AFRICA NUTRITION

The Effects of Measles Vaccination and Related Factors On Child Nutritional Status in Africa

An analytical report based on the Demographic and Health Surveys

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Food Security and Nutrition Monitoring Project

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EXECUTIVE SUMMARY

While measles today is a relatively mild disease where it exists in developed countries, in developing countries it is a devastating disease and one of the most important causes of young child morbidity and mortality. An estimated 2 million children die each year from measles, and an uncountable number suffer from its potentially crippling effects including, blindness, lung disease, and faltered growth. Indeed, there is little question that in sub-Saharan Africa, where severe measles is frequently seen, measles can have serious adverse effects on the nutritional status of young children.

In this paper, the association between measles vaccination and long term nutritional status of approximately 27,000 children 1 to 5 years of age from 10 sub-Saharan countries was studied. Cross sectional data from Demographic and Health Surveys undertaken in these countries between 1991 and 1995 were used. It was hypothesized that children not immunized against measles would be more likely to exhibit chronic malnutrition, or stunting (i.e. height-for-age below -2 SD of the median height-for-age of the international reference population), than children immunized close to the recommended age of 9 months. Prevention of measles virus infection and its morbid sequelae were the hypothesized mechanisms for such differences in nutritional status. The outcome studied was height-for-age z-score (HAZ) and the main independent variable of interest was measles vaccination status, with children characterized into one of four categories, i.e. non-vaccinated, vaccinated at >12 months, vaccinated at ≤12 months, or vaccinated at an unknown age. The analysis also took account of numerous demographic, socioeconomic and health service utilization factors that could affect both the likelihood of being immunized against measles as well as the likelihood of being well nourished.

Nearly 40 percent of all the children studied were found to be stunted, and those who were vaccinated late (i.e. after 12 months), or not vaccinated at all, were more than 30 percent more likely to be stunted than those vaccinated at the appropriate age (i.e. ≤ 12 months). Only three-fourths of children who should have been vaccinated were, and of those, just three-fourths (or 55 percent of all the children studied) were vaccinated between 8 and 12 months of age. Multivariate analysis revealed that the absence of measles vaccination was associated with significantly lower mean HAZ, even after controlling for child age, mother's age at the child's birth, preceding birth interval, birth order, number of dead siblings, urban-rural residence, sex, being a singleton or multiple birth, polygamy status, country, parental education and occupation, possession of appliances, type of toilet, quality of antenatal care and place of delivery. Among children who were vaccinated late, representing 20 percent of all the vaccinated children, mean HAZ was lowered twice as much as it was among the unvaccinated children, suggesting late vaccinated children were probably infected prior to being vaccinated. The detrimental effects of measles on long term growth were most apparent from the age of 2 years onward.

The results of this study imply that in many countries measles immunization programs may need to be scrutinized more closely. Not only are coverage rates important to continue improving, but specific attention needs to be paid to the age at which children are receiving the vaccine. Improving the proportion of children who receive measles vaccine at the appropriate age could potentially lower the prevalence of chronic malnutrition in many parts of sub-Saharan Africa.

1. INTRODUCTION AND BACKGROUND

The importance of measles as a cause of child death is well recognized (Assad, 1983), as is the role of measles immunization in improving child survival (Kapoor, 1991; Koenig, 1990). A severe form of measles, which has higher mortality and more adverse morbid and nutritional sequelae, has been seen, most frequently among children in Africa (Scheifele, 1973; Morley, 1983). The main determinants of the higher prevalence of severe measles in Africa are the subject of debate (Aaby, 1988, 1989). However, there is little question that this form of the disease can have serious debilitating effects on the nutritional status of those affected.

This paper describes an analysis of the association between measles vaccination and nutritional status based on data collected through the Demographic and Health Surveys (DHS) Program. The main hypothesis of this study is that children not immunized against measles are more likely to exhibit chronic undernutrition than children vaccinated at the appropriate age. Prevention of measles virus (MV) infection would be the hypothesized mechanism for such differences in nutritional status.

A number of studies have identified measles as a risk factor for undernutrition in children under five. One such study which looked at the influence of measles on nutrition included prospective, community-based data collected in an urban slum in India in Hyderabad city (Bhaskaram, 1987; Reddy, 1986). In this study, a baseline survey registered all 1544 children under 5 years in the slum and each child was followed up weekly for the next 15 months to collect morbidity and anthropometric data. During the surveillance period, 318 cases of measles were detected and followed up daily during the acute stage of illness. Age and sex matched controls (without measles) were also followed during that time. A subsample of 281 cases were followed for six months after measles.

