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The impact of distance of residence from a peripheral health facility on pediatric health utilisation in rural western Kenya

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Summary

OBJECTIVE To explore the impact of distance on utilisation of peripheral health facilities for sick child visits in Asembo, rural western Kenya.

METHODS As part of a demographic surveillance system (DSS), censuses of all households in the Asembo population of 55 000 are conducted three times a year, data are collected at all outpatient pediatric visits in seven DSS clinics in Asembo, and all households are GIS-mapped and linkable to a child's unique DSS identification number. Between May 1, 2003 and April 30, 2004, 3501 clinic visits were linked to 2432 children among 10 973 DSS-resident children < 5 years of age.

RESULTS Younger children and children with more severe illnesses travelled further for clinic visits. The median distance travelled varied by clinic. The rate of clinic visits decreased linearly at 0.5 km intervals up to 4 km, after which the rate stabilised. Using Poisson regression, controlling for the nearest DSS clinic for each child, socio-economic status and maternal education, and accounting for household clustering of children, for every 1 km increase in distance of residence from a DSS clinic, the rate of clinic visits decreased by 34% (95% CI, 31–37%) from the previous kilometer.

CONCLUSION Achieving equity in access to health care for children in rural Kenya will require creative strategies to address a significant distance-decay effect in health care utilisation.

keywords health care utilisation, access to care, distance, Kenya

Introduction

Access to health facilities in developing countries is an essential component in achieving the 4th Millennium Development Goal of decreasing infant mortality by two-thirds by 2015. Health facilities will initially be the sole sources of new, more effective drugs, such as artemisinin-based combination anti-malarials and zinc for treatment of diarrhoea, and important diagnostic testing, such as microscopy for malaria (Nabarro & Tayler 1998; Amin *et al.* 2003; WHO/UNICEF 2004). Better characterisation of the components of access and utilisation of health services is important to focus efforts to achieve equity of health care in the places where most childhood disease and death occur (Makinen *et al.* 2000).

Access and utilisation of health services is multi-faceted, influenced by cultural, behavioural and financial factors (Shannon *et al.* 1969; Stock 1983). One critical variable that has consistently been shown to affect access to care in developing countries is the distance of the patient's household from a clinic. The phenomenon of decreasing health care utilisation with increasing distance lived from a facility is often called the distance-decay effect (Shannon *et al.* 1969; Stock 1983; Gething *et al.* 2004). The distance-decay effect has been documented in multiple countries, among pediatric and adult patients, among antenatal clinic attendees, among patients with different diagnoses and among inpatients and outpatients (Shannon *et al.* 1969; Stock 1983; Kloos 1990; Muller *et al.* 1998; Schellenberg *et al.* 1998; Mwaniki *et al.* 2002; Weber *et al.* 2002; Noor *et al.* 2003; Gething *et al.* 2004). Understanding the dynamics of the distance-decay effect in different developing country settings can direct local resource allocation and health sector initiatives to address the inequities of access to care.

We used the unique platform of a demographic surveillance system (DSS) in rural western Kenya to assess the distance-decay effect among outpatient pediatric visits.

Because of its ongoing definition of a circumscribed population, the DSS allowed for a particularly detailed characterisation of the distance-decay effect that overcame some potential biases inherent in evaluating this effect.

Methods

Study area and population

Asembo is a rural location in Bondo District, Nyanza Province in western Kenya along the shores of Lake Victoria (Phillips-Howard *et al.* 2003; Adazu *et al.* 2005). The population of 55 000 in 75 villages is predominantly subsistence farmers and fishermen belonging to the Luo ethnic group. The landscape is mostly cultivated with small fields with many bushy areas, gently sloping towards Lake Victoria with few steep hills. Malaria transmission is high year-round in the area. The area has high child mortality with an under five, mortality rate of 227 per 1000 live births in 2002 (Adazu *et al.* 2005). Asembo has high HIV seroprevalence rates – 11% in men and 21% in women aged 13–34 years in 2003 (Amornkul *et al.* 2004). In 2003–2004, Asembo had no paved roads, except on its northern border. Few public transport vehicles serviced the area and the most common mode of transport was walking.

