Original Contribution

The Effect of Distance to Health-Care Facilities on Childhood Mortality in Rural Burkina Faso

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This study aims to investigate the relation between distance to health facilities, measured as continuous travel time, and mortality among infants and children younger than 5 years of age in rural Burkina Faso, an area with low health facility density. The study included 24,555 children born between 1993 and 2005 in the Nouna Health and Demographic Surveillance System. The average walking time from each village to the closest health facility was obtained for both the dry and the rainy season, and its effect on infant (<1 year), child (1–4 years), and under-5 mortality overall was analyzed by Cox regression. The authors observed 3,426 childhood deaths, corresponding to a 5-year survival of 85%. Walking distance was significantly related to both infant and child mortality, although the shape of this effect varied distinctly between the 2 age groups. Overall, under-5 mortality, adjusted for confounding, was more than 50% higher at a distance of 4 hours compared with having a health facility in the village ($P < 0.0001$, 2 sided). The region of residence was an additional determinant for under-5 mortality. The findings of this study emphasize the importance of geographic accessibility of health care for child survival in sub-Saharan Africa and demonstrate the need to improve health-care access to achieve the Millennium Development Goals.

Africa south of the Sahara; Burkina Faso; child mortality; health facilities; health services accessibility; infant mortality; population surveillance; survival analysis

Abbreviations: CI, confidence interval; HDSS, Health and Demographic Surveillance System.

During the past decades, childhood mortality in sub-Saharan Africa has been decreasing but too slowly to achieve the Millennium Development Goal of a two-thirds reduction by 2015 (1). In sub-Saharan Africa overall, the mortality risk for children younger than 5 years of age (“under-5 mortality”) has decreased from 182 to 142 per 1,000 livebirths between 1990 and 2008, which is equivalent to a decrease of about 22%. In Burkina Faso, the under-5 mortality risk was 201 in 1990, and this has decreased by only about 16% to 169 deaths per 1,000 livebirths in 2008 (2). A more pronounced decline was found in the population of the Nouna Health and Demographic Surveillance System (HDSS), where a yearly decline in the childhood mortality rate of 2.4% was observed between 1993 and 2007 (3).

A key factor in the reduction of child mortality and the promotion of child health is universal accessibility of health-care services (4), which is determined by many different factors including travel distance (5). A long distance to health facilities has been shown to significantly reduce the use of health services by the population (distance decay effect) (6–8).

The influence of distance on such major health outcomes as vaccination status, morbidity, and mortality among children under 5 years of age has been the subject of several studies (9–18). However, a recently published review of studies focusing on the effect of distance to health services on mortality states that the association between distance and child death has not yet been clearly established. The authors attribute the inconclusive findings of previous studies mainly to methodological differences and difficulties in measuring real travel distance. They call for future studies to avoid these limitations, for example, by implementing distance as travel time rather than straight-line distance (19).

Although the shape of the association between distance and use of health services has been studied repeatedly, to our
knowledge the shape of the association between distance and mortality has not been sufficiently investigated. Commonly, distance was analyzed as a binary variable (far/close), using, for instance, a cutpoint of 10 km, as done in a previous study at the same site in Burkina Faso (14).

This study aims to investigate in detail, by using a large study population, how geographic access to health facilities influences under-5, infant, and child (1–4 years) mortality in a rural area of Burkina Faso with low health-facility density. To overcome previous methodological limitations, we implemented distance as continuous walking time, and seasonal differences were taken into account.

MATERIALS AND METHODS

Study area

The study is based on the Nouna HDSS that is located in Burkina Faso and run by the Centre de Recherche en Santé de Nouna. Nouna HDSS is a member of the INDEPTH network, which connects health and demographic surveillance sites worldwide (20). The HDSS is located in Nouna Health District in the province of Kossi in the Northwest of Burkina Faso at a distance of about 300 km from the capital, Ouagadougou. The area is a dry orchard savannah, characterized by a sub-Sahelian climate with 1 dry (November–May) and 1 rainy (June–October) season per year. Apart from the semiurban population of the only small town Nouna, there is no electricity, and the main water source is wells. During the rainy season, several roads often become impassable, making it difficult to access the whole area, covering about 1,775 km². The study area comprises 42 villages, of which 39 belonged to the study area from the start of the HDSS and a further 3 villages, including Nouna town, were added in 2000 (Web Figure 1 posted on the Journal’s Web site (http://aje.oupjournals.org/)).

