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An examination of environmental correlates with childhood height-for-age in Ghana

Ebenezer Nikoi[1,]* and Peter Anthamatten[2]
[1]Department of Geography, University of Minnesota, 414 Social Sciences Building, 267 19th Avenue South, Minneapolis, MN 55455, USA: [2]Department of Geography and Environmental Sciences, Auraria Campus, Denver, CO, USA

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Abstract

Objective: The relationship between a child's environment and nutritional status is difficult to examine yet could offer an important guide to policy. The objective of the present work was to examine individual and environmental correlates with childhood height-for-age in Ghana.
Design: Data were derived from the 2008 MEASURE Demographic and Health Survey in Ghana, the 2000 Ghana Population and Housing Census, and the World Wide Fund for Nature's eco-regions database. A generalized linear mixed regression model was used to estimate the effects of individual and environmental correlates on height-for-age.
Subjects: The study examined 2225 Ghanaian children aged 0–59 months.
Setting: The setting was all districts in Ghana for the year 2008.
Results: After accounting for individual characteristics of children, mothers and households, height-for-age was significantly associated with population density. Other significantly associated variables in the final model were the age of the child, vaccination status, the size of the child at birth, months of breast-feeding, mother's BMI, whether the child's mother had health insurance and wealth quintile.
Conclusions: In addition to a number of characteristics of the children and their households, the social milieu is important to understanding differences in height-for-age among children in Ghana. The biophysical environment was not associated with height-for-age.

Keywords
Childhood
Nutrition
Africa
Environment

Malnutrition, defined here as 'a cellular imbalance between the supply of nutrients and energy and the demand for them to ensure growth, maintenance, activity, and specific functions'[1], continues to be a significant challenge for children in low-income countries, particularly in Africa. Undernutrition remains one of Africa's most fundamental challenges for improving human development. UNICEF defines 'undernutrition' as[2]:

> the outcome of insufficient food intake and repeated infectious diseases. It includes being underweight for one's age, short for one's age (stunted), thin for one's height (wasted) and deficient in vitamins and minerals (micronutrient malnutrition).

Because the time and capacities of caregivers are limited, many children on the continent are unable to access or effectively utilize the food and health services they need for a healthy life[3]. According to UNICEF estimates, nearly one-third of all sub-Saharan African children under 5 years of age are underweight[4]; that is, below −2 standard deviations from the median weight-for-height in a global reference population.

Ghana ratified the United Nations Convention on the Rights of the Child (UNCRC) in 1990 and demonstrated its commitment by launching a 10-year National Program of Action in 1992. This programme translated the UNCRC document into six major Ghanaian languages, reformed laws related to children, initiated compulsory and universal basic education, and created the Ministry for Women and Children. These initiatives contributed to increased school enrolment (particularly for girls) and improved immunization rates. Results from five Ghana Demographic and Health Surveys (GDHS) document subsequent improvements in infant and childhood mortality rates[5].

Many national governments do not have the financial resources necessary to achieve the nutrition goals prescribed by the UNCRC. Sadly, many also lack the appropriate knowledge and political will to ensure progress in implementing measures that are financially feasible. Providing specific information at different scales can enable more cost-effective and efficient ways to address child nutritional deficits. Research is not necessary to demonstrate that impoverished children who lack quality

*Corresponding author: Email niko0032@umn.edu

shelter, diet, education and health care are especially vulnerable to malnutrition. Research can however identify the people and places with the greatest need, enhance our understanding of the variables that best explain children's failure to thrive in particular situations and guide interventions that could improve children's well-being.

Some scholarship, particularly by climatologists, biologists, ecologists and soil scientists, focuses on the biophysical environment, but few make the connection to nutritional well-being[6,7]. Work that examines this connection shows that the biophysical environment has important implications for children's nutritional outcomes, through its impact on the potential for agricultural sustainability and food production, but evidence is inconclusive. Factors such as rainfall and soil type are among the biophysical environmental conditions that impact the quantity, quality and diversity of food produced. Poor nutritional status has been linked to the altitudes at which children reside in Tibet[8] for example, and the influence of ecology on nutrition and body composition measures has been cited as a reason for significant group differences among pre-school children in coastal, Himalayan and desert ecology regions in India[9]. In West Africa, the most serious child malnutrition occurs in more arid regions, where drought-resistant crops dominate, while the least malnourished children are in the more humid areas where root crops are dominant[10]. The nature of large-scale measurements such as biophysical environment makes them highly susceptible to error that requires careful examination of the links between these contexts and children's nutritional outcome. Several studies have found household variables to explain more variation in child hunger in the developing world context than environmental factors[11,12].

