Decreasing Disparities in Infant Survival using Surveillance Data from Burkina Faso

Anja Schoeps,* Gisela Kynast-Wolf, Robin C. Nesbitt, Olaf Müller, Ali Sié, and Heiko Becher

Institute of Public Health, University of Heidelberg, Heidelberg, Germany; Centre de Recherche on Santé de Nouna (CRSN), Nouna, Burkina Faso; University Medical Center Hamburg-Eppendorf (UKE), Hamburg, Germany

Abstract. We assessed changes in the effect size of risk factors for infant mortality comparing a birth cohort from 2005 to 2010 with a birth cohort from 1993 to 1999 in the Nouna Health and Demographic Surveillance System (HDSS) in Burkina Faso. Single- and three-level Cox proportional hazards regression models were used for analysis. Independent variables among others included year of birth, ethnicity, religion, age of the mother, birth order, death of the mother, being a twin, and distance to the closest health facility. We observed an infant mortality rate of about 51/1,000 person-years. The strongest risk factors were death of the mother and being a twin, which were also the strongest risk factors from the previous analysis period. Compared with the period 1993–1999, the effect of most risk factors decreased, notably ethnicity, religious affiliation, distance to the closest health facility, birth order, and season of birth. The strongest reduction in mortality occurred in the groups with the previously highest infant mortality rates in 1993–1999.

INTRODUCTION

Reducing mortality in children under five in developing countries has been one of the major foci of the Millennium Development Goals (MDG-4) and will likely remain an important goal in the post-2015 agenda.^{1,2} According to data from a demographic and health survey (DHS) in 1993 and a population census in 2006, infant mortality (death in the first year of life) in Burkina Faso decreased from 108/1,000 in 1993 to 92/1,000 in 2006, which corresponds to an average annual decrease of about 1.2%.³ This is far too low to reach the two thirds reduction of child mortality between 1990 and 2015, called for by MDG-4. In fact, a recent study estimates that the world will not meet the target until 2026, 11 years behind schedule.⁴ The implementation of the integrated management of childhood illness (IMCI) strategy that addresses the most common causes of mortality in children under five has contributed to substantial progress in child survival.⁵

Because of improvements in child survival globally, death during the neonatal period (the first month of life) now accounts for a greater proportion of child mortality.⁶ Thus, addressing mortality occurring in early life has become increasingly important. Previous analyses in different settings revealed health disparities in infants, which are defined as “potentially avoidable differences in health . . . between groups of people who are more and less advantaged socially.”⁷ Such disparities are mostly seen between groups defined by socioeconomic position, ethnicity, or religious affiliation.⁷

Several factors that are related to infant mortality have been identified in children born between 1993 and 1999 from the Nouna Health and Demographic Surveillance System (HDSS) in Burkina Faso.⁸ Among these were demographic characteristics (ethnicity, religious affiliation), distance to the closest health facility, as well as family-related variables, such as vital status of the mother, twin births, and age of the mother. This way, several disadvantaged groups were identified with particularly higher rates of infant mortality, such as the Dafing ethnic group, and families living in more remote areas (distance to the next health facility > 10 km).

Since 1999, several measures to improve infant and child survival have been implemented in the study area, including

vaccination campaigns, malaria prevention and treatment programs, the opening of new health facilities, and the introduction of a community-based health insurance (CBHI).^{9–13} It is of interest to know whether these interventions have improved infant survival in the study area.

Objective. This study examines changes in the effect size of risk factors for infant mortality in the most recent birth cohorts 2005–2010, compared with cohorts from 1993–1999. A secondary objective is to describe the distribution of variance in infant mortality on the individual, household, and village levels using a multilevel model.