Both the mean weight during measles and the weight gain in the three months after measles were significantly lower in the cases than in the age-matched controls. Cases also exhibited a prevalence of moderate and severe malnutrition that was significantly higher during measles than before and this difference lasted up to six months after their measles episode.

Another study was conducted in Bangladesh to look at the synergistic effect of measles and diarrhea on nutrition and mortality (Koster, 1981). In this longitudinal study, 5775 children in 12 villages were monitored for morbidity episodes weekly and weighed and measured bimonthly over a 12 month period. During this period, 896 measles cases were identified in children under 10 years. Children age four or less with measles and prolonged diarrhea had the greatest weight loss and delayed "catch-up" growth.

In a study by Debroise described in Nutrition Reviews (Nutrition Reviews, 1968), children up to 12 years of age from six villages in Senegal were studied from 1964 to 1967. During the seven measles outbreaks occurring during the study, 426 measles cases were identified. There was higher mortality among the underweight children with measles. In addition, most of the children who survived measles experienced a significant weight loss, which often took several months to regain.

These and other studies (Bhaskaram, 1992, 1984; Cole, 1989; Reddy, 1987; Natu, 1985; Morley, 1983; and Axton, 1979) make a strong case for the adverse effect of measles on children's nutritional status. The mechanisms through which measles can cause malnutrition have also been described. Measles infection can have a negative impact on a child's nutritional status through decreased food intake (Pereira, 1987); increased protein and energy requirements; adverse effects on the large and small bowel (Duggan, 1986; Axton, 1979; Dossetor, 1975); impaired immunity (Bhaskaram, 1983; Lancet, 1983; BMJ, 1973), and secondary infections resulting in pneumonia (Han, 1990) and diarrhea (Greenberg, 1991; Koster, 1981).

A description of the clinical picture of a child with severe measles, such as the following by Morley, can be informative for the reader without firsthand experience of the disease. "Many of the symptoms and signs of measles arise from the changes it creates in epithelial surfaces. Apparently, all epithelial surfaces are equally affected, and in those children who have a severe rash epithelial surfaces other than the skin become involved, and the picture of severe measles is produced. In the rural areas of developing countries, the majority of children with measles are still breast-fed, and the breast-feeding mother is well aware of the stomatitis associated with severe measles. The child's sore, infected mouth may make it difficult for him to suck for a period...At the same time, the child's eyes are inflamed, he loses his voice from laryngitis, and in the next week he is in danger of developing pneumonia and, too frequently diarrhea" (Morley, p. 460, 1983).

The role of measles as a risk factor for blindness in many parts of the world is also well established. In malnourished children, the risk of blindness is increased with measles as it affects corneal surfaces already vulnerable to xerophthalmia from vitamin A deficiency. As Sauter describes, "in malnourished children the inflammatory reaction (of the eyes) is usually strikingly mild and quite often entirely absent. They show an alarmingly rapid progression of the corneal lesions, which unfortunately frequently escape the attention of the doctor or nurse in charge. Being in a very miserable condition and often semi-conscious they keep their eyes closed and the eye-balls turned upwards. As they do not utter any complaints these victims are left in peace until it is far too late and - after melting away of large parts of the cornea - both eye-balls are perforated." (Sauter, p. 219, 1982)

The health and survival of children with measles can be improved by access to treatment of complications and nutritional support (Voorhoeve, 1992; Coutsoudis, 1991; Sauter, 1982; Gopalan, 1973). Without such intervention, however, malnourished children may be less likely to survive than the well nourished (Beckford, 1985; Gupta, 1975; Nutrition Reviews, 1968). As with other services, it is often the children most at risk who are least likely to receive such care.

In this paper, data collected through the Demographic and Health Surveys Program (DHS) are used to look at the association between measles vaccination and nutritional status of children 12-59 months of age. This analysis adds to the literature by using a very large combined sample of children from 10 sub-Saharan African countries to show the persistence of this relationship. The objective of this analysis is not to explain the causal relationship between measles and nutritional status since the DHS data are cross-sectional and do not allow examination of this issue. Rather, an

attempt is made to examine and describel the influence of measles vaccination on nutritional status, taking into account the effects of many demographic, socioeconomic and service utilization factors that might confound the relationship between immunization and nutritional status. That is, factors that affect both the likelihood of being vaccinated as well as the likelihood of being well nourished.