KEMRI/CDC Demographic Surveillance System

In September 2001, the U.S. Centers for Disease Control and Prevention (CDC) and the Kenya Medical Research Institute (KEMRI) initiated the DSS in Asembo, later expanding it to a second area, Gem, to the north. The methods of the KEMRI/CDC DSS have been described in detail (Adazu *et al.* 2005). In brief, trained field workers perform censuses on all DSS households three times per year. All in-migrations, out-migrations, pregnancies, births and deaths are recorded at the time of the household visit and used to update a computerised household registration system. All DSS residents receive permanent ID numbers that they maintain even when they move within the DSS. As part of the enumeration of household in the DSS, all homes in the surveillance area were GIS-mapped with an estimated accuracy of ± 15 meters (URL: http://www.garmin.com, http://www.trimble.com) using hand-held, 12-band global positioning system (GPS) receivers – Garminetrex and Trimble (Garmin Ltd, Kansas, USA and Trimble Navigation Ltd, CA, USA).

Surveillance of sick visits

Caregivers of all children attending any of the seven first-level government or community health facilities in Asembo (hereafter referred to as DSS clinics) for sick visits were interviewed by trained study staff after their child was examined and treated by clinic nurses. Caregivers were questioned about the child's health over the past 2 weeks using a standard questionnaire prompting caregivers to recall specific symptoms. The diagnoses and prescriptions of the clinical staff were recorded. At the time of the visit, study staff attempted to locate both the child's and the mother's permanent ID numbers from printed DSS registration logbooks in the clinic.

Data management

All data were entered onto scannable forms (Cardiff Teleforms, Cardiff Software Inc., Vista, CA). For data quality control, scanned data were subject to logic checks to ensure compatibility with existing information. Inconsistent or illogical data were returned to the field for correction.

For visits to health facilities in which the child or mother's permanent ID could not be found in the logbooks in the clinic, a data clerk searched the computerised DSS database to attempt to locate that child's ID number. In addition, a computer algorithm was used to search the DSS database for the child's ID. The algorithm was based on decreasing degrees of matching certainty based on several data points, including mother's name, head of compound's name and birth date of the child. All matches were visually inspected for verification of identity (Lindblade *et al.* 2007).

A child's household of residence on the date of the health facility visit was determined by searching a location database. Only among children for whom the permanent DSS ID number of the child or the mother was available could the distance to health facilities be calculated. Using ArcView Geographic Information Systems (GIS), straight-line distances in kilometers from the mapped households to every health facility in the DSS vicinity were calculated.

Statistical methods

For this analysis, the time period was May 1, 2003–April 30, 2004. We included children under the age of 5 years who were permanent residents of the DSS during this year and whose closest DSS clinic was one of the seven clinics in Asembo under surveillance. [Some children who were residents of Asembo lived closest to a DSS clinic in Gem, and were not included in this analysis. One clinic, Rarieda, was located in the Asembo DSS, but because of low volume of patients was not included in the surveillance (Figure 1).] Because children's ages changed during the year of surveillance, we calculated children's ages using fixed