METHODS

Study area. The study was conducted in the Nouna HDSS, which is located in northwestern Burkina Faso. In 2010, the Nouna HDSS area was inhabited by approximately 89,000 people of different ethnicities and religious beliefs, living in the semi-urban town of Nouna and 58 surrounding villages (Figure 1).⁹ Burkina Faso's northwest is characterized by a dry orchard savannah with one dry season (November–May) and one rainy season (June–October).⁹ The Nouna HDSS was established by an initial census in 39 villages in 1992. Since then, all households in the study area are visited three times a year to register vital events such as births, deaths as well as in- and out-migration. In the year 2000, two further villages and Nouna town were added to the HDSS, since 2004 the surveillance includes 58 villages plus Nouna town. The detailed procedures are described elsewhere.^{9,14}

The study area is extremely poor and the literacy rates are low. Most inhabitants live from subsistence farming. Grid electricity and piped water are available only to dwellers in Nouna town. The number of health facilities in Nouna HDSS has increased in the recent years. Although it was served by one district hospital in Nouna town and only three smaller health centers in 1992, the number of health centers increased to 13 in the year 2009.⁹

Statistical analysis. This study included all children born between 2005 and 2010 in the 58 villages of Nouna HDSS. Both single- and three-level Cox proportional hazards regression models were used for the analysis.^{15,16} For comparability, the single-level analysis was performed identically to the previous analysis for the cohorts from 1993–1999, that is, a multivariable model with the same covariates was built.⁸ The survival

*Address correspondence to Anja Schoeps, Im Neuenheimer Feld 324, 69120 Heidelberg, Germany. E-mail: schoeps@uni-heidelberg.de

The same set of variables was used in the three-level model but region of residence was included as an independent variable with four categories as indicated in Figure 1. Random intercepts were allowed for the village and the household or residence. This is a three-level random intercept Cox proportional hazards model with individuals at level one, households at level 2 and villages at level 3. Intra-class correlation coefficients (ICCs) were calculated with the linear threshold method.

All analyses were performed using SAS 9.3 and MLwiN version 2.28.¹⁸

In total, 14,961 children born between 2005 and 2010 were included in the analysis. There were 657 infant deaths out of 12,991 person-years, corresponding to an infant mortality rate of approximately 51/1,000 person-years. The children came from 6,347 households in all 58 villages. The mean number of children per household was 2.4, with a range 1–17. The number of children per village varied between 26 and 798, with a mean of 258 children. The number of births was fairly constant over the period 2005–2010 with approximately 2,500 births each

TABLE 1

Distribution of demographic variables by vital status in 14,304 children born between 2005 and 2010 in the Nouna Health and Demographic Surveillance System, Burkina Faso