Dickinson *et al.*[13] propose that environmental factors be combined with social factors to help rural communities confront the barriers to improving their intake of micronutrients, such as Fe and Zn. The current research assessed factors associated with children's differential nutritional status, as indicated by height-for-age, in Ghana. Two related questions of both scholarly and practical significance are addressed in the analysis reported here:

1. What characteristics of children, mothers and households are associated with height-for-age among children in Ghana?
2. After accounting for associated factors for children, mothers and households, do the socio-economic and biophysical characteristics of the place where children reside provide additional explanation for observed differences in height-for-age?

The goal of the work was to examine individual and environmental correlates with difference in childhood height-for-age in Ghana.

Methods

Data sources

The MEASURE Demographic and Health Surveys (DHS) are recognized as an accurate source of nationally representative information about the demographic and health status of low-income countries, with an emphasis on young children and their mothers. Selection of the DHS stratified sample for every survey entails two stages. Enumeration areas[14], or population clusters, based on the national census, are randomly selected with probability proportional to the number of households. After the list of households in each of the selected enumeration areas has been updated, households are randomly selected with equal probability for interview[15]. Standardized modules are used to construct questionnaires for each national survey. More detailed information about the specifics of the DHS sampling and data collection methods can be found at its website (http://www.measuredhs.com/).

What is remarkable about DHS data – in contrast to national census data, for example – is that variables are reported for individuals and their households. This enables multivariate analysis at the level of the individual child. The individual child is the most logical unit of analysis for research on childhood malnutrition, since it is he or she who consumes food, experiences infectious diseases and exhibits a particular nutritional status.

In the most recent GDHS conducted in 2008, 412 enumeration areas were randomly selected from a list based on the 2000 Ghana Population and Housing Census (PHC). Interviews were conducted in 11 778 households, yielding a response rate of 97 % for women and 96 % for men[5]. These samples are representative for Ghana as a whole, for urban and rural areas, and for the country's ten official regions.

The present study also uses data from the 2000 Ghana PHC. In 2000, the Ghana PHC collected census information on both population and housing for the first time. The census was carried out by the Ghana Statistical Service and covered all persons in households and all living quarters in Ghana at midnight of Census Night (26 March 2000). Ecological zone classifications are derived from the World Wide Fund for Nature's classification system[16], built from careful research designed to represent natural conditions without human intervention[17]. According to this regionalization, Ghana straddles three major habitat biomes that are subdivided into five ecological zones. These are Eastern Guinea Forest, West Sudanian Savannah, Guinea Forest–Savannah Mosaic, Central African Mangroves and Guinea Mangroves. These zones are not congruent with districts or regional boundaries in Ghana.

Outcome variable

Height-for-age refers to the expected height of a healthy child, given a child's age. This measure can be used as a measure of long-term adequacy of consumption of nutrients, especially protein. An individual child's stature may result from genetic characteristics, low birth weight (also the result of a complex interaction of numerous variables) or infectious disease. Low height-for-age, often called stunting, can be interpreted as an indication of poor nutritional status, a common practice in public health and nutrition research[18–21].

Height-for-age data for Ghana were captured by the GDHS, with children ranging from 5·68 standard deviations below the population mean (−5·68 SD) to 5·96 standard deviations above the mean (+5·96 SD). Traditionally, stunting and wasting were defined in relation to a comparison population in a high-income country in the same region, based on the assumption that ethnically similar populations are also genetically similar, manifested in characteristics such as height and weight[22]. More recently, the WHO has argued that, under optimal conditions, growth is the same for all populations[23]. It has therefore issued standards that can be applied to young children worldwide. The use of National Center for Health Statistics/WHO reference standards makes the findings from the present study comparable to previous studies in Ghana and elsewhere. Additional information about international growth standards is available at the WHO website (http://www.who.int/childgrowth/en/).