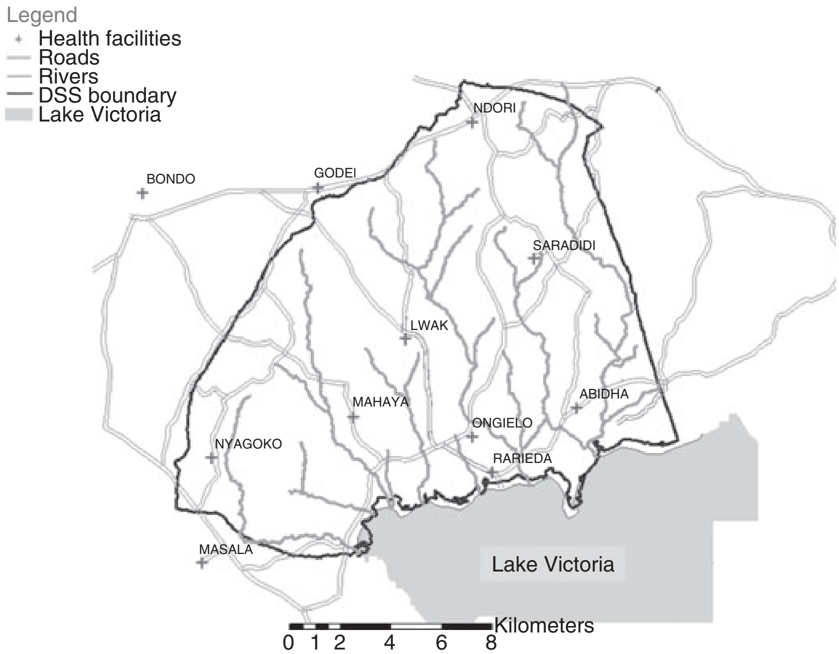

Figure 1 Map of KEMRI/CDC demographic surveillance site with peripheral health facilities, Asembo, western Kenya. All facilities within DSS boundaries were part of surveillance, except Rarieda Clinic which had very low volume of visits. All roads within the DSS area were dirt in 2003–2004, except the tarmac road on the northern border of the DSS area passing through Ndori and Gobei clinics.

dates. If born before the midyear date of surveillance, November 1, 2003, a child's age was calculated on November 1, 2003. If born after November 1, 2003, a child's age was calculated on the last day of surveillance, April 30, 2004. Only children younger than 5 years according to the above age calculations were included in the database. Other clinics were located just outside the boundaries of the DSS area and it was possible for a child to live closer to one of these clinics than to one of the seven clinics in Asembo where the DSS had health facility recorders (Figure 1). For the primary analysis, we did not exclude children resident in the DSS whose closest clinic was outside the DSS.

We evaluated the distance travelled for a clinic visit based on the age and sex of the child, the particular clinic visited and the severity of the illness. Because distances of residence were not normally distributed around clinics, we compared median distances using non-parametric statistical tests, Wilcoxon rank sum test and Kruskal–Wallis test.

To assess whether children with more severe illnesses travelled further for clinic visits, we dichotomised illnesses into severe and non-severe. Integrated Management of Childhood Illness (IMCI) algorithms had not been implemented in area clinics so could not be used to characterise severe illness. Therefore, we classified illnesses as severe according to a previous analysis on the same dataset that evaluated the 30-day post-clinic visit risk of mortality based on diagnosis (Lindblade *et al.* 2007). Severe illnesses were those with significantly increased mortality in the 30 days following a clinic visit with that diagnosis compared with all clinic visits. Severe illnesses using this definition included anemia, malnutrition, meningitis, severe pneumonia (pneumonia diagnosis with convulsions), severe malaria (fever with convulsions) measles, diarrhoea and any illness resulting in referral to hospital for admission.

Rates of clinic visits based on the distance lived from a clinic were calculated using person–year denominators. A child could contribute less than a year of person–time if he or she did not live in a location for the full year. Likewise, a child who moved within the DSS could contribute person–time in more than one location. Person–time was categorised in 0.5 km intervals based on the distance a child lived to the nearest DSS clinic. Numerators were calculated as the number of clinic visits made by children living in that distance category to any clinic in the DSS, not just the nearest one. Rate ratios and 95% confidence intervals were calculated using the rate among children living 0–0.5 km from a clinic as the referent group.