Apart from the only town Nouna, the population is settled exclusively within small villages, as living outside the village limits is not possible because of missing water sources. The Nouna HDSS and its main research activities were described by Becher and Kouyate (21) in 2005.

By 2007, the study area was served by 1 district hospital equipped with nearly 100 beds and surgical facilities in Nouna town and by 8 peripheral health centers (Centres de Santé et de Promotion Sociale, indicated as “+” in Web Figure 1), which offer basic outpatient services, dispensaries, and maternity units. All health facilities charge the Nouna Health and Demographic Surveillance System comprise a population of 68,500 inhabitants, of which 24,200 lived in Nouna town in 2007.

Data collection

Data on the vital events of the study population, such as births, deaths, migration, and associated information, originate from the Nouna HDSS database. After the initial census in 1992, vital events have continuously been registered. Initially, this registration was performed by a monthly visit to the key informant of each village, who was then asked about any changes concerning all members of the village. This procedure changed in the year 2000. Since then, vital event registration is done by interviewers visiting each household within the area in cycles of 3–4 months. Each household is asked for any changes related to the members previously registered or actually living in the household. In this process, the identification numbers of the mother, father, and household are recorded for each new member of the HDSS, so that each child can be linked to his or her parents and siblings.

The travel distance to the closest health facility for each individual was provided by an expert panel of members of the Centre de Recherche en Santé de Nouna with local knowledge of the study area. This team consisted of 1 demographer, 1 geographer, and the 6 interviewers, who regularly collect data on the vital events within all villages of the Nouna HDSS. Within the study area, there are no ambulance services or public transport available, and few inhabitants have the ability to travel by bike or with a donkey. As the main means of traveling is walking, travel distance was recorded as walking time (in minutes) from each village to the closest health facility. The time needed to reach the next health facility can vary greatly as the result of road flooding during the rainy season; therefore, values were estimated separately for the dry season and the rainy season for each village, considering the local situation. For example, the inhabitants of the village Seriba, located 8 km from the next health facility in Korob (Web Figure 1), have an estimated walking time of 105 minutes in the dry season and 135 minutes in the rainy season. For people living in a village with a health center, walking time was set to 5 minutes during the dry season and 10 minutes during the rainy season. Within Nouna town, travel times of 10 and 20 minutes were assigned, respectively, considering the larger size of Nouna town. For sensitivity analyses, we measured the distance along the road from each village to the next health facility by using ArcView software (Environmental Systems Research Institute, Inc. (Esri), Redlands, California) with global positioning system data of the area. If there were no roads connecting the villages, we used the shortest alternative of either the straight-line distance between the villages, multiplied with an adjustment factor of 1.33, or the adjusted straight-line distance to the next road plus the road distance from that point. For the rainy season, road distances and distances across country were multiplied by the factors 1.33 and 1.67, respectively. Individuals from villages with a health facility were assigned a distance of 0.2 km, and individuals from Nouna town were assigned a distance of...
Statistical methods

Data were analyzed descriptively and with the Cox proportional hazards model. Kaplan-Meier survival curves were estimated for different subgroups of walking distance and compared with the log-rank test. All children born between 1993 and 2005 in the study area were included in the analysis, a total of 24,555 children. In the Kaplan-Meier analysis, travel time in the year of birth was assigned to each child. Because of missing information on the sex of the child, 19 observations had to be omitted from Cox regression, leaving 24,536 children included in the analysis. Survival time was entered as time from birth until death, exit from the study, or the child’s fifth birthday. The end of follow-up was December 31, 2007.

Walking distance to the closest health facility, the main explanatory variable of interest, was entered into the Cox model as a time-dependent covariate, thus adjusting for changes over the study period and taking seasons into account. Changes in walking time occurred only because of the opening of several new health facilities within the study area in 2003 and 2006, which affected 15 of the 42 villages, and because of seasonal changes. To assess the functional shape of the relation between distance and mortality, we used the fractional polynomial method. As an a priori assumption, we assumed a monotone dose response. This implies that a first-degree fractional polynomial is sufficient. All first-degree fractional polynomial transformations were tested against the untransformed dose variable according to the procedure described by Royston and Sauerbrei (22). This procedure was performed for both distance variables (travel time and weighted distance).