Exposure variables

Scholarly research has shown that a large number of variables are associated with child nutritional outcomes[11,18–21,24,25]. We surveyed the literature to determine the variables to include in our analysis. The variables selected included characteristics of the child, including age of the child[26,27], sex of the child[20,28], vaccination status[29], size of the child at birth[20] and months of breast-feeding[30]. Additionally, facets of the child's mother and household are related to a child's risk for malnutrition; these included mother's education[19,31], mother's age at first childbirth[21], mother's BMI[32], whether the mother has insurance, size of the household[33], ethnicity and poverty[34–36].

Poverty is often regarded as the single most important determinant of health[34]. Poverty is frequently estimated from household income figures. Unfortunately, these figures are often misleading measures of wealth because the data are often unreliable or of poor quality. Additionally, many families engage in informal economic activities that do not register with standard income data – a common phenomenon in Ghana – which can serve to render traditional measures of poverty invalid. In response to these problems, the DHS began collecting data for a 'wealth score' in 2004. This index:[37]

> is a composite measure of the cumulative living standard of a household. It is calculated using easy-to-collect data on a household's ownership of selected assets, such as televisions and bicycles, materials used for housing construction, and types of water access and sanitation facilities. Generated with… principal components analysis, the wealth score places individual households on a continuous scale of relative wealth… Even in countries that collect [income] data, the DHS wealth index has outperformed the traditional indicators.

The wealth score is provided in the form of a continuous value as well as a categorical variable ('wealth index') that roughly divides the population into quintiles. The categorized value was employed in the present study.

Contextual variables included in the analysis were population density, poverty index (P_0), district-level literacy, proximity to health and school facilities, urbanization, percentage of the population who are migrants and ecological zone. Administrative districts were used in the present study to indicate context because they are the basic spatial units for most socio-economic, political and developmental decisions in Ghana and are the basic spatial units for the national census data and the GDHS 2008 population clusters. Regional and district codes embedded in the GDHS 2008 were used to determine the district of residence for each child in the sample. Data for population density (the population per square kilometre), the percentage urban, percentage migrant, percentage illiterate and the level of urbanization for each district were derived from the 2000 PHC. The P_0 measures the proportion of the population in a given district that is poor and is intended to represent the general wealth of the district. Although this measure is widely used because of its ease of interpretation, it does not indicate the degree of poverty[38]. The GDHS 2008 child data were joined to ecological zones data in a geographical information system database using ArcGIS 9·3 software. The database join serves to assign each child in the study to an ecological zone based on their location.

Analysis

Data analysis was performed using the SPSS 20·0 for Windows statistical software package. All children aged 0–59 months with valid anthropometric measures were included, constituting a total of 2225 children. Since standard analysis of fixed-effects covariates for height-for-age neglects the correlation structure and dependence in the hierarchically structured GDHS data, a two-level generalized linear mixed-modelling approach was employed, with level-1 represented by individual child characteristics and level-2 represented by the characteristics of the district in which children reside. The height-for-age outcome of a child is therefore assessed as a function of child-level and district-level characteristics. This reduces the tendency to underestimate standard errors of fixed effects at the child level which inflates apparent significance of estimates.

A model that assesses the effects of only level-1 variables was first estimated for height-for-age (individual model).

A separate model with only level-2 variables was then estimated (district model) before a final full model with both level-1 and level-2 variables was estimated. The coefficients of both fixed and random effects along with confidence intervals for $P<0{\cdot}05$ as well as model summaries are reported.

The full model is specified by the general notation:

$$Y = X\beta + Zu + \varepsilon,$$

where Y represents the height-for-age for an individual child, $X\beta$ the fixed-effect regressors and parameters, Zu the regressors and random effects, and ε the errors.

Results

Sample characteristics

The present study analysed the height measurements of 2225 children, 49·6 % of whom were female and 50·4 % male. The average age of a child in the sample was 29 months and more than 95 % of all children had received part or all of the recommended vaccinations for their age. Children were breast-fed for an average of 16 months and 23 % had height-for-age <−2 SD. Most children lived in rural areas (67 %) and in the forest ecological zone (44 %).

