78.7	8.1	13.4
Cissé	76	135	80.7	51.9	69.9	**138.5**	**131.8**	**80.5**
Tissi	16	133	15.9	37.0	23.6	37.0	0.0	22.6
Lekuy	13	126	15.4	31.8	23.1	32.5	17.0	7.9
Sampopo	18	109	29.1	56.6	19.4	9.3	26.1	25.0
Dionkongo	33	107	46.3	75.5	77.8	46.7	26.8	42.4
Labarani	25	104	86.2	**120.0**	27.3	19.4	29.4	26.3
Dankoumana	28	90	13.7	68.5	68.2	93.0	40.8	37.4
Boune	27	86	76.1	75.0	66.7	34.5	74.1	11.4
Tebere	14	84	0.0	40.5	12.4	22.7	32.3	52.1
Biron-Marka	6	83	11.6	11.8	11.5	12.2	0.0	12.4
Dennissa-M	3	83	0.0	25.6	0.0	12.2	0.0	0.0
Barakuy	6	81	0.0	0.0	11.4	11.4	26.0	24.1
Boron	14	73	50.0	30.3	54.8	0.0	25.3	23.8
Dembelela	12	67	29.4	29.0	27.8	31.8	33.9	28.2
Dokoura	12	59	55.6	50.0	0.0	31.8	50.9	17.9
Tonsere	12	56	40.0	40.0	18.2	17.9	67.8	31.8
Diamasso	6	52	20.4	0.0	18.9	62.5	0.0	17.9
Limini	7	51	21.3	20.4	40.0	37.0	0.0	18.5
Denissa-Marka	6	40	45.5	0.0	54.1	0.0	0.0	0.0
Sirakorosso	2	33	0.0	27.8	0.0	27.8	0.0	0.0
Zanakuy	1	31	0.0	0.0	0.0	0.0	33.3	0.0
Dina	5	26	41.7	41.7	41.7	0.0	37.0	32.3
Lei	4	25	0.0	40.0	95.2	0.0	0.0	31.3
Sien	5	24	0.0	55.6	43.5	90.9	0.0	29.4
Biron-Bobo	3	17	0.0	0.0	100.0	0.0	0.0	0.0
OVERALL		4911	35.0	44.67	38.6	46.2	32.8	33.5

Bold numbers indicate mortality rates significantly ($P \leqslant 0.05$) above average in the respective year.

[a] Arithmetic mean of midyear populations.

Villages in bold print were selected for the Zinc Study.

the census areas of 15 villages including Cissé and Labarani was identified for 1994. In all 106 cases of childhood mortality were observed (78.2 expected) and the cluster had a relative risk of 1.4. No statistically significant cluster was identified for 1995. For 1996 the identified statistically significant cluster ($P < 0.001$) comprises the village of Cissé; 18 childhood mortality cases were observed (5.5 expected) with a high relative risk of 3.3. Cissé was also identified as a statistically significant cluster ($P < 0.001$) for 1997 (17 childhood mortality cases observed, 3.9 expected, overall relative risk 4.4). A significant second cluster ($P < 0.001$) was identified for 1997. This cluster comprises seven villages (61 cases observed, 37.4 expected, relative risk 1.6). For 1998, the statistically significant cluster ($P < 0.001$) identified comprises the census areas of five villages including Cissé and Solimana (37 cases observed, 18 expected, relative risk of 2.0).

The scan statistic was thereafter applied to perform a spatio-temporal analysis. The results are presented in Table 4. It is seen

Table 3 Total childhood mortality in Kossi province for 1993–1998 using purely spatial analysis scanning for high rates; Demographic surveillance system study population