Figure 1 illustrates a conceptual framework depicting the relationship between measles infection and subsequent nutritional status. Some of the major determinants of measles infection, measles vaccination, and nutritional status are also shown, in addition to sequelae of measles which can lead to undernutrition.

Clearly, the main determinant of measles infection is whether or not the child has been vaccinated at an appropriate age. The currently recommended age for measles vaccination is 9 months (Cutts, 1993) though younger infants at high risk of exposure can become infected at earlier ages. Since infants less than six months of age have natural immunity (Sinha, 1980), earlier immunization is generally not recommended. Though the epidemic pattern and average age at infection vary from one setting to the next, most unvaccinated children will ultimately get measles (Assad, 1983). Immunization status is influenced directly or indirectly by a host of other factors. Demographic and socioeconomic variables can be powerful predictors of service utilization. Maternal education, for example, consistently emerges as a significant determinant of use, though the mechanism through which this variable operates is not well understood. Characteristics of services, such as availability and access, may also influence vaccination status. At the same time, these and the other factors listed as determinants of vaccination can also be important determinants of child nutrition.

Food availability and feeding practices are two important variables which influence nutritional status. Infections and curative care (service availability and access) can also be significant determinants of nutritional status and these variables can either work independently of measles or as a sequelae of measles infection. In the case of measles, as described earlier, the child experiences a depressed appetite and secondary infections leading to diarrhea and pneumonia. And the child who was malnourished prior to contracting measles will be at higher risk of further adverse nutritional consequences. The severity of the impact of measles on measures of nutritional status will be reflected to varying degrees depending on the indicator used and the amount of time that has passed since infection.

2. BASIC INDICATORS OF NUTRITIONAL STATUS

The assessment of nutritional status is based on the concept that in a well-nourished population the distribution of children's height and weight, for a given age, will approximate a normal distribution. This means that about 68 percent of children will have a height or weight within 1 standard deviation of the median for that age. About 14 percent of children will have a height or weight within 1 or 2 standard deviations of the median for that age. Of the remainder, 2 percent will have a height or weight less than 2 standard deviations from the median of that age. Because all

populations have similar genetic potential for growth (Habicht et al., 1974), the U.S. National Center for Health Statistics (NCHS) Reference Data are recommended by WHO (1979) to be used in the evaluation of nutritional status.

Three indicators using measures of height and weight in combination with age are commonly used to determine nutritional status in infants and children.

Stunting,defined as height-for-age (HAZ) more than two standart deviations below (-2SD) the median of the NCHS reference population, is the failure to grow adequately in height in relation to age. It reflects past or chronic undernutrition and results from inadequate food intake over a long period of time and/or repeated episodes of illness, particularly diarrhea.

Wasting, defined as weight-for-height (WHZ) more than two standart deviations below (-2SD) the median of the NCHS reference population, is the failure to gain weight adequately in relation to height and reflects recent or acute undernutrition. Wasting results from a recent shortage of adequate nutrition and/or recent or current acute illness, especially diarrhea.

Underweight, defined as weight-for-age (WAZ) more than two standart deviations below (-2SD) the median of the NCHS reference population, is a composite indicator that reflects either chronic or acute malnutrition status or both. It does not add additional information beyond that provided by the indicators of stunting and wasting, however, it is often used as a general indicator of a population's health status.

Conceptually, it was clear that measles vaccine, or the presence or absence of (MV) infection and its morbid sequelae, could affect all three indicators of nutritional status, i.e. HAZ, WHZ, and WAZ. However, a decision was made to focus the analysis in this paper on the effect of measles vaccination on one indicator of nutritional status only, i.e. HAZ. It was felt that HAZ would be the indicator most likely to be measurably affected by vaccination (or by the presence or absence of measles infection). WHZ, in contrast, was felt not to be a good indicator to study because the influence of the presence or absence of measles and morbid sequelae would only be captured if these occurred relatively recently. In addition, although all indicators of nutritional status can be affected by events such as diarrhea, acute respiratory infection, malaria, food availability, season of data collection, etc., the effects of these events on the three indicators differ. WHZ is very volatile, and is almost always measurably affected by recent acute events, including episodes of disease, seasonal food shortages and epidemics, etc. HAZ is typically only measurably affected by such events if they are prolonged or repeated over a period of time. HAZ is therefore less volatile than WHZ. WAZ, being a composite indicator of HAZ and WHZ, would be subject to the same limitations as WHZ.