Child-level characteristics and height-for-age

An individual-level model was estimated to examine their effects on the outcome. The results showed that the overall model ($F=23{\cdot}738$; $P<0{\cdot}001$) and seven variables including the age of the child ($F=48{\cdot}204$; $P<0{\cdot}001$), vaccination status ($F=5{\cdot}643$; $P=0{\cdot}004$), the size of the child at birth ($F=11{\cdot}660$; $P<0{\cdot}001$), months of breast-feeding ($F=58{\cdot}292$; $P<0{\cdot}001$), mother's BMI ($F=31{\cdot}937$; $P<0{\cdot}001$) and possession of health insurance ($F=4{\cdot}557$; $P=0{\cdot}033$) were statistically significantly associated with height-for-age. Many child-level characteristics did not achieve statistical significance in any of the models. These included the sex of the child, mother's education, size of the household and ethnicity. The results of the individual model are presented in Table 1.

Although the wealth status of the child's household did not appear significant in the traditional test of fixed effects for the overall model and individual effects, the poorest and poorer categories showed a statistically significant association with height-for-age in the parameter estimates for the overall model and individual effects. All other things being equal, we can expect the height-for-age of children from the poorest households to be 0·433 SD ($P=0{\cdot}009$) lower than the height-for-age of a child from the richest household. Similarly, the height-for-age of a child from a household in the poorer wealth quintile is

Table 1 Results of the individual model: individual-level correlates with height-for-age in Ghanaian children aged 0–59 months (*n* 2225), 2008

Fixed effects	Estimate	SE	*P* value	95 % CI
Intercept	−0·088	0·040	0·029*	−0·167, −0·091
Child's age (months)	−0·015	0·002	0·000*	−0·020, −0·011
Vaccination status				
Not vaccinated	+0·048	0·014	0·001*	+0·200, +0·760
Partially vaccinated	+0·024	0·078	0·761	−0·129, +0·176
Fully vaccinated (ref.)				
Size of child at birth				
Very large	+0·080	0·123	0·000*	+0·056, +0·104
Larger than average	+0·514	0·124	0·000*	+0·027, +0·768
Average	+0·553	0·123	0·000*	+0·299, +0·806
Smaller than average	+0·360	0·133	0·007*	+0·094, +0·621
Very small (ref.)				
Months of breast-feeding	−0·037	0·005	0·000*	−0·046, –0·027
Mother's BMI	+0·039	0·007	0·000*	+0·025, +0·052
Health insurance				
No	−0·165	0·078	0·033*	−0·032, −0·013
Yes (ref.)				
Wealth quintile				
Poorest	−0·433	0·166	0·009*	−0·759, −0·011
Poorer	−0·385	0·140	0·006*	−0·658, −0·111
Middle	−0·248	0·126	0·050	−0·496, +0·000
Richer	−0·205	0·011	0·064	−0·421, +0·012
Richest (ref.)				
Random effects				
Intercept	0·061	0·026	0·017*	0·027, 0·140
Residuals	2·001	0·062	0·000*	1·883, 2·126
Model fit statistics				
−2 log likelihood	7994·571			
AIC	7998·587			
BIC	8009·966			

ref., reference category; AIC, Akaike information criterion; BIC, Bayesian information criterion.
*$P<0{\cdot}05$.

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Table 2 Results of the district model: district-level correlates with height-for-age in Ghanaian children aged 0–59 months (n 2225), 2008

