Modeling Spatial Inequalities in Health in Cities of Developing Countries: The Case of Accra, Ghana

Extended Abstract

Introduction and Background

Sustainable development in Africa, as elsewhere in the world, requires that future population growth be absorbed by cities, because only in or near cities can we anticipate the kind of employment growth needed to rise above and stay above the poverty level. At the same time, sustainable development requires a healthy population because only a healthy population can generate the levels of economic productivity necessary to lift an economy out of widespread poverty. The conjunction of these two propositions means that sustainable development in the context of continued population growth demands an urban environment that promotes improved levels of health services, as well as of health equity among its residents. Because of the very limited resources available to most nations of sub-Saharan Africa, urban health promotion in the future will require ever more efficient, parsimonious use of scarce resources. Economic development was once thought to be the precursor to improved nutrition, but there is now recognition that improved nutrition and health can in fact help to promote economic development (World Bank 2005). It is thus important to identify the minimum threshold requirements of adequate levels of health in the urban environment, so that resources can be devoted to bringing every neighborhood up to at least that level.

We posit that variability in health within urban places, just as between urban and rural places, is importantly a function of the composite characteristics of *place*, not just of the people themselves (Weeks *et al.* 2006). The medical model of health has, since the 19th century introduction of the germ theory, emphasized the risk of disease experienced by individuals, regardless of context, whereas a purely ecological approach would emphasize the importance of contextual environmental factors (Meade and Earickson 2000). A more holistic, human ecological, or social epidemiological, approach places dual emphases on people and place. Characteristics of place include the provision of potable water, adequate sewerage and disposal of waste, accessibility (geographic and financial) to health clinics and personnel, as well as the adequacy of housing (protection from heat, cold, and water intrusion), the overall quality of the built environment in protecting people from pests and environmental hazards, the physical structure of the neighborhood that promotes or prevents the spread of communicable disease, the exposure to disease vectors such as mosquitoes (Tatem and Hay 2004), and the promotion of adequate diet and exercise (Diez Roux 1998; Ellaway, Macintyre, and Bonnefoy 2005; Saelens, Sallis, and Frank 2003), along with the institutional structure that exists to service the needs of the population (Geronimus 2000; Hardoy, Mitlin, and Satterthwaite 2001; Montgomery and Ezeh 2005). Personal characteristics such as education, income, and occupation clearly play a role, of course, in determining access to an adequate diet, personal hygiene, disease avoidance, access to health care professionals, and adherence to medical regimens, but the literature suggests that personal characteristics often interact with neighborhood characteristics to produce health outcomes that are joint products of who a person is and where they live (e.g.,Cohen *et al.* 2003; Ellen, Mijanovich, and Dillman 2001; Williams, Neighbors, and Jackson 2003).

Differences in mortality by social status are among the most pervasive inequalities in modern society, and they are most noticeable in cities (Weeks 2008). So, an individual who is in a family of low socioeconomic status is at greater risk of death. Data from nearly all places in the world suggest that the higher one's position in society, the longer he or she is likely to live. These same personal characteristics may also influence the level of advocacy that will lead to demands for access to communal infrastructure (e.g., water, sewerage, solid waste disposal) that can improve health levels. Thus, to understand health levels we must understand the characteristics of people themselves, and also the characteristics of their environment. Mitchell, Dorling and Shaw (2002:15) capture the idea this way: "The first explanation, commonly referred to as 'compositional', suggests that area level mortality or morbidity rates reflect the risks of ill health which the resident individuals carry with them. The relationships between individual level factors such as social class and employment status, and the risk of mortality or morbidity, are well documented, powerful, and very robust. The composition thesis thus argues that places with apparently high levels of sickness or death rates are those in which a higher proportion of the residents are at higher risk of sickness or death. The second explanation, commonly referred to as 'contextual', suggests that the nature of day-to-day life in an area can exert an influence on the population's overall health and well-being and thus the mortality risk of residents, over and above their individual characteristics. The influences might, for example, stem from the social or physical environment. Somehow, life in an area raises or lowers the risk of ill health for the resident individuals so that they experience different risk of illness from that which they might experience living somewhere else."

An important conceptual issue is whether or not the neighborhood effects are endogenous to the compositional characteristics of those neighborhoods, and thus essentially indistinguishable from the compositional effects (Kaufman 2006). Researchers such as Stjärne et al. (2006), in their study of neighborhood impacts on myocardial infarction in Stockholm, have concluded that they are, in fact, distinguishable. In our research, however, the neighborhood context is measured not just from aggregations of individual characteristics, but more specifically from the physical context that defines a neighborhood.