3. DATA and VARIABLES USED

Child-based data from DHS surveys conducted between 1986 and 1995 in ten countries in sub-Saharan Africa were used in this study (Table 1). The countries from which data were collected

include: Cameroon, Central African Republic (CAR), Kenya, Ghana, Madagascar, Niger, Senegal, Uganda, Zambia, and Zimbabwe. The data used in this analysis are from interviews conducted using the household and individual questionnaires. Data on socioeconomic characteristics of respondents' households come from the household interview. The individual questionnaire, administered to women aged 15-49 within the household, provides information on the background characteristics of respondents, fertility, mortality, family planning, and child health and nutrition.

From each country, children aged 12 to 59 months with valid date of birth and complete anthropometric data, i.e. height-for-age (HAZ) and weight-for-height (WHZ), were selected. The lower age limit of 12 months was chosen to ensure that children were old enough to have been fully immunized. Children with incomplete birth dates, or implausible anthropometric measurements (i.e. HAZ < -3.09 and WHZ > 3.09, or HAZ > 3.09 and WHZ < -3.09), were excluded from the analyses. Because of differences in their DHS survey designs, in three countries (Central African Republic, Ghana, and Zimbabwe) data were available only for children up to three years of age, and in Uganda data were available for children only up to four years of age.

Initially, separate analyses were conducted for individual countries. However, the results varied to such an extent that it was difficult to come to conclusions about the influence of any one variable, or group of variables, on the effect of measles vaccine on nutritional status. The child files from the ten countries were therefore combined to form one file for analysis, giving a total of 26,935 children studied. In the analysis, a "country" factor was included, to control for the specific influence of countries on the overall outcome.

In order to study the prevalence and patterns of measles vaccination, and because the interval since infection may affect current nutritional status, children were categorized into one of four categories: not vaccinated, vaccinated at one year of age or less, vaccinated at over one year of age, or vaccinated at an unknown date. The grouping together of children vaccinated at one year of age or less (as opposed to separating out children vaccinated younger than the recommended age of 9 months) was done for two reasons: (1) because there exists some debate about the ideal age for measles immunization, with some investigators encouraging that the age for immunization should be lowered in certain environments (Faveau et al., 1991); and (2) because only a small proportion of children vaccinated in the first year were vaccinated in the first half of infancy, as discussed in section 5.2., below.

A list of the variables included in the model is shown in Table 2. The explanatory variables of interest are: not vaccinated, vaccinated at age less than 13 months, vaccinated at age 13+ months, and vaccinated at unknown age. Child age is also considered an important explanatory variable, since nutritional status varies considerably according to age. A variable indicating the country data source is included, as described above. All other independent variables are included in the model to control for the potentially confounding effects of demographic and socio-economic factors as well as service utilization behaviors that reflect a propensity to use health services. In the conceptual framework in Figure 1 these indicators are marked with an asterisk.

Some of the control variables reflect the status of the child's mother at the time of the interview. For example, whether or not she is in a polygamous relationship (for countries where this question was applicable), whether she resides in an urban or a rural area, her and her partner's occupation, and the number of selected possessions owned by her household. This information is used as a snapshot of influences that might affect both the child's likelihood of being immunized as well as his or her nutritional status. It is assumed that, on average, these current status measures are an accurate measure of these influences over time.

Service utilization behavior is proxied by including variables describing whether or not the child's mother saw a doctor, nurse, or midwife during her pregnancy with the child, if so, how many times, and whether the birth of the child was attended by a doctor, nurse, or midwife in a facility or at home.

4. STATISTICAL METHODS

The software package SPSS was used to perform the statistical analyses. Data from each country were not weighted because the goal of the analysis was not to produce descriptive information about each country, but rather to generalize about the effects of similar factors on nutritional status across countries. Bivariate and multivariate analysis techniques were used. Cross-tabulations were conducted for the bivariate analyses, with Chi-square tests used to determine significance levels. Ordinary least squares (OLS) regression analysis was used to determine the effect of measles vaccination on HAZ, first without adjusting for any other factors, and then adjusting progressively for child age, demographic factors, the "country" factor, socioeconomic factors and health service utilization factors. Thus the simplest model incorporated the effect of measles vaccine and its timing (i.e. age of child age at vaccination), on HAZ. Groups of similar factors were then forced into the equation in a series of additional steps. No assumptions of linearity were made, i.e. it was not assumed that any independent factor was linearly related to HAZ, therefore continuous variables (eg. child age, mother's age at birth, birth interval, etc.) were transformed into categorical variables. For each variable one reference category was chosen, and then for each of the remaining categories a dummy variable was created for the analysis.