Fixed effects	Estimate	SE	*P* value	95 % CI
Intercept	−0·17640	0·43569	0·686	−1·03180, +0·67800
Population density	+0·00004	0·00003	0·170	−0·00002, +0·00009
Poverty index (P_0)	−0·75794	0·49211	0·124	−1·72298, +0·20710
% of population within 10 km of hospital	−0·00158	0·00242	0·514	−0·00633, +0·00317
% of population within 10 km of clinic	−0·00288	0·00277	0·299	−0·00831, −0·00255
% of population within 5 km of school	+0·00283	0·00217	0·191	−0·00142, +0·00708
% of illiterate population	−0·00289	0·00481	0·548	−0·01233, +0·00654
% of urban population	+0·00271	0·00211	0·199	−0·00143, +0·00684
% of migrant population	−0·00422	0·00432	0·329	−0·01268, +0·00425
Ecological zone				
Eastern Guinea Forest	+0·18087	0·24194	0·455	−0·29357, +0·65532
West Sudanian Savannah	−0·30840	0·17665	0·081	−0·65481, +0·03801
Guinea Forest–Savannah Mosaic	−0·26686	0·17540	0·128	−0·61083, +0·07711
Central African Mangrove (ref.)				
Random effects				
Intercept	0·074	0·031	0·018*	0·032, 0·168
Residuals	2·340	0·072	0·000*	2·203, 2·485
Model fit statistics				
−2 log likelihood	8265·726			
AIC	8269·731			
BIC	8281·130			

ref., reference category; AIC, Akaike information criterion; BIC, Bayesian information criterion.
*$P<0·05$.

0·385 SD ($P=0·006$) lower than the height-for-age of a child from the richest household.

District-level characteristics and height-for-age

A separate model including only district-level variables was estimated for height-for-age to examine the relationship between contextual variables and children's nutritional outcome. None of the eleven variables included in the model was significantly associated with the height-for-age outcome for children in Ghana (Table 2), even though the overall model intercept ($F=3·814$; $P<0·001$) was significant.

Full model for height-for-age in Ghana

The full model analysed both child-level and district-level variables simultaneously, uncovering some differences from the first two models. Notably, in the full model, population density showed a statistically significant association with height-for-age outcome among children in Ghana. The fixed-and random-effect estimates for height-for-age are presented in Table 3.

Discussion

Consistent with other studies[35,39], the present study observed that children's age was significantly associated with lower height-for-age values. As ample previous research has shown, this finding could be attributed to the challenges of transitioning from breast-feeding to more solid foods and drinking water. Another factor may be older children's ability to explore their environment, giving them more exposure to infections that compromise their nutritional status[20].

Curiously, children who were not vaccinated were more likely to have a higher height-for-age status, contradicting previous work which suggests that vaccination, which should protect children against infectious disease, serves to improve nutritional outcomes[29]. Additional investigation might uncover some explanation for this finding.

Children's weight at birth, in both the individual and full models, emerged as one of the strongest predictors of early growth. Birth weight is often used to estimate the quality of prenatal care. Previous work has demonstrated that good prenatal care is essential for survival among very young children in poor contexts[40], and this may be viewed as evidence that prenatal care may similarly have an impact on nutritional status later in life.

Studies also show that an initial period of exclusive breast-feeding is essential to lower the risk of nutritional deficiency and infectious disease, after which supplementary foods should be gradually introduced. The present study found prolonged breast-feeding to be associated with poorer nutritional status. The negative association of lengthy breast-feeding with children's nutritional status probably reflects failure of optimal complementary feeding. This may in turn indicate the inability of households to provide supplemental foods[25] and inappropriate child-feeding practices that could be addressed through education.

The present work found that the 40 % of children living in households with some form of health insurance had a better height-for-age outcome. Other work has found that forms of protection, such as social capital, can serve to protect families against economic shocks, ultimately benefiting nutritional status[41]. Health insurance may similarly serve to protect poor families from such shocks.

Table 3 Results of the full model: correlates with height-for-age in Ghanaian children aged 0–59 months (*n* 2225), 2008