	Number of children who died in their first year of life	Number of children alive at the end of follow-up	Total (%) [*]
Sex			
Female	311; 4.15	7,176; 95.85	7,487 (50.0)
Male	346; 4.63	7,128; 95.37	7,474 (50.0)
Spacing to older sibling			
< 18 months	39; 6.08	602; 93.92	641 (4.3)
≥ 18 months or no older sibling	618; 4.32	13,702; 95.68	14,320 (95.7)
Death of next older sibling before birth			
No	588; 4.21	13,388; 95.79	13,976 (93.4)
Yes	69; 7.01	916; 92.99	985 (6.6)
Death of mother			
No	644; 4.32	14,257; 95.68	14,901 (99.6)
Yes	13; 21.67	47; 78.33	60 (0.4)
Twin birth			
No	596; 4.10	13,932; 95.90	14,528 (97.1)
Yes	61; 14.09	372; 85.91	433 (2.9)
Year of birth			
2005	147; 6.18	2,233; 93.82	2,380 (15.9)
2006	161; 6.51	2,311; 93.49	2,472 (16.5)
2007	151; 5.72	2,489; 94.28	2,640 (17.6)
2008	89; 3.49	2,462; 96.51	2,551 (17.1)
2009	47; 2.04	2,262; 97.96	2,309 (15.4)
2010	62; 2.38	2,547; 97.62	2,609 (17.4)
Age of mother at birth			
< 18	51; 5.28	915; 94.72	966 (6.5)
18–35	467; 4.08	10,987; 95.92	11,454 (76.6)
36+	119; 6.87	1,614; 93.13	1,733 (11.6)
Unknown	20; 2.48	788; 97.52	808 (5.4)
Religion			
Muslim	420; 4.65	8,609; 95.35	9,029 (60.4)
Catholic	163; 3.81	4,116; 96.19	4,279 (28.6)
Protestant	29; 3.62	773; 96.38	802 (5.4)
Animist/other	45; 5.29	806; 94.71	851 (5.7)
Ethnicity			
Dafing	296; 5.00	5,629; 95.00	5,925 (39.6)
Bwaba	174; 3.78	4,426; 96.22	4,600 (30.7)
Mossi	90; 3.77	2,300; 96.23	2,390 (16.0)
Peulh	76; 5.05	1,430; 94.95	1,506 (10.1)
Samo	14; 4.12	326; 95.88	340 (2.3)
Other	7; 3.50	193; 96.50	200 (1.3)
Distance to health facility (2007/2008)			
≤ 10 km	568; 4.36	12,453; 95.64	13,021 (87.0)
> 10 km	89; 4.59	1,851; 95.41	1,940 (13.0)
Birth order			
First	148; 4.47	3,160; 95.53	3,308 (22.1)
Second to fourth	281; 4.18	6,436; 95.82	6,717 (44.9)
Fifth or higher	211; 4.93	4,070; 95.07	4,281 (28.6)
Unknown	17; 2.60	638; 97.40	655 (4.4)
Season of birth			
Dry	364; 4.37	7,963; 95.63	8,327 (55.7)
Rainy	293; 4.42	6,341; 95.58	6,634 (44.3)
Region of residence			
Central	121; 3.98	2,922; 96.02	3,043 (20.3)
Northeast	168; 4.79	3,339; 95.21	3,507 (23.4)
Southeast	101; 3.17	3,082; 96.83	3,183 (21.3)
Southwest	267; 5.11	4,961; 94.89	5,228 (34.9)
Total	657; 4.39	14,304; 95.61	14,961 (100)

^{*}Percentage of infants with respective characteristic.

year (Table 1). The main ethnic groups in the study area were Dafing, Bwaba, and Mossi, and the majority of people (60%) were Muslims. Twin births and death of the mother were very rare and occurred in only 2.9% and 0.4% of the study children. At the same time, mortality risk was highest in twins (14%) and children whose mother had previously died (22%). There was a decrease in mortality risk between the previously analyzed period from 1993 to 1999 (6.6%) and the current

period from 2005 to 2010 (4.4%). Within the current study period, the mortality risk strongly decreased from 6.2% in 2005 to 2.4% in 2010.

Comparison of effects. When comparing the results from the 1993–1999 cohort using the same multivariable single-level model for the cohorts 1993–1999 and 2005–2010, most effects have decreased (Table 2, columns A and B), suggesting decreasing disparity in infant mortality rates. This is

TABLE 2

Hazard ratios and 95% confidence intervals for infant mortality in children from Nouna HDSS, Burkina Faso. Column A: 10,122 children born between 1993 and 1999. Column B: 14,961 children born between 2005 and 2010. Column C: Random intercept 3-level analysis in 14,961 children born between 2005 and 2010