Year	Type	Location	Cases	Expected	Relative risk	*P*-value
1993	Most likely	Lei, Sien, Solimana Seriba, **Cissé**	29	17.6	1.7	0.26
1994	Most likely	Dankouma, Sampopo, Koro, Ouette, Zanakuy, Sien, Boune, Limini, Sirakorosso, Dina, Dionkongo, Tissi, Lei, **Cissé**, Labarani	106	78.2	1.4	**0.01**
1995	Most likely	Sampopo, Dankouma, Koro, Sien, Ouette, Lei, Seriba, Dina, Solimana, Dionkongo, Tissi, **Cissé**, Diamasso, Boune, Limini	79	62.0	1.3	0.31
1996	Most likely	**Cissé**	18	5.5	3.3	<**0.001**
1997	Most likely	**Cissé**	17	3.9	4.4	<**0.001**
	Secondary	Toni, Dembelela, Kamadema, Pa, Sobon, Dokoura, Kemena	61	37.4	1.6	<**0.001**
1998	Most likely	Lei, Sien, Solimana, Seriba, **Cissé**	37	18.4	2.0	<**0.001**

Table 4 Total childhood mortality in Kossi province for 1993–1998 using space-time analysis scanning for high rates; Demographic surveillance system study population

Type	Location	Time frame	Cases	Expected	Relative risk	*P*-value
Most likely	Cissé	1996–1998	47	14.4	3.3	<**0.001**
Secondary	Kamadema	1994–1996	48	24.2	2.0	0.02

that the village of Cissé was identified as a statistically significant cluster ($P < 0.001$) for the period covering 1996–1998 (47 cases observed, 14.4 expected, overall relative risk for this period 3.3). The identified statistically significant secondary clusters were the village of Kamadema ($P = 0.02$) for the 1994–1996 period (48 cases, 25.2 expected, relative risk 2.0).

Since the village of Cissé was consistently identified as belonging to clusters of significantly higher childhood mortality, we decided to omit this village and apply the statistic again. Only the following two statistically significant clusters were identified. For 1994, a significant cluster ($P = 0.01$) included the villages of Dankoumana, Sampopo, Koro, Ouette, Zanakuy, Sien, Seriba, Solimana, Diamasso, Boune, Limini, Sirakorosso, Dina, Dionkongo, Tissi, Lei and Labarani (97 cases, 71.2 expected, overall relative risk 1.3). This is the northwestern region of the study area to which Cissé also belongs. For 1997, a significant cluster ($P < 0.001$) included the villages of Kenema, Dembelela, Toni, Pa, Sobon, Dakoura and Kamadema (61 cases, 34.0 expected, overall relative risk 1.8). This cluster has also been identified as a secondary cluster in the first analysis. For all other years, no significant clusters were found. In Figure 1 the clusters are displayed.

The results after omitting Cissé show that the significant cluster in 1994 remains unaffected (the same villages except Cissé form a cluster, $P = 0.01$). For 1995 and 1996 no significant cluster was identified. For 1997 the previously identified secondary cluster was identified. For 1998 the previously identified cluster except Cissé (Solimana, Sien, Seriba) was again identified, however not significant ($P = 0.1$). These results show that while Cissé seems to be the village with the strongest increase in mortality, the whole subregion appears to be conspicuous.

The scan statistic was also applied to scan for clusters of significantly lower mortality. No such cluster was identified. This may provide a good evidence of no systematic underreporting in certain villages versus others.

The DSS database provides information on some other variables possibly linked to childhood mortality. In particular, we investigated the variables 'distance to next health centre', 'religion' and 'ethnicity'. The increased risk for children in Cissé appeared to be independent of these factors: The nearest health centre to Cissé is 18 km away, only slightly above average for all villages (range: 0–34 km, mean 11.3 km). The predominant ethnic group in Cissé is the Peulh in contrast to the surrounding villages. However, the Peulh have an overall childhood mortality which is below average. The most frequent religion in Cissé is Islam (94.3% in Cissé, 60.5% in the total study region). However, the overall mortality in Muslims is below average. Thus, all these factors do not explain the increased risk.

The randomized controlled trial cohort

Table 5 shows the data from the Zinc study. We observed 17 deaths in the observation period, which corresponds to a mortality rate of 57 per 1000 person-years (95% CI: 32.7–89.3). We did not distinguish between treatment and placebo groups because (1) zinc supplement was not shown to have an effect on malaria mortality or morbidity and (2) the randomization unit was the child and not the village. This is higher than the rate for the age group 0–4 in the total DSS population, which may partly be explained by the lower age of this cohort. In all, 13 out of the 17 deaths are concentrated in the two villages in the study area (Cissé [7 deaths] and Solimana [6 deaths]).