The regression analysis was performed for all children combined. However, because it was felt that measles vaccination could affect mean HAZ differently according to child age, separate regressions were run for six child age groups, i.e. 12-17 months, 18-23 months, 24-29 months, 30-35 months, 36-47 months and 48-57 months. The results of the full models for all ages combined were then compared with the results of the full models for each of the six age groups.

For children who had siblings in the eligible age range, no attempt was made to exclude multiple children of one mother. It was felt that factor effects would not be unduly biased by some children having the same mother, i.e. by some "dependence" between cases. We reasoned that there were probably many influences similar to having the same mother that could not be adequately measured or controlled for, such as living in compound with other mother child pairs, living under

the aegis of village elders, speaking a unique local dialect, etc. Thus, a small proportion of the children studied were two or three siblings of the same mother.

5. RESULTS

5.1. *Prevalence and distribution of stunting according to background characteristics*

Table 3 shows the percentage distribution of stunting and measles vaccination status among all children according to demographic, socioeconomic and health service utilization characteristics. Overall, 37 percent of the children were stunted, or below -2 SD of the median HAZ score of the reference population, and this varied significantly by every characteristic included in Table 3. Children who were not vaccinated at all, or vaccinated late (i.e. later than 1 year of age) were considerably more stunted than those vaccinated at one year or less or those vaccinated at an unknown age.

There is a clear age-specific pattern of stunting. The lowest rate of stunting occurs at 12-17 months, followed by a large increase to the peak stunting rate of 44 percent among the 18-23 month old children. Stunting declines slightly after this, but remains at relatively high levels, between 36 and 39 percent, through the third and fourth years of life. In the fifth year the rate declines to that seen in the 12-17 month old group.

Stunting also is higher among children of the youngest mothers, of those born less than 3 years after a previous sibling, of birth orders of 6 or higher, who have dead siblings, who live in rural areas, who were one of a multiple birth, and whose parents are polygamous.

Relative to socioeconomic factors, stunting was higher among children whose parents had little or no education or were farmers, where household possessions were few in number, and in homes where pit latrines were used or, worse, where there were no toilets.

When stunting was examined by health service utilization behaviors, more stunting occurred when the child's mother received antenatal care by non-medically trained personnel or no one at all, when the mother was attended at delivery by non-medically trained personnel or no one at all, when the child was born at home, and when no antenatal visits were made by the mother.

Among the countries studied, stunting ranged from a low of 27 percent in Madagascar to a high of 48 percent in Zambia (Figure 2). In other words, between one-fourth and one-half of all the children studied were too short for their age.

5.2. *Prevalence and distribution of measles vaccination according to background characteristics*

Figure 3 depicts the distribution of children not vaccinated for measles by age at vaccination among all the children who had a measles vaccination date recorded on a health card. The mean age

at vaccination among these children was 11 months, and the mode was 9 months. About 74 percent of these children (or 55 percent of all children studied) were vaccinated between 8 and 12 months, 6 percent were vaccinated prior to 8 months, and the remaining 20 percent vaccinated after the first year.

Overall, about three quarters of the children studied had received a measles vaccine, including those vaccinated at one year or less, at later than one year, or at an unknown age (Table 3). One fourth of the children were not vaccinated at al, about 40 percent were vaccinated at less than one year, 10 percent of the children were vaccinated late, and one-fourth were vaccinated at an unknown date. The prevalence of measles vaccination varied significantly across every independent variable in Table 3, except whether the birth was single or multiple. As expected, the likelihood of being vaccinated increased with child age, with about 80 percent of the oldest children having been vaccinated. The highest rates of vaccination were among children of mothers aged 20 to 34 years when the child was born, who were the first or second child born, who had no dead siblings, who lived in urban areas, who were female and who came from non-polygamous families. The same categories of children also had the highest rates of being vaccinated in the first year of life as opposed to later.

Among the socioeconomic variables, rates of measles vaccination were highest among children whose parents had the highest levels of education, who had professional, managerial or clerical jobs, where households had the most appliances, and where there were flush toilets. Correspondingly, the highest rates of vaccination in the first year, as opposed to later in life, were found among the same more priviledged categories of children.

Not surprisingly, overall measles vaccination rates were highest among children whose mothers had medically trained antenatal care providers and delivery attendants, who delivered in a modern (public or private) health facility, and who made the most frequent number of antenatal visits. Once again, the same categories of children had the highest rates of vaccination in the first year of life instead of later.