We performed Poisson regression to model the number of clinic visits made as related to the distance a child lived from the nearest clinic. We accounted for clustering at the household level using the generalised estimating equation. We adjusted for a child's eligible time at a certain distance using an offset statement. We also controlled for the nearest clinic, because the distance-decay effect might have varied by specific clinic, and maternal education (classified as none, primary, more than primary and missing) by including these as independent variables in the model. We also controlled for socio-economic status of the child's household using a score derived from eight socio-economic indicator variables as defined by principal components analysis; the scores were regrouped into low, medium and high socio-economic level based on their distribution (Vyas & Kumaranayake 2006). We also added to the model a variable for the distance to the nearest major road from a child's residence. Lastly, because of the possible bias that children who lived on the periphery of the DSS, and whose closest clinic was outside of the DSS area would have lived further from the seven DSS clinics under surveillance and hence have been less prone to visit them, we reran the model excluding such children.

All data analysis was done using SAS for Windows (version 9.1).

Ethical approval

The KEMRI/CDC DSS was reviewed by the institutional review boards of the CDC (Atlanta, GA, USA) and KEMRI (Nairobi, Kenya). Informed written consent was obtained from compound heads for participation of their families in all aspects of the DSS.

Results

From May 1, 2003 to April 31, 2004, 4881 visits to Asembo DSS health facilities were made by children less than 5 years of age. The DSS permanent ID could be found in 3897 (79.8%). The main reason for not finding the DSS permanent ID was that the child was not a permanent resident of Asembo, and therefore not enrolled in the DSS. A further 249 clinic visits could not be linked with GIS data for the child's household and 147 clinic visits were made by children whose closest DSS clinic was located in the Gem DSS area. This resulted in a total of 3501 visits to DSS clinics in Asembo made by 2432 children under five, representing 22% of 10 973 eligible resident children.

Among these 10 973 children, the median distance lived to the nearest DSS clinic was 2.07 km. The distance lived to a DSS clinic did not vary significantly by age or sex of the child. The median distance that children travelled for the 3501 DSS clinic visits was 2.01 km (Table 1). This distance varied by age, with younger children travelling further than older children for clinic visits, ranging from a median distance of 2.11 km in children less than 1 year of age to 1.72 km in children 4 years of age ($P = 0.026$, Table 2). The number of visits by boys and girls was similar (boys 51%, girls 49%). The median distance travelled to the clinic for boys was greater (2.06 km) than for girls (1.92 km), but this difference was not statistically significant ($P = 0.092$).

Most children (95%) travelled less than 5 km to visit a clinic (Figure 1). The number of sick visits to individual clinics ranged from 272 in Ndori to 989 in Abidha (Table 1). The median distance travelled to a DSS clinic varied significantly by clinic, ranging from 1.45 km at Ndori and Saradiddi to 2.43 km at Mahaya (Table 1). Most children (73%) visited the DSS clinic closest to their residence. This varied, however, by clinic from 95% of children living closest to Nyagoko to 53% of those living closest to Mahaya.

The number of clinic visits per child ranged from 0 to 8 during the year. The overall rate of clinic visits for all children was 0.42 visits per child-year (95% CI, 0.41–0.43). The rate of clinic visits decreased with increasing distance of residence from a clinic (Table 3). The rate

Table 1 Distance travelled by children for sick visits to each DSS clinic in Asembo, western Kenya 2003–2004

Clinic	Number of children who live closest to clinic, N (% total)	Median distance from residence to the closest DSS clinic (km)†	Number of clinic visits, N (% total)	Median distance travelled to visit clinic (km)†	Percent decrease in likelihood of visit for each 1 km distance from that clinic (95% CI)‡
Abidha	1676 (15)	2.01	989 (28)	2.19	31 (22–39)
Lwak	1908 (17)	2.54	390 (11)	2.43	34 (27–41)
Mahaya	1566 (14)	2.17	382 (11)	2.20	33 (26–39)
Ndori	1324 (12)	1.99	272 (8)	1.45	43 (35–50)
Nyagoko	1209 (11)	2.44	349 (10)	1.74	43 (37-49)
Ongielo	1465 (13)	1.63	667 (19)	2.12	26 (14–36)
Saradidi	1825 (17)	2.09	452 (13)	1.45	37 (30–44)
Total	10 973	2.07	3501	2.01	35 (32–38)

†Comparing median distances by clinic, Kruskal–Wallis test < 0.0001.
‡Poisson regression controlling for household clustering.