Space scan statistic results of the randomized controlled trial cohort

Using data from the Zinc study shown in Table 5, a purely spatial analysis scanning for high rates was carried out. The statistically significant most likely cluster ($P < 0.001$) of childhood mortality identified comprises the villages of Cissé, Tissi, Dionkongo, Sériba and Solimana (14 cases recorded, 5.7 expected). The cluster has a high relative risk of 2.4. All the five

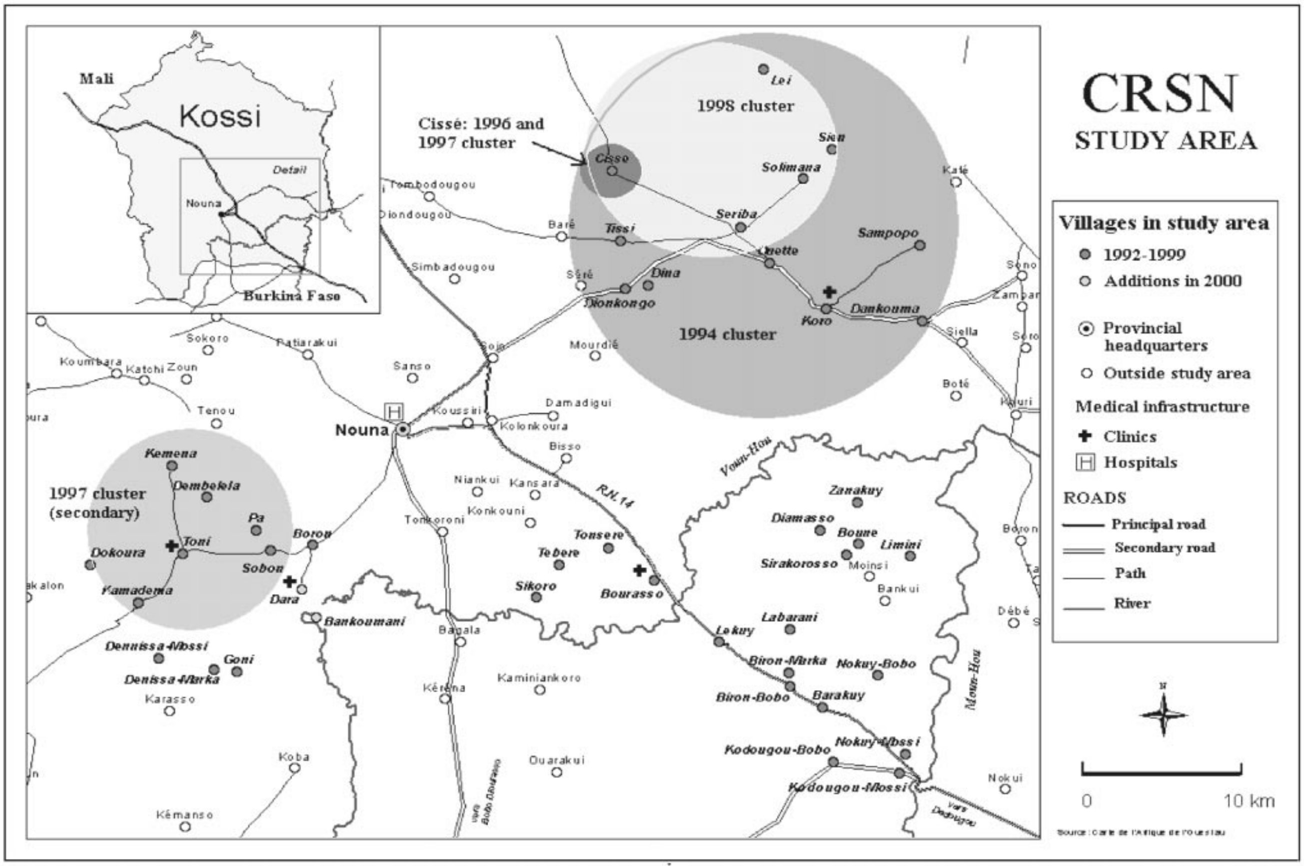

Figure 1 Map of study area showing location of significant clusters of higher total childhood mortality rates in 1994, 1996, 1997 and 1998