Our principal aim in this paper is to identify the nature of neighborhood-level (place) differentials in health within a data-rich city of a developing nation, so that we can ultimately model spatial inequalities in other cities of developing nations. Our approach is essentially ecological, with an emphasis on measuring outcomes and determinants for a range of spatial units, although our access to individual-level data also provides the opportunity to control for the extent to which spatial inequalities in health may simply be a function of individuals with similar health risk profiles (especially in terms of socioeconomic status) living near each other.

Research Hypotheses

We hypothesize that (1) morbidity and mortality ("health outcomes") vary significantly within the city of Accra; and that (2) this spatial variability can be estimated for areas for which we do not have detailed health outcome data.

Data and Methods

We test these hypotheses by drawing upon georeferenced survey and census data for Accra, Ghana. We use the phrase "health outcomes" to describe the dependent variable(s) of interest in this abstract, without being very specific because we have a large number of potential candidates for measuring health outcomes, derived from the Women's Health Survey of Accra in 2003 (with re-interviews taking place in 2008). A major preliminary task before the paper is completed will be to undertake extensive exploratory analysis of the many health outcome variables captured by the WHSA.

Data were collected from 3,200 women aged 18 and older in a multi-stage cluster probability sample of 200 of the 1,724 EAs in Accra (Duda *et al.* 2005a; Duda *et al.* 2007; Duda *et al.* 2006; Duda *et al.* 2005b). The basic categories of data collected include the following: (1) self-rated overall health now and in comparison to a year ago; (2) several categories of overall activity limitation; (3) 4-week recall of health problems and activity limitations; (4) 30 day recall of self-care issues; (5) 30 day recall of pain and discomfort; (6) 30 day recall regarding mental alertness and activity within the community; (7) eyesight and hearing; (8) breathing and sleeping problems; (9) self-reported depression/anxiety; (10) risk factors for non-communicable disease including tobacco use, alcohol consumption, and physical activity; (11) nutrition and food security; (12) self-reports of specific diseases, including hypertension, diabetes, heart attack, stroke, chronic lung condition, asthma, depression/anxiety, cancer (specific to site), malaria, TB, obesity, urinary incontinence, broken bone, arthritis/joint pain, schizophrenia, epilepsy/seizure or fit, and cataracts—and for each of these, data were gathered as to who diagnosed it, what the treatment has been, whether there were lab or other tests, whether the person is still afflicted, and if it restricts activity; (13) history of menarche and menopause; (14) sexual activity and sexually transmitted infections; (15) pregnancy history; (16) breastfeeding history; (17) family planning; (18) health-seeking behavior; (19) use of medications; (20) changes made to improve health during the past 12 months; and (21) the impact of health conditions on personal and family resources during the prior 30 days.

The 2000 census included questions on children ever-borne and surviving as the only health-related measures. We have access to a georeferenced 10% anonymized sample, drawn from the 2000 census, of households for each enumeration area. This provides good estimates of variations in child mortality. We will also use these data to calculate measures of child survival using the methods developed originally by Brass specifically for application to Africa, but now widely used in all settings where census and/or survey data are superior in quality to vital statistics data. These methods are described in the United Nations Population Division Manual X (1983). More recent developments by MacLeod (1999) and Noel-Miller (2005) allow us to calculate an index of child mortality for individual women. Such measures can then be aggregated into small areal units for spatial analysis that includes the characteristics of the mothers as co-variates.

For Accra overall, our calculations suggest an under-five mortality for boys of 154 deaths by age five per 1,000 live births, and for girls the rate is 148 per 1,000. These rates are somewhat higher than data for Ghana obtained in the 1998 and 2003 Demographic and Health Surveys (Ghana Statistical Service and Inc. 2004; Ghana Statistical Service and Macro International Inc. 1999). The Demographic and Health Surveys have also generated lower estimates of mortality than the Demographic Surveillance System site in Navrongo, Ghana (INDEPTH Network 2004), so it is possible that the DHS levels are underreporting levels of mortality in Ghana. We have entered the under-five mortality rates into model life tables for West Africa, as calculated by the INDEPTH Network (2004), to yield life expectancies at birth in Accra of 55 years for females and 52 for males. These levels are slightly lower than those reported by the United Nations Population Division for Ghana (United Nations Population Division 2005), but the likely explanation is that the United Nations is heavily dependent upon the Demographic and Health Surveys for its estimates.