Table 2 Frequency of sick visits by children to peripheral health facilities in the Asembo, western Kenya DSS by age group 2003–2004

Age Group (years)	Number of children who visited DSS clinic	Number of children who did not visit	Median distance travelled for DSS visit†
Less than 1	727 (23%)	2458 (77%)	2.11
1	704 (32%)	1513 (68%)	2.10
2	427 (24%)	1383 (76%)	2.06
3	345 (18%)	1577 (82%)	1.96
4	229 (12%)	1610 (88%)	1.72
Total	2432 (22%)	8541 (78%)	2.06

†Among 2383 children with visits to DSS clinics in Asembo. P = .026, Kruskal–Wallis test.

Table 3 Rates of sick visits to peripheral health facilities among children living in the western Kenya DSS by distance lived from the nearest clinic 2003–2004

Distance (km)	No. children who visited clinic based on distance lived from clinic	Child-Time (years) of children by distance lived to clinic	Rate of clinic visits by distance lived from clinic, visits/child-year (95% C.I.)	Rate Ratio of clinic visits by distance lived from clinic (95% C.I.)
0.000–0.50	402	482	0.83 (0.76–0.92)	Ref
0.501–1.00	507	832	0.61 (0.56–0.66)	0.73 (0.64–0.83)
1.001–1.50	654	1179	0.55 (0.51–0.60)	0.67 (0.59–0.75)
1.501–2.00	710	1515	0.47 (0.44–0.50)	0.56 (0.50–0.63)
2.001–2.50	607	1612	0.38 (0.35–0.41)	0.45 (0.40–0.51)
2.501–3.00	441	1240	0.36 (0.32–0.39)	0.43 (0.37–0.49)
3.001–3.50	133	555	0.24 (0.20–0.28)	0.29 (0.24–0.35)
3.501–4.00	27	374	0.072 (0.049–0.10)	0.087 (0.059–0.13)
4.001–4.50	24	268	0.090 (0.060–0.13)	0.11 (0.071–0.16)
4.501–5.00	26	224	0.12 (0.079–0.17)	0.14 (0.094–0.21)
5.001–5.50	11	159	0.069 (0.038–0.13)	0.083 (0.046–0.15)
5.501–6.00	1	16	0.063 (0.008–0.44)	0.075 (0.011–0.55)

decreased progressively with each 0.5 km interval up to 4 km, after which the rate levelled off (Table 3). Higher socio-economic level and higher maternal education were both significantly associated with having more clinic visits (P < 0.001). Adjusting for these two factors, as well as the nearest DSS clinic, the distance a child lived from a DSS clinic was found to have a significant inverse relationship with the number of clinic visits made. For every 1 km increase in distance of residence from a DSS clinic, the rate of clinic visitation fell by 34% (95% CI, 31–37%) from the previous kilometer. Distance a child lived to the closest major road did not significantly change the result. A similar distance-decay phenomenon was observed for each individual clinic, although the amount of decay varied by clinic from 26% to 43% (Table 3). In a secondary analysis that eliminated 2308 children whose nearest clinic of residence was a clinic outside the DSS area, the distance-decay effect remained significant with a decrease in the rate of clinic visits of 32% (95% CI, 28–35%) for each additional 1 km lived from the nearest clinic.

The most common diagnoses for clinic visits were malaria (79%), upper respiratory tract infection (35%), gastroenteritis (12%), pneumonia (5%) and worms (5%). Multiple diagnoses were given in 46% of visits. There was no difference in the distance travelled for children with a single *vs.* multiple diagnoses. Thirty-six percent of children were determined to have a severe illness. Children with severe illnesses travelled further than those with non-severe illnesses (median 2.2 km *vs.* 1.9 km respectively, P < 0.001, Figure 2).