We included sex of the child, birth order, age of mother at birth, twin birth, year of birth, death of older sibling, death of mother, birth spacing to next younger and older siblings, religion, and ethnicity as potential confounding variables, consistent with the previous analysis (14). In addition, study region was included in the model in order to investigate and account for higher-than-average mortality in certain geographic areas (refer also to Sankoh et al. (23)). Three different ages were considered separately: 1) children younger than 5 years of age, 2) infants (<1 year), and 3) children (1–4 years). To account for clustering of deaths within villages, we used robust standard errors obtained by the sandwich method (24). All analyses were performed with SAS, version 9.2 (PROC PHREG and PROC LIFETEST), software (SAS Institute, Inc., Cary, North Carolina).

RESULTS

From the 24,555 children included in the study, a total of 90,169 person-years and 3,426 deaths were observed during the study period, corresponding to an average mortality rate of 38.0 deaths per 1,000 person-years between 1993 and 2007 for children younger than 5 years of age. The infant mortality rate was 67.8 and child mortality (1–4 years) was 27.7 per 1,000 person-years. For the initial 39 villages, survival increased from 76.3% for children born in 1993 to 84.3% for children born in 2002, which is equivalent to a mortality decrease of approximately one third.

A comparison of survival curves with the log-rank test showed that survival increased significantly with decreasing travel time ($P < 0.0001$, 2 sided) (Figure 1). The estimated 5-year survival for children living less than 30 minutes from a health facility was 87.7% (95% confidence interval (CI): 86.9, 88.4), while it was only 82.1% (95% CI: 81.1, 83.1) for those with travel times over 120 minutes.

The average time that children from the first 39 villages had to travel to the closest health facility in the dry season decreased from 103 minutes in 1993 to 91 minutes in 2005, because of the opening of several new health facilities. When all 42 villages were included, the average walking time in 2005 was 65 minutes. Although the median walking time over the whole study period was 1 hour, some children had to travel as far as 6 hours in the dry season and 8 hours in the rainy season to reach the closest health facility (Table 1).

In Cox regression, the effect of walking distance to the closest health facility on infant and child mortality was strong and highly significant. For all children younger than 5 years, a log-linear model was selected in the fractional polynomial analysis; that is, the walking time is included as a time-dependent covariate in the model. The estimated hazard rate (HR) function is $HR = \exp(x, 0.00188x)$, where $x$ represents the travel time in minutes (Figure 2). The mortality hazard increased by a factor of 1.12 (95% CI: 1.07, 1.17) for each additional hour of walking time, which results in a doubled risk for children who had to travel more than 6 hours to the closest health facility (Table 2). Highly significant results were yielded as well, when using the alternative measurement for distance (results not shown). As expected, both distance measures were highly correlated ($r_{\text{pearson}} = 0.94$).

When analyzing infants (<1 year) and children (1–4 years) separately, we found for children over 1 year a more
strongly increasing risk with short distances and a slower increase with larger distances. The opposite relation was obtained for infants.

The region of residence within Nouna HDSS (Web Figure 1) was strongly related to under-5 mortality. Nouna and the southeastern region had significantly lower mortality risks compared with the northern and southwestern regions of the Nouna HDSS. There was no remarkable change in the effect with or without adjustment for other covariables.

**DISCUSSION**

This study demonstrates that travel distance to the closest health facility is a major risk factor for infant, child, and overall under-5 mortality in the Nouna HDSS in Burkina Faso. The mortality risk clearly increases with increasing distance. Our findings from this study are consistent with those of the previous study from 2004 (14) regarding the effect of distance to a health facility on infant mortality. However, unlike in the previous study, we now found a significant effect of distance on child mortality also (14). This may be attributable to the more detailed measurement of distance in our present analysis and to the larger size of this study.