	A*		B*		C	
	Results for children born between 1993 and 1999		Results for children born between 2005 and 2010 (Level 1 analysis)		Results for children born between 2005 and 2010 (Level 3 analysis)	
	HR	95% CI	HR	95% CI	HR	95% CI
Sex						
Female	1.0		1.0		1.0	
Male	1.12	0.96–1.30	1.11	0.95–1.29	1.10	0.94–1.29
Spacing to older sibling						
< 18 months	1.36	0.99–1.87	1.37	0.98–1.92	1.27	0.88–1.82
≥ 18 months or no older sibling	1.0		1.0		1.0	
Death of next older sibling						
No	1.0		1.0		1.0	
Yes	1.45	1.06–1.96	1.44	1.10–1.87	1.23	0.92–1.64
Death of mother						
No	1.0		1.0		1.0	
Yes	15.6	7.61–31.8	26.6	11.8–59.9	31.5	13.0–76.3
Twin birth						
No	1.0		1.0		1.0	
Yes (0–5 months)	4.33	3.22–5.83	4.47	3.24–6.15	4.72	3.36–6.63
Yes (6–11 months)	2.28	1.12–4.66	2.28	1.42–3.69	2.52	1.57–4.05
Year of birth (years)	0.80	0.77–0.84	0.83	0.79–0.88	0.83	0.79–0.87
Age of mother at birth						
< 18	1.40	1.09–1.79	1.24	0.90–1.71	1.26	0.91–1.76
18–35	1.0		1.0		1.0	
36+	1.29	0.98–1.70	1.70	1.35–2.14	1.69	1.33–2.15
Unknown	0.80	0.55–1.16	0.64	0.41–1.00	0.62	0.39–0.98
Religion						
Muslim	1.0		1.0		1.0	
Catholic	1.03	0.79–1.34	1.05	0.80–1.38	1.04	0.78–1.39
Protestant	1.40	0.93–2.10	1.00	0.64–1.54	0.99	0.63–1.57
Animist/other	1.66	1.21–2.27	1.37	0.93–2.00	1.35	0.89–2.03
Ethnicity						
Dafing	1.0		1.0		1.0	
Bwaba	0.59	0.45–0.79	0.72	0.54–0.96	0.73	0.53–1.03
Mossi	0.51	0.39–0.66	0.77	0.60–0.98	0.77	0.58–1.01
Peulh	1.14	0.90–1.45	1.01	0.78–1.30	0.99	0.73–1.32
Samo	0.52	0.28–0.98	0.80	0.47–1.37	0.77	0.43–1.40
Other	0.94	0.57–1.54	0.77	0.36–1.63	0.85	0.39–1.84
Distance to health facility (2007/2008)						
≤ 10 km	1.0		1.0		1.0	
> 10 km	1.33	1.13–1.57	1.04	0.83–1.30	1.06	0.81–1.38
Birth order						
First	1.32	1.07–1.64	1.17	0.94–1.46	1.14	0.91–1.44
Second to fourth	1.0		1.0		1.0	
Fifth or higher	1.10	0.89–1.37	0.95	0.78–1.17	0.97	0.79–1.19
Season of birth						
Dry	1.0		1.0		1.0	
Rainy	1.21	1.01–1.46	1.01	0.87–1.18	1.02	0.87–1.20

HR = hazard ratio; CI = confidence interval.

* Analyses in columns A and B are identical; effect estimates and confidence intervals in column A are taken from Becher and others.⁸

especially true for religious affiliation, distance to the closest health facility, birth order, and season of birth, for which no significant effects were seen in the later period. Although the effect of ethnicity was strong and highly significant in the earlier cohorts, the disparity in infant mortality rates between ethnic groups had decreased and differences were only borderline significant in the later cohorts. With hazard ratios (HRs) between 0.51 and 0.59, Mossi, Samo, and Bwaba had only half the mortality risk than in Dafing. These effects were strongly attenuated in this analysis of the later cohorts between 0.73 and 0.77.

Death of the mother, being a twin, and year of birth were the strongest factors affecting survival in both the earlier and the later cohorts (Table 2, columns A and B). The effect of

mothers' death has about doubled in this analysis but with a wide confidence interval (CI), owing to the very small numbers. The effect of older maternal age at birth approximately doubled when comparing both analyses (1.70 versus 1.29), while the effect of young age of the mother on child mortality had decreased.

The strong effects of year of birth in the previous as well as in this analyses have to be interpreted with caution. A yearly decrease of 17% (HR = 0.83) would have led to a decrease of about 96% in mortality during the period 1993–2010, which is not the case. When looking at yearly mortality rates over the whole period, it becomes apparent that the analyzed time intervals are by coincidence those showing a strong decrease, while rates have increased or remained constant over the

FIGURE 2. Yearly infant mortality rates in the rural areas of the Nouna Health and Demographic Surveillance System (HDSS) between 1993 and 2010.

intermediate intervals (Figure 2). When analyzing the effect of year of birth in a different Cox regression model with the total number of children born between 1993 and 2010, the resulting HR was 0.985, corresponding to a 23% decrease in infant mortality over the whole period (data not shown).