Table 5 Study population and number of deaths by village. Randomized controlled trial cohort

Name of village	No. died during study period	Total no. of children in the study
Biron Marka	0	26
Bourasso	0	59
Cissé	7	60
Dankoumana	0	29
Dionkongo	1	30
Kodougou Bobo	0	57
Koro	0	55
Labarani	0	30
Nokuy Bobo	2	53
Ouette	0	30
Sampopo	0	30
Seriba	0	60
Sikoro	0	57
Solimana	6	52
Tebere	1	29
Tissi	0	29
OVERALL	17	686

villages are located in the northeastern part of the study area and are close to each other (Figure 1).

Discussion

Data from this DSS have been collected since 1993, and many efforts have been made to provide as complete and accurate a database as possible. For example, in order to minimize errors in data collection, interviewers use pre-printed database registration forms. Three field supervisors examine the questionnaires in the field to check if the data collected by the interviewer makes sense. Among several steps, the supervisors take a sample of the completed questionnaires and return to the households to verify the information they contain.

However, irrespective of the above efforts, the conditions for data collection in rural parts of developing countries have their limitations. It is not possible to achieve a record of all deaths. The question is whether underreporting of cases or other incomplete recording of events (birth, in- and out-migration) could have had an impact on our results. If, for example, in several villages a constant underreporting of cases had occurred, this would have an immediate effect on our results. Although we cannot rule out the possibility that some infant deaths remained unreported, we do not have evidence of differential underreporting of cases between the villages. The non-existence of clusters with significantly lower total childhood mortality in the study area indicates that there was no systematic underreporting in some villages.

The following characteristics hold in the whole study region and not specifically in some parts of it: (1) the death rates obtained from the DSS are well within the order of magnitude expected, when compared with other DSS results (e.g. Bergane *et al.*[19]). (2) The interviewers who visited the villages and collected the information were well trained according to standardized procedures. (3) The information used in this paper was total mortality only, rather than cause-specific mortality. The latter was much more difficult to obtain from the data set with sufficient reliability, as the causes of death were basically obtained by verbal autopsy from the mother, and it is often difficult to decide on a particular cause of death from that information. In several cases, the cause of death is unknown. However, the majority of cases included in this analysis were from infectious diseases (malaria, diarrhoea), often in combination with malnutrition. As an immediate consequence from our findings, a qualitative study is underway with the aim to scrutinize possible causal factors with in-depth interviews.

Using the method for analysing temporal trend described above, we found a significant decrease in childhood mortality over the observation period when omitting the birth year (1992) from the analysis. However, this was a data-driven procedure as the rate for 1993 was found to be considerably lower than in the years after. Therefore, the significant finding of a decreased trend must be considered as a trend rather than a definite finding, and more years of observation are needed before one can conclude that the childhood mortality in the DSS catchment area is decreasing significantly.

In the study by Benzler and Sauerborn[2] which used the main components of the DSS in Nouna, several attributes of newborns and households were used as potential predictors of childhood death in a cohort of 1367 newborn children in the study area from 1992 to 1994. The authors found an average mortality rate of 6.8% per year. However, specific patterns of death rates by village have not been reported in their analysis.

In our study we analysed the DSS data as to a possible spatial-temporal pattern of mortality. The result of a very pronounced cluster of higher rates with the centre of the cluster being the village of Cissé is rather alarming. This finding is supported by the results from the randomized controlled trial described above as in this trial excess mortality was again observed in the village of Cissé. Thus, we strongly believe that our finding on clustering of total childhood mortality in the Nouna region is indeed real and not due to systematic bias. We looked at the distribution of exact date of death, in particular in the village of Cissé, to look for seasonal peaks in mortality. We found a surprisingly uniform distribution over the years which does not support the hypothesis that an infectious disease outbreak has occurred causing the excess mortality.