Previous studies on distance and mortality are very heterogeneous, both in their findings and study design and in methods of analysis. In the vast majority of analyses, distance was implemented as a grouped variable, with a maximum of 2 cutpoints between 0 and 10 km (11, 12, 14, 15) or 30 and 60 minutes (15, 18). To our knowledge, only 1 other study examining childhood mortality analyzed distance as a continuous variable (17). This study, conducted in a setting of high health-facility density, found no significant effect of distance on childhood mortality, as in a number of other studies (15, 18, 25). Several earlier publications are, however, in line with our findings of a strong association (11–13, 26). Yet the present study is the first to report details on the shape of the association between distance and mortality, enabled by using continuous travel time and by the unusually large sample size.

We found an about doubled mortality risk at a distance of about 6 walking hours for all ages; however, the estimated shapes of the dose-response curves differ distinctly among the 3 models. For infants, there is only a small effect if living closer than about 3 hours from the closest health facility, but there is a highly increased risk for infants living farthest away from the health facilities, at a distance of about 8 hours. For children between 1 and 4 years of age, the shape of the effect of distance is somewhat reversed, showing stronger changes in effect size at smaller distances and relatively little additional increase in risk if the distance changes from, for example, 4 to 8 hours.

The difference of the distance effect for infants and children (1–4 years) might be the result of a different care-seeking behavior regarding infants and children. However, it is more probable that we detected long-term effects in children, which were not apparent in infants. Higher mortality rates in childhood might be the result of lower vaccination rates during infancy. Concerning the population of the present study area, Sanou et al. (27) found that having a health facility within the village of residence significantly increased the probability of being fully vaccinated.

It could be shown that, in addition to walking time, residence in different regions within Nouna HDSS poses an important risk factor for infant and child mortality. This is in accordance with previous findings from the study area by Sankoh et al. (23), who identified clusters with high childhood mortality. The regions with high risk are located in the North and in the Southwest of Nouna town (Web Figure 1). The advantage in 5-year survival for the population of

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**Table 1.** Person-Years, Deaths, and Mortality Rate by Distance, Measured in Travel Time, in the Nouna Health and Demographic Surveillance System, Burkina Faso, 1993–2007

<table>
<thead>
<tr>
<th>Distance to Closest Health Facility, minutes</th>
<th>Person-Years</th>
<th>No. of Deaths</th>
<th>Under-5 Mortality/1,000 Person-Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>5–30</td>
<td>33,265</td>
<td>1,006</td>
<td>30.24</td>
</tr>
<tr>
<td>31–60</td>
<td>17,134</td>
<td>714</td>
<td>41.67</td>
</tr>
<tr>
<td>61–90</td>
<td>6,095</td>
<td>193</td>
<td>31.67</td>
</tr>
<tr>
<td>91–120</td>
<td>13,610</td>
<td>539</td>
<td>39.60</td>
</tr>
<tr>
<td>121–150</td>
<td>2,548</td>
<td>106</td>
<td>41.60</td>
</tr>
<tr>
<td>151–180</td>
<td>5,782</td>
<td>240</td>
<td>41.51</td>
</tr>
<tr>
<td>181–210</td>
<td>3,240</td>
<td>166</td>
<td>51.24</td>
</tr>
<tr>
<td>211–240</td>
<td>3,559</td>
<td>128</td>
<td>35.97</td>
</tr>
<tr>
<td>241–270</td>
<td>1,615</td>
<td>62</td>
<td>38.40</td>
</tr>
<tr>
<td>271–300</td>
<td>721</td>
<td>50</td>
<td>69.37</td>
</tr>
<tr>
<td>301–330</td>
<td>93</td>
<td>5</td>
<td>53.62</td>
</tr>
<tr>
<td>331–360</td>
<td>1,663</td>
<td>116</td>
<td>69.77</td>
</tr>
<tr>
<td>361–450</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>451–480</td>
<td>845</td>
<td>101</td>
<td>119.46</td>
</tr>
<tr>
<td>All</td>
<td>90,169</td>
<td>3,426</td>
<td>38.00</td>
</tr>
</tbody>
</table>

a “Under-5 mortality” refers to mortality for children younger than 5 years of age.