Discussion

In rural western Kenya, we demonstrated that children's attendance for sick visits at peripheral health facilities decreased with distance lived from a facility. First documented in the 1920s in America, in recent years the distance-decay effect is mostly described in developing countries. It has been demonstrated in Kenya before (Shannon *et al.* 1969; Schellenberg *et al.* 1998; Mwaniki

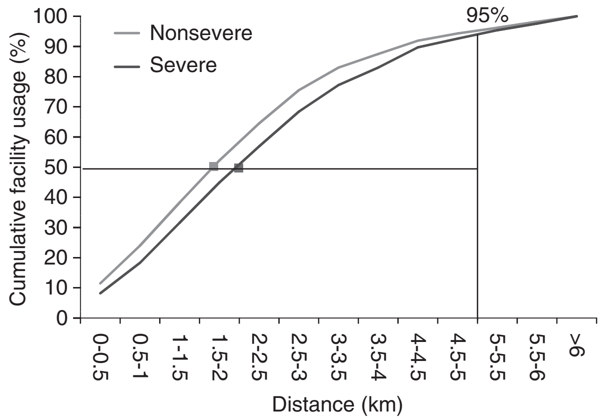

Figure 2 Clinic utilisation based on the distance a child lived from the visited facility for severe and non-severe illnesses, Asembo, western Kenya 2003–2004. (see Methods).

et al. 2002; Noor *et al.* 2003; Gething *et al.* 2004), other African countries (Stock 1983; Kloos 1990; Weber *et al.* 2002) and Asian countries (Rahaman *et al.* 1982; Muller *et al.* 1998), indicating that it is a robust finding in developed country settings.

Our study made several contributions to the evaluation of the distance-decay effect. Because this was done within a DSS, GIS coordinates were available on all children resident to the area, rather than just children making clinic visits, allowing for accurate distance strata-specific denominators. The GIS information of children visiting the clinic could be linked with prospectively collected geospatial and demographic data. This allowed accurate calculation of rates of clinic attendance based on distance lived from the clinic. Moreover, because we performed clinic surveillance at all the major peripheral health facilities in the Asembo DSS area, we were able to calculate rates of visitation to any clinic, not just one central clinic. The latter could be subject to bias if children, particularly those living at greater distances near the periphery of the central clinic's catchment area, visit clinics other than the central clinic (Gething *et al.* 2004). We found a significant distance-decay effect even when eliminating from the analysis children living closer to non-DSS clinics outside the periphery of the DSS.

In contrast to previous studies, our data demonstrated a pronounced decline in clinic attendance almost immediately with increasing distance of residence (Shannon *et al.* 1969; Stock 1983; Muller *et al.* 1998; Noor *et al.* 2003). The rate of clinic visits declined progressively until 4 km, where the rates levelled off. Moreover, the rate of clinic attendance was found to halve by 2 km, in contrast to other studies that found rates to halve from 3.0 to 3.5 km (Stock 1983; Muller *et al.* 1998). A sharp distance-decay effect was also seen in rural Ethiopia (Kloos 1990). The reasons for the steeper declines in clinic attendance with distance in rural western Kenya are unclear. In rural Asembo in 2003–2004, few transport options existed except for walking. As such, the gradient of time expended in visiting the clinic would increase steeply as distance from the clinic increased. In other African settings where other forms of public transport exist, physical distance might be less of a factor in clinic visitation than the cost of transport (Airey 1992; Weber *et al.* 2002). In a study in central Kenya, the building of a new tarmac road resulted in little decrease in the distance-decay effect, probably because most patients travelled by public transport and the cost of such transport did not fall with the new road (Airey 1992).