Although the census has a very limited range of health outcome variables, there are several variables in common between the census and the WHSA which will allow us to model health outcomes for the entire city based on results from the sample of women in the WHSA. The analysis begins with measures of health outcomes, behaviors, or knowledge drawn from the WHSA together with a set of explanatory covariates, the latter being chosen for their commonality with the census, as noted above. These variables include individual-level data such as age, sex, relationship to head of household, nationality, ethnicity, marital status, education (several indices), employment and economic activity; for some health models it will also be appropriate to include children born and surviving (asked only of adult females). Additional predictor variables available at the household level include source of drinking water, toilet facilities, sewerage, lighting source, cooking fuel, persons per room, and housing tenure. We will further enrich the specification with the neighborhood-specific data (and estimates) that are available for each neighborhood in Accra (and for several different definitions of neighborhood). These include indices of proximal space, AMOEBA clustering scores (Aldstadt and Getis 2006), and measures of the built and natural environment derived from the object-oriented classification of a Quickbird high-resolution satellite image of Accra. This is an extension to the usual approach taken in poverty mapping, which has not generally exploited such neighborhood-specific data.

Using the survey data on health and explanatory covariates, together with the additional neighborhood data just described, we will proceed to estimate a multivariate model of health. Poverty mapping research has taken spatial autocorrelation into account only through a simple random-effects disturbance term with a neighbourhood component. We will be able to estimate richer spatial correlation structures, whose specification will be informed by spatial filtering

(Getis 1995; Getis and Griffith 2002; Weeks *et al.* 2004). The next step is to apply the estimated coefficients of the health model to the counterpart explanatory variables from the census, so as to generate a predicted health measure for each household in the 10% microsample of the census. In this way, the fusion of survey data from the sampled EAs with the satellite and census data for all EAs produces a "health map" at a level of geographic detail that matches that which is provided by the census data (the EA, or aggregations of EAs). Note that we will not simply attach the estimated coefficients derived from the survey data to the census record. Instead, as described by Elbers et al. (2003), Monte Carlo simulation is used to appropriately represent first-stage sampling error and spatial autocorrelation. The coefficient vectors are drawn from their estimated joint normal sampling distribution, and random draws are also made for the disturbance terms, in this case from a distribution that incorporates spatial autocorrelation of the form specified in the health model. A health predicted value is formed for each such draw, and the average predicted value is then calculated across the draws of the simulation--- this average is what is finally assigned to the census record.

Expected Results

Using these data, we will calculate generalized entropy measures of health inequality at the EA and other neighborhood levels of aggregation within Accra. These estimates will allow total health inequality across Accra to be decomposed into its within-neighborhood and between-neighborhood components, and will allow for identification of those neighborhoods that exhibit high levels of health vulnerability. To our knowledge, this is the first application of the small-area poverty mapping methods developed by the World Bank and its allied researchers to a range of health behavior and outcome measures. If the small-area method proves to be successful with respect to health, this will open up a range of new applications that go well beyond what we propose here.

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References

Aldstadt, Jared and Arthur Getis. 2006. "Using AMOEBA to Create a Spatial Weights Matrix and Identify Spatial Clusters." *Geographical Analysis* 38.

Cohen, Deborah A., Karen Mason, Ariane Bedimo, Richard Scribner, Victoria Basolo, and Thomas A. Farley. 2003. "Neighborhood Physical Conditions and Health." *American Journal of Public Health* 93:467-471.

Diez Roux, A.V. 1998. "Bringing Context Back into Epidemiolog: Variables and Fallacies in Multilevel Analysis." *American Journal of Public Health* 88:216-222.

Duda, Rosemary B., G.L. Chen, Allan G. Hill, R.M.K. Adanu, J. Seffah, and John Anarfi. 2005a. "Screening for cervical cancer still not included as routine care for women." *International Journal of Tropical Medicine* 1:1-6.

Duda, Rosemary B., M.P. Kim, R. Darko, R.M.K. Adanu, J. Seffah, John Anarfi, and Allan G. Hill. 2007. "Results of the Women's Health Study of Accra: Assessment of Blood Pressure in Urban Women." *International Journal of Cardiology* 117:115-122.

Duda, Rosemary B., M.P. Kim, R. Darko, R.M.K. Adanu, J. Seffah, John K. Anarfi, and Allan G. Hill. 2006. "Prevalence of elevated blood pressure in women residing in Accra, Ghana: Report from the Women's Health Survey of Accra." *International Journal of Cardiology*.

Duda, Rosemary, Rudolph Darko, Richard Adanu, Joseph Seffah, John Anarfi, Shiva Gautam, and Allan G. Hill. 2005b. "HIV Prevalence and Risk Factors in Women of Accra, Ghana: Results from the Women's Health Study of Accra." *American Journal of Tropical Medicine and Hygiene* 73:63-66.

Elbers, Chris, Jean O. Lanjouw, and Peter Lanjouw. 2003. "Micro-Level Estimation of Poverty and Inequality." *Econometrica* 71:355-364.