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**Figure 2.** The effect of travel time on mortality for children younger than 5 years of age in the Nouna Health and Demographic Surveillance System, Burkina Faso (1993–2007), with corresponding 95% confidence interval.
Nouna town compared with the other villages is not surprising, as urban populations are known to have lower mortality rates than rural populations have (15, 28, 29). The differences between the southeastern region and the other surrounding regions of Nouna town are more unexpected. A different distribution of breeding sites of *Anopheles* mosquitoes over the study area, associated with a higher prevalence of malaria, could be responsible for the regional differences in mortality (30). A further explanation is the favorable location of the southeastern region around the principal road, connecting Burkina Faso’s capital, Ouagadougou, with Mali and passing near Nouna town. The inhabitants of the villages along this road might have higher chances of being picked up by a car or a donkey cart to reach the next health facility and especially the only hospital in Nouna town. Additionally, variation in the supply and quality of the health facilities in the research area could be responsible for the regional differences in mortality. Although the services offered by the different peripheral health centers are supposedly uniform, there may be undetected differences among facilities depending on the skills and attitudes of the health personnel.

The implementation of distance as continuous travel time is a big strength of this study, as this allowed incorporating changes in accessibility due to seasonal differences. The setting in Nouna HDSS and analysis by Cox regression allowed for studying a long period (1993–2007) and for the adjustment of distance over time, corresponding to the opening of new health facilities within the study area.

A potential limitation of this study is the determination of travel time by local experts, rather than by objective measures. Compared with the objective measurement of travel distance in kilometers, determination of travel time is complicated by its dependence on seasonal and personal factors, such as physical fitness. A more precise way to measure walking time from each village to the closest health facility would have been for research personnel with different degrees of physical fitness to sample the time needed at different time points in different seasons to get a direct estimate of both the travel time and its variability. However, even that procedure would not provide the individual travel time for a given child. Comparison with the alternative approach, using global positioning system data of the study area, showed the robustness of the values used in our analysis. Because we can assume a nondifferential measurement error in assigning the individual walking time, this would rather have led to an underestimation of the true effect. It is also a weakness of this study that individual data on means of transportation in the case of illness of a child and determinants of socioeconomic status such as literacy, educational level or income of the household, access to drinking water, and other variables were not available. Inclusion of the potential confounders, region of residence, ethnicity, and religion, in our model did not change our effect estimates for distance. Because the ethnic group is related to socioeconomic status in the study area, we think that a considerable proportion of the influence of this potential confounder is absorbed by the factor ethnicity. However, we cannot fully exclude residual confounding that might have caused an overestimation of the effect of travel distance on mortality.

In summary, the findings of this study show a strong and significant effect of distance to the closest health facility on infant and child mortality in the study area. As the area is characterized by a low density of health services, our findings indicate the need for more health facilities in Nouna HDSS, especially in the northern region, where health facility density is extremely low and infant and child mortality is comparatively high. The results from the present study may well be extrapolated to other areas, where people live under similar conditions and availability of health services.

### Table 2. Effect of Travel Time to Health Facility and Region of Residence on Under-5 Mortality in the Nouna Health and Demographic Surveillance System, Burkina Faso, 1993–2007

<table>
<thead>
<tr>
<th>Region</th>
<th>Crude Hazard Ratio</th>
<th>P Value, 2 Sided</th>
<th>95% Confidence Interval</th>
<th>Adjusted Hazard Ratio</th>
<th>P Value, 2 Sided</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nouna (baseline)</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>North</td>
<td>1.30</td>
<td>0.0001</td>
<td>1.14, 1.49</td>
<td>1.14</td>
<td>0.019</td>
<td>1.02, 1.27</td>
</tr>
<tr>
<td>Southwest</td>
<td>1.44</td>
<td>&lt;0.0001</td>
<td>1.27, 1.63</td>
<td>1.26</td>
<td>0.0001</td>
<td>1.12, 1.42</td>
</tr>
<tr>
<td>Southeast</td>
<td>0.92</td>
<td>0.26</td>
<td>0.80, 1.06</td>
<td>0.87</td>
<td>0.061</td>
<td>0.77, 1.01</td>
</tr>
</tbody>
</table>

*Under-5 mortality* refers to mortality for children younger than 5 years of age.

* Adjusted for year of birth, sex, religion, ethnicity, age of the mother, death of the mother, birth spacing, twin birth, birth order, and death of an older sibling.

* Obtained from modeling with travel distance as a continuous covariable.
is poor. This demonstrates the need to improve spatial access to health care in developing countries to achieve the Millennium Development Goals.

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