Similar to other studies, we showed that the distance-decay effect was less pronounced among infants and children with more severe illnesses (Rahaman *et al.* 1982; Stock 1983; Schellenberg *et al.* 1998; Weber *et al.* 2002). Although boys tended to travel further than girls, this was not statistically significant, in contrast to findings in Nigeria, Bangladesh and Papua-New Guinea (Rahaman *et al.* 1982; Stock 1983; Muller *et al.* 1998). Also the distance-decay effect was more marked in some clinics than others, suggesting that factors intrinsic to the clinic also play a role in health care utilisation. These variations in the distance-decay effect based on sex, age and severity of illness, and particular clinic characteristics, show that other important factors influence a parent's decision to bring their child to the clinic in addition to distance lived. The mutability of the distance-decay effect suggests that parents can likely be educated about health-seeking priorities, thereby offsetting, at least partially, the distance-related obstacles to health care seeking (Shannon *et al.* 1969). Attention to the clinic itself, such as the competency of the clinical staff and supply of drugs, can influence how far mothers will travel with their sick children (Shannon *et al.* 1969; Stock 1983).

Our study had several limitations. We were only able to link the DSS ID number in 80% of visits. It is possible that this could have introduced a differential bias if children who lived further from the health facility were less likely to have their DSS ID found. However, this bias was likely minimal because the computerised searching exercises to find DSS ID numbers were done on the entire DSS dataset and the distance-decay effect finding was statistically robust. Another limitation was that we were unable to evaluate the distance-decay effect for specific diagnoses at the clinic. This was because of the high frequency of multiple diagnoses and also the non-specificity of diagnoses without objective diagnostic testing in most facilities. Other studies have shown that the distance-decay effect seems to be consistent across diagnoses, having been shown in malaria, acute respiratory infection and diarrhoea (Rahaman *et al.* 1982; Stock 1983; Muller *et al.* 1998). Lastly, the possibility exists that the association between clinic visitation and distance was confounded by other variables. We adjusted for socio-economic status, maternal education, distance to a road and household clustering in the analysis, yet it is possible that residual or unmeasured confounding existed (Makinen *et al.* 2000). We doubt, however, that such confounders would have fully explained the strong distance-decay effect we observed, especially because most of Asembo is homogeneously poor and rural.

The Kenya Ministry of Health has undertaken a restructuring of the health sector to enhance access to care (Ministry of Health 1997; Noor *et al.* 2003) Part of this plan is to maximize the number of people living within 5 km of a health facility. While this objective is supported by the evidence that most clinic visits occur among those living within 5 km, our data suggest that it will not fully mitigate the problem of differential access in rural Kenya, and likely other similar African settings. The distance-decay effect also occurs markedly within 5 km of the clinic, starting as close as half a km from the clinic. Other aspects of access, such as behavioural and educational factors, should be addressed (Shannon *et al.* 1969; Muller *et al.* 1998; Noor *et al.* 2003). Alternatives to clinic-based health initiatives, such as expanded availability of certain treatments or preventative interventions in the informal health sector or the home, might be further explored to achieve equity of health services in rural developing countries (Amin *et al.* 2003). Lastly, clinic-based surveillance estimates of disease burden must adjust for the pronounced distance-decay effect in rural African settings (Stock 1983; Schellenberg *et al.* 1998; Weber *et al.* 2002).

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References

Adazu K, Lindblade KA, Rosen DH *et al.* (2005) Health and demographic surveillance in rural western Kenya: a platform for evaluating interventions to reduce morbidity and mortality from infectious diseases. *American Journal of Tropical Medicine and Hygiene* **73**, 1151–1158.

Airey T (1992) The impact of road construction on the spatial characteristics of hospital utilization in the Meru district of Kenya. *Social Science and Medicine* **34**, 1135–1146.

Amin AA, Marsh V, Noor AM, Ochola AS & Snow RW (2003) The use of formal and informal curative services in the management of paediatric fevers in four districts in Kenya. *Tropical Medicine and International Health* **3**, 1143–1152.