Ellaway, Anne, Sally Macintyre, and Xavier Bonnefoy. 2005. "Graffiti, Greenery, and Obesity in Adults: Secondary Analysis of European Cross Sectional Survey." *BMJ* 331:611-612.

Ellen, Ingrid Gould, Tod Mijanovich, and Keri-Nicole Dillman. 2001. "Neighborhood Effects on Health: Exploring the Links and Assessing the Evidence." *Journal of Urban Affairs* 23:391-408.

Geronimus, A. 2000. "To Mitigate, Resist, or Undo: Addressing Structural Influences on the Health of Urban Populations." *American Journal of Public Health* 90:867-872.

Getis, Arthur. 1995. "Spatial Filtering in a Regression Framework: Examples Using Data on Urban Crime, Regional Inequality, and Government Expenditures." Pp. 172-185 in *New Directions in Spatial Econometrics*, edited by L. Anselin and R. Florax. Berlin: Spriger-Verlag.

Getis, Arthur and Daniel A. Griffith. 2002. "Comparative Spatial Filtering in Regression Analysis." *Geographical Analysis* 34:130-140.

Ghana Statistical Service and Macro International Inc. 2004. *Ghana Demographic and Health Survey, 2003*. Calverton, MD: Ghana Statistical Service and Macro International.

—. 1999. *Ghana Demographic and Health Survey, 1998*. Calverton, MD: Ghana Statistical Service and Macro International.

Hardoy, Jorge E., Diana Mitlin, and David Satterthwaite. 2001. *Environmental Problems in an Urbanizing World*. London: Earthscan Publications.

INDEPTH Network. 2004. *INDEPTH Model Life Tables for Sub-Saharan Africa*. Aldershot, UK: Ashgate Publishing Company.

Kaufman, Jay S. 2006. "Socioeconomic Context." *Epidemiology* 17:4.

MacLeod, W. 1999. "The Decline of Child Mortality in The Gambia." Harvard School of Public Health, Harvard University, Cambridge, MA.

Meade, Melinda S. and Robert J. Earickson. 2000. *Medical Geography, Second Edition*. New York: The Guilford Press.

Mitchell, Richard, Danny Dorling, and Mary Shaw. 2002. "Population Production and Modelling Mortality--An Application of Geographic Information Systems in Health Inequalities Research." *Health & Place* 8:15-24.

Montana, Livia, Melissa Neuman, Vinod Mishra, and Rathavuth Hong. 2006. "Spatial Modeling of HIV Prevalence in Cameroon, Kenya, and Tanzania." in *Annual Meeting of the Population Association of America*. Los Angeles.

Montgomery, Mark and Alex C. Ezeh. 2005. "Developing-Country Urban Health: Insights from Demographic Theory and Practice." in *The Handbook of Urban Health*, edited by S. Galea and D. Vlahov. New York: Kluwer Press.

Noel-Miller, Claire. 2005. "Methods for Studying Child Mortality Differentials in Populations with Limited Death Registration." Sociology, University of Pennsylvania, Philadelphia.

Saelens, Brian E., James. F. Sallis, and Lawrence D. Frank. 2003. "Environmental Correlates of Walking and Cycling: Findings From the Transportation, Urban Design, and Planning Literatures." *Annals of Behavioral Medicine* 25:80-91.

Tatem, A.J. and S.I. Hay. 2004. "Measuring Urbanization Pattern and Extent for Malaria Research: A Review of Remote Sensing Approaches." *Journal of Urban Health* 81:363-376.

United Nations Population Division. 1983. *Manual X: Indirect Techniques for Demographic Estimation*. New York: United Nations.

—. 2005. *World Population Prospects, the 2004 Revision*. New York: United Nations.

Weeks, John R. 2008. *Population: An Introduction to Concepts and Issues, Tenth Edition*. Belmont, CA: Wadsworth Thomson Learning.

Weeks, John R., Arthur Getis, Allan G. Hill, M. Saad Gadalla, and Tarek Rashed. 2004. "The Fertility Transition in Egypt: Intra-Urban Patterns in Cairo." *Annals of the Association of American Geographers* 94:74-93.

Weeks, John R., Allan G. Hill, Arthur Getis, and Douglas Stow. 2006. "Ethnic Residential Patterns as Predictors of Intra-Urban Child Mortality Inequality in Accra, Ghana." *Urban Geography* 27(6):526-548.

Williams, David R., H. W. Neighbors, and J. S. Jackson. 2003. "Racial/ethnic discrimination and health: Findings from community studies." *American Journal of Public Health* 93:200-208.

World Bank. 2005. *Repositioning Nutrition as Central to Development: A Strategy for Large Scale Action*. Washington, DC: The World Bank.