Fixed effects	Estimate	SE	*P* value	95 % CI
Child's age (months)	−0·016	0·002	<0·001*	−0·012, −0·011
Vaccination status				
Not vaccinated	0·485	0·142	0·001*	+0·207, +0·763
Partially vaccinated	0·026	0·078	0·753	−0·129, +0·179
Fully vaccinated (ref.)				
Size of child at birth				
Very large	0·805	0·122	<0·001*	+0·566, +1·045
Larger than average	0·521	0·123	<0·001*	+0·279, +0·763
Average	0·565	0·128	<0·001*	+0·314, +0·815
Smaller than average	0·355	0·129	0·006*	+0·011, +0·609
Very small (ref.)				
Months of breast-feeding	−0·036	0·005	<0·001*	−0·046, −0·027
Mother's BMI	0·039	0·007	<0·001*	+0·025, +0·052
Health insurance				
No	−0·183	0·07775	0·018*	−0·019, −0·030
Yes (ref.)				
Wealth quintile				
Poorest	−0·379	0·17967	0·033*	−0·730, −0·029
Poorer	−0·333	0·15323	0·028*	−0·633, −0·033
Middle	−0·194	0·13382	0·138	−0·457, +0·068
Richer	−0·169	0·12093	0·159	−0·406, +0·068
Richest (ref.)				
Population density	0·00007	0·00003	0·024*	+0·00001, +0·00013
Random effects				
Intercept	0·074	0·029	0·012*	0·034, 0·162
Residuals	1·996	0·062	0·000*	1·878, 2·121
Model fit statistics				
−2 log likelihood	8002·975			
AIC	8006·980			
BIC	8018·350			

ref., reference category; AIC, Akaike information criterion; BIC, Bayesian information criterion.
**P* < 0·05.

Household wealth was also related to height-for-age. Poverty often results in inadequate diet, poor sanitation and greater exposure to pathogens, and low access to vaccinations and basic medical care. Forty-five per cent of Ghanaians live on less than $US 1 per day and while the highest fifth of households receive nearly half of all income, the poorest two-fifths receive only 16 % of the total income[42]. Improving children's health and nutritional status may ultimately require addressing economic inequalities and making services more accessible to the poor.

Population density, a contextual variable modelled at the district level, was significantly associated with more favourable nutritional outcomes after accounting for individual wealth and other contextual variables, such as district-wide poverty and urbanization, suggesting that processes related to settlement patterns are related to nutrition. It is possible that a tight population network, large nearby neighbourhoods or communities, can enable the kind of social capital that serves to provide families and their children with a more consistent source of nutrition and nutritional information[41,43]. Apart from population density, none of the socio-economic or biophysical contextual variables bore a significant relationship with childhood height-for-age in the final model, suggesting that the most critical scale at which mechanisms behind malnutrition are played out is at the individual and household levels.

As with any analysis of secondary data, some limitations should be noted with the present work. The study was based on diverse sources of secondary data which were not specifically designed for examining the relationships analysed here. In spite of these limitations, the large size and representativeness of the secondary data used in the study made possible the kinds of statistical analyses conducted here. The study findings can potentially assist stakeholders by providing a better understanding of the diverse array of factors that influence children's nutritional outcome in Ghana.

Future work

The study of children's nutrition has been limited, to a degree, by division into diverse disciplines, with many social scientists focused on individual- and household-level factors, nutritionists concerned with hereditary and gender differences, and soil and climate scientists fixated on the potential impact of climate and soil on agricultural sustainability and food production. While these fields of enquiry are conceptually linked by, for instance, the UNICEF framework, few studies systematically assess this variety of factors simultaneously. Although the present study attempts to close this gap, constructing dynamic and engaged interdisciplinary research that involves diverse spheres of knowledge would not be an insignificant future undertaking for work on children's well-being. Such interdisciplinary research might pave the way for more focused interventions in children's nutrition in developing countries.

Consideration should also be given to the strategies that children, households and communities utilize to solve socio-economic problems that impact children's nutritional outcomes. Children's families and communities are often required to make creative choices to guarantee favourable nutritional outcomes. Understanding the challenges and coping mechanisms that children, their households and communities use can provide important insights into how policy should be oriented.

Future research should also address the mechanisms through which childhood nutrition and different types of environments are connected. Understanding these mechanisms is crucial to the design of district-based interventions because these processes are more amenable to change than entrenched structural properties of communities (e.g. concentrated poverty). Although the present study does not investigate these mechanisms, the findings here provide limited evidence that area effects play a role in growth. Most of the contextual variables, however, did not achieve significance in the multivariate analyses discussed here, some of which have been widely reported to be associated with children's nutritional outcomes in different contexts. Future research could seek explanations for the lack of association with children's nutritional outcomes in the Ghanaian context.

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