Amornkul PN, Vandenhoudt H, Odhiambo F *et al.* (2004) *HIV prevalence among 13–34 year olds in a large cross-sectional survey in rural western Kenya.* Oral presentation, abstract #22, August 30, 2004. AIDS Vaccine 04 Conference. Lausanne, Switzerland.

Gething PW, Noor AM, Zurovac D *et al.* (2004) Empirical modeling of government health service use by children with fevers in Kenya. *Acta Tropica* **91**, 227–237.

Kloos H (1990) Utilization of selected hospitals, health centres and health stations in central, southern and western Ethiopia. *Social Science and Medicine* **31**, 101–114.

Lindblade KA, Hamel MJ, Feikin DR *et al.* (2007) Mortality of sick children after outpatient treatment at first-level health facilities in rural western Kenya. *Tropical Medicine and International Health* **12**, 1258–1268.

Makinen M, Waters H, Rauch M *et al.* (2000) Inequalities in health care use and expenditures: empirical data from eight developing countries and countries in transition. *Bulletin of the World Health Organization* **78**, 55–65.

Mbatia PN (2003) Responding to crisis: patterns of health care utilization in central Kenya amid economic decline. *African Studies Review*, April. Retrieved April 1 2006 at http://www.findarticles.com/p/articles/mi_qa4106/is_200304/ai_n921915.

Ministry of Health (1997) *Health Policy Framework*. Ministry of Health, Government of Kenya, Nairobi.

Muller I, Smith T, Mellor S, Rare L & Genton B (1998) The effect of distance from home on attendance at a small rural health centre in Papua New Guinea. *International Journal of Epidemiology* **27**, 878–884.

Mwaniki PK, Kabiru EW & Mbugua GG (2002) Utilisation of antenatal and maternity services by mothers seeking child welfare services in Mbeere District, Eastern Province, Kenya. *East African Medical Journal* **79**, 184–187.

Nabarro DN & Tayler E (1998) The "Roll Back Malaria" campaign. *Science* **280**, 2067–2068.

Noor AM, Zurovac D, Hay S, Ochola SA & Snow RW (2003) Defining equity in physical access to clinical services using geographical information systems as part of malaria planning and monitoring in Kenya. *Tropical Medicine and International Health* **8**, 917–926.

Phillips-Howard PA, Nahlen BL, Wannemuehler KA *et al.* (2003) Impact of Permethrin-treated bed nets on the incidence of sick child visits to peripheral health facilities. *American Journal of Tropical Medicine and Hygiene* **68** (Suppl. 4), 38–43.

Rahaman MM, Aziz KMS, Munshi MH, Patwari Y & Rahman M (1982) A diarrhea clinic in rural Bangladesh: influence of distance, age and sex on attendance and diarrhea mortality. *American Journal of Public Health* **72**, 1124–1128.

Schellenberg JA, Newell JN, Snow RW *et al.* (1998) An analysis of the geographical distribution of severe malaria in children in Kilifi District, Kenya. *International Journal of Epidemiology* **27**, 323–329.

Shannon GW, Bashshur RL & Metzner CA (1969) The concept of distance as a factor in accessibility and utilization of healthcare. *Medical Care Review* **26**, 143–161.

Stock R (1983) Distance and the utilization of health facilities in rural Nigeria. *Social Science and Medicine* **17**, 563–570.

Vyas S & Kumaranayake L (2006) *Constructing socioeconomic status indices: how to use principal components analysis*. HIV Tools Research Group, Health Policy Unit, Department of Public Health and Policy, London School of Hygiene and Tropical Medicine, London, UK.

Weber MW, Miligan P, Sanneh M *et al.* (2002) An epidemiological study of RSV infection in the Gambia. *Bulletin of the World Health Organization* **80**, 562–568.

WHO/UNICEF (2004) *Joint WHO/UNICEF Statement on clinical management of acute diarrhea*. Accessed at http://whqlibdoc.who.int/hq/2004/WHO_FCH_CAH_04.7.pdf.

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