A possible drawback of the analysis using the Kulldorff method is that clusters are defined as circles. This feature has some implications which must be considered in the interpretation of the results: (1) if a village with low mortality is surrounded by villages with high mortality, it is always included in the cluster although some characteristics of this village may be different than the others; and (2) if a clustering of cases is, say, along a river, a circle is not the appropriate form to detect it. The first feature can be observed in the analysis of the controlled trial cohort, where the two villages with high numbers of deaths are surrounded by others in which no deaths or only one death was recorded. By construction of the test statistic, all these were also included in the cluster identified.

This study may be regarded as a first step in prioritizing areas for analytical studies. In general, malnutrition, malaria, diarrhoea, measles, and acute respiratory infections remain the major causes of childhood disease and death in most of rural Africa.[20] Childhood mortality is also on the increase in many parts of Africa, partly due to the consequences of the AIDS epidemic and partly due to increasing resistance of malaria parasites to the main first-line therapy drug chloroquine.[21] Although little is known about the prevalence of HIV in the Nouna study area, there is little evidence today to suggest that HIV/AIDS contributes much to childhood mortality in rural Kossi province.

Studies in other parts of Africa have documented significant space-time clustering of malaria. For instance, Snow *et al.*[22] report a space-time clustering of severe childhood malaria on the Coast of Kenya with seasonal peaks in incidence of severe malaria comprising discrete mini-epidemics. Similar studies on the microepidemiology of malaria are now underway in the Nouna study area, and the results are likely to help us better understand the observed clustering of mortality in the area. There is some evidence that the cultural pattern of hygiene and health-seeking behaviour contributing to the observed differences in health outcomes (Müller, unpublished results) in the Nouna study area.

Acknowledgements

This work was supported by the Deutsche Forschungsgemeinschaft, SFB 544 'Control of tropical infectious diseases'. The authors would like to thank Dr Martin Kulldorff (National Cancer Institute, Bethesda, MD, USA) for his advice and for providing the SaTScan software, Ralf Würthwein at the University of Heidelberg, and anonymous referees for their helpful comments. We also thank Ms Gabriele Stieglbauer at the University of Heidelberg for her assistance in preparing the data set for the analysis. Last but not least the authors would like to thank the people from the Nouna study area, both the villagers and the field staff, for their indefatigable contribution to our data collection.

KEY MESSAGES

- A demographic surveillance system in a rural area in Burkina Faso provides data for childhood mortality analysis (1993–1998).
- The spatial scan statistic was used to identify spatial and space-time clustering of childhood mortality.
- Regions of different sizes, however, always including one particular village with significantly increased mortality, were identified.
- Data from a controlled trial which included this particular village showed a similar result.
- Available demographic and other variables (e.g. ethnicity, religion) did not explain the finding.

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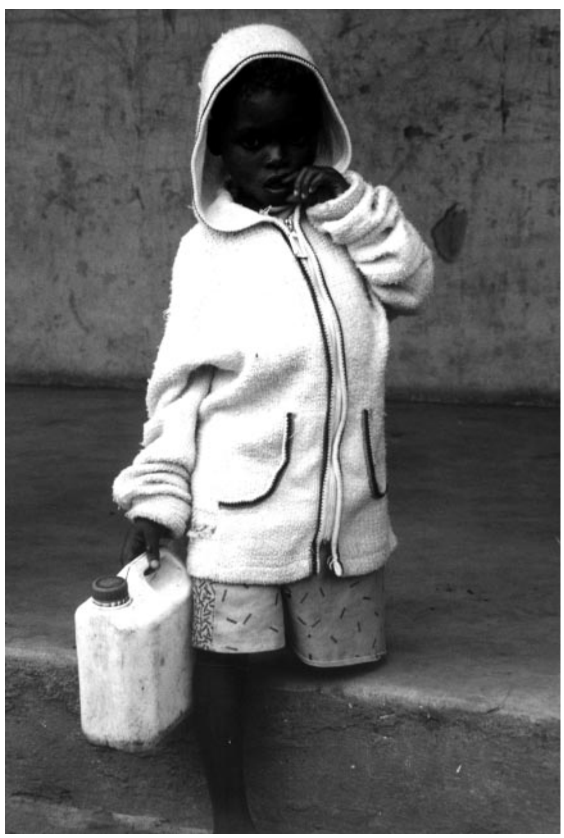

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