Multilevel analysis. There are minimal differences in the effect of risk factors when comparing a single-level model to a multilevel model (Table 2, columns B and C). Most estimates and their CIs were almost identical. Small but nonsignificant decreases in effects were seen for the birth spacing and death of the next older sibling. Slight increases of effects were seen for death of the mother and being a twin.

About 26% of the overall variance in child mortality was on the household level and only 1.7% was on village level (Table 3). By inclusion of the independent variables, the share of the household and village variance in the total unexplained variance decreased to 19% and 0.9%, respectively. In a second three-level regression model, we included region of residence (Figure 1) as a further independent variable. This decreased the share of the higher level variances further to 16% for the household and 0.7% for the village. Inclusion of the variables explained a larger share of the higher level variances than of

the individual variance, the share of which increased from 72% in the empty model to 83% in the full model.

DISCUSSION

In this follow-up analysis, we showed decreasing disparity in infant survival between most population groups, defined by ethnicity, religious affiliation, area of residence, and others. When looking at infant mortality rates in the different groups in 2005–2010, the strongest decreases occurred in the groups with the highest infant mortality rates in 1993–1999, such as Animistes, children with Peulh or Dafing ethnicity, with mothers younger than 18 years at birth, or residing further than 10 km from the closest health facility. This suggests that the most disadvantaged groups profited the most from the recent decrease in infant mortality rates in the study area. The decrease of disparity is therefore observed both on the relative and absolute scale. These statements are equally valid if results are presented by mortality rate or mortality risk, two concepts that are mathematically different however are used interchangeably by public health researchers since the numerical difference in most cases is small enough to be neglected.

Just like in this analysis of infant mortality, a recent study from Guinea-Bissau showed decreasing child mortality paralleled by decreasing differences between ethnic groups in later birth cohorts (1997–2007) as compared with earlier birth cohorts (1977–1996), after adjustment of multiple related factors.¹⁹ A study from Nepal showed decreasing disparity in under-five-mortality between rural and urban areas between 1996 and 2011, but found increasing differences between children of mothers with different educational attainment and household wealth.²⁰ The increasing disparity according to educational status was also presented in a study from Sri Lanka, while a study from Indonesia showed decreasing disparity for educational attainment and an unclear time trend for household wealth and region of residence.^{21,22}

The decreasing disparity in infant mortality in the Nouna region might be explained by several changes that have been

TABLE 3

Random effects from three-level random intercept Cox regression in 14,961 infants born between 2005 and 2010 in Nouna HDSS, Burkina Faso

	Empty three-level model	Full three-level model (as in Table 2)	Full three-level model with region of residence
Variance			
Individual	(3.29)	(3.29)	(3.29)
Household	1.197 (< 0.001)	0.788 (< 0.001)	0.638 (< 0.001)
Village	0.078 (0.03)	0.039 (0.1)	0.027 (0.2)
ICC*			
Individual	72.1%	79.9%	83.2%
Household	26.2%	19.1%	16.1%
Village	1.7%	0.9%	0.7%

*Intra-class correlation coefficient (based on an individual-level variance of 3.29).

achieved in the study area between 1999 and 2010. The number of health centers in the area has more than tripled in the study area, so travel distance to the closest health facility has decreased dramatically for most inhabitants.^{9,23} Since 2004, a community-based health insurance has been initiated in the study area to make health care affordable for a larger part of the population. Since 2007, the most disadvantaged 20% of the study area population, identified by community wealth ranking, received a 50% discount on the membership fee.¹⁰ Health insurance in combination with less travel distance might have improved access to modern health services for the more disadvantaged population. However, it has to be considered that only approximately 10% population residing in the study area has been enrolled in health insurance per year. Increased vaccination coverage and timeliness in Burkina Faso might also have contributed to a reduction in infant and child mortality in the more disadvantaged groups.²⁴ Among 1-year-old children with an available vaccination card, BCG and full vaccination coverage were estimated to be 97% and 78% in the study area in 2008–2009, respectively. These estimates were based only on children for whom a vaccination card was seen, which likely led to an overestimation of vaccination coverage. However, even taking missing vaccination cards into account, the percentage of children vaccinated should have been well above 75% and 60% for BCG and full vaccination coverage in 2008–2009, respectively.²⁵

Coverage with insecticide-treated bed nets (ITNs) and artemisinin-based combination therapies (ACT) has much increased over the study period.^{12,13} As malaria is the main cause of mortality in the second half of infancy and as roughly half of all childhood mortality is attributed to malaria in the study area,^{26,27} increasing access to and use of malaria interventions will likely have played a major role with regard to the observed mortality effects.

Multilevel analysis. Results from the three-level Cox regression suggest that most of the variation in infant mortality was on the individual and the household level, while only about 2% was on the village level. Indeed, villages in the study area do not differ much with regard to socioeconomic status. Piped water and electricity are still unavailable in all villages of this area.²⁸ The relative magnitude of the ICCs in the empty model in this analysis is consistent with other literature on child mortality from Nigeria and Sweden.^{29–31} Similarly, data from a DHS in Burkina Faso showed 17% of the total variance on the family level and about 4% on the community level.³²

Inclusion of several variables on individual and village level explained a large part of the variance on household and village level. The largest part of the variance on the household level was explained by region of residence, death of the next older sibling, being a twin, and the year of birth. This is reasonable, as a clustering of infant deaths has been observed within children of the same mother in the Nouna HDSS (G. Kynast-Wolf and others, unpublished manuscript). Ethnicity and region of residence explained the major part of the mortality differences between villages. Although the regions do not differ much with regard to poverty and education, they differ in their accessibility to roads and to the hospital in Nouna town. Clustering of child deaths in the northeast and the south-west region of the study area has been shown before.³³

Strengths and limitations. On the basis of a large longitudinal dataset from an HDSS existing since 1993, we were able to compare the effect of certain risk factors for infant mortality

over time with adequate power. We could consider time-varying and village-level variables, such as distance to the next health facility and region of residence, in an adequate manner with use of a three-level Cox proportional hazards regression model. It is a limitation of this study that data from 1993–1999 were not analyzed in a multilevel model. However, effect estimates and *P* values from single- and multilevel analyses should not diverge too much, as this was also not the case for the analyses of data from 2005–2010. It is a further limitation that data on breastfeeding, nutritional status, or morbidity were not available for the total study population and could therefore not be considered in analysis or results interpretation. Socioeconomic status has been shown to be unrelated to infant and child mortality in the rural area of this study region and was therefore not considered in this study.²⁸ Data on educational attainment of mother and father were only available for a subgroup of the study children from a census conducted in 2009. In a sensitivity analysis, basic education of the mother was associated with a decreased risk of infant mortality when compared with mothers without any formal education (HR = 0.70, 95% CI: 0.50–0.98). This, however, did not change the estimates for the other included variables.

Conclusion. It is a positive finding that first infant mortality has decreased considerably and second the most disadvantaged groups seem to have profited the most from the recent decreases. Aiming at further and continuous improvements in infant mortality, existing structures in the study area should be maintained and further efforts should be undertaken to support twins and children of deceased mothers, as these are still the strongest risk factors for infant mortality.

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Authors' addresses: Anja Schoeps, Gisela Kynast-Wolf, Robin C. Nesbitt, Olaf Müller, and Heiko Becher, Institute of Public Health, University of Heidelberg, Heidelberg, Germany, E-mails: schoeps@uni-heidelberg.de, gisela.kynast-wolf@urz.uni-heidelberg.de, r.nesbitt@uni-heidelberg.de, olaf.mueller@urz.uni-heidelberg.de, and heiko.becher@urz.uni-heidelberg.de. Ali Sié, Centre de Recherche on Santé de Nouna (CRSN), Nouna, Burkina Faso, E-mail: alisie.crsn@fasonet.bf.

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