Interestingly, the highest percentages of children reported to be vaccinated but without a known vaccination date (i.e. without a health card) included those with no dead siblings, who live in urban areas, who were singletons at birth, whose parents are non-polygamous, who are from the highest socioeconomic levels as measured by their parents' educational levels and occupations, possession scores, and type of toilet, and whose mothers had the strongest tendencies to use modern antenatal health services.

Figure 4 shows the distribution of measles vaccination coverage rates of children 12-59 months of age among the countries studied. Coverage rates range from a low of 47 percent, in Niger, to a high of 90 percent, found in Zimbabwe.

5.3. *Multivariate analysis of the effects of measles vaccination and other factors on height-for-age, all children combined*

Multivariate (OLS regression) analysis was conducted to examine the influence of measles vaccine and related demographic, socioeconomic and service utilization factors on mean HAZ, as well as the change in the effect of measles vaccine once other independent factors were considered. Because it was felt that the adjusted effects of independent factors on mean HAZ might also vary according to a child's age and stage of development, separate regression analyses were also conducted on children grouped into six age categories, using the same modelling approach.

Table 4 shows the results of the regression analysis using all children 12-59 months combined. The regression coefficients in the table represent the amount of change in the overall mean HAZ score due to each category of the factor. Only regression coefficients which were significant at a level of $p<0.05$ are included in the table; factor categories with a "-" were not significant. Those factors with "0" for a coefficient represent the reference category against which the other categories of the factor are compared. The first column in Table 4 represents the simplest model, with measles vaccine and no other factors included, while the last column represents the final model, with all factors included.[1] The mean HAZ for the 26,935 children included in this analysis was -1.62.

In the simplest model (column 2 of Table 4) , when measles vaccine was considered with no other factors, not being vaccinated or being vaccinated at later than one year decreased mean HAZ by -0.41 and -0.43 SD , respectively, relative to being vaccinated at one year or less (coefficient of "0"). Adding child age did not change the effect of measles vaccine; being 18-23 months of age decreased mean HAZ by -0.40 relative to the youngest infants, and being older than 2 years had a smaller but still negative effect.

When demographic factors were added to the model in the next step, the effect of measles vaccine was diminished, to -0.27 for not being vaccinated and to -0.30 for being vaccinated at later than one year. The effect of child age was not meaningfully changed (i.e. no coefficient changed by more than about 15 percent, or 3 to 5 one-hundredths of a standard deviation (SD)). Young maternal age at the child's birth decreased mean HAZ by about a third of a SD relative to maternal age of 20-34 years, and being 35 years or older had a positive effect. Birth intervals smaller than 3 years had a negative effect, while birth intervals of 3 years or more had the equivalent effect of being first born. Similarly, birth order beyond first or second had an increasingly negative effect. Being a male child, having dead siblings, or being the child of a polygamous woman all had negative effects. Living in urban instead of rural areas, and being a singleton rather than part of a multiple birth, had strong positive effects, each increasing mean HAZ by half a SD relative to its opposite reference category.

When the country factor was added to the model, the effects of measles vaccine, child age,

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[1] As a check on the final regression estimates, the analysis was run with all factors entered in a stepwise fashion. These coefficients were not different, and therefore are not included in the table.

and the demographic factors did not change meaningfully. However, several of the countries did have a significant effect on mean HAZ, indicating that something unique about those countries not accounted for by the previous factors in the models, did influence child growth. Using Cameroon as the reference country (for alphabetical convenience), Zambia had a strong negative effect, lowering mean HAZ by two-thirds of a standard deviation. CAR and Niger had substantial but smaller negative effects, and Uganda, Ghana, and Kenya also had negative effects.

Adding the socioeconomic factors at the next step did, as expected, decrease the effects of measles vaccination. However, while these factors decreased the effect of not being vaccinated by two thirds, i.e. from -0.24 to -0.16, the effect on vaccination at later than one year was only slight, from -0.28 to -0.23. There was no affect on child age, preceding birth interval, sex, or single/multiple birth. The effect of young maternal age at birth was reduced by a third. The effect of birth order was also diminished, reinforcing the notion that these variables do, in fact, act as proxies for socioeconomic status. The effect of urban versus rural residence declined substantially, from 0.50 to 0.18, which is not surprising since urban-rural residence is overtly used as an indicator of socioeconomic status. The effects on countries were variable, including diminished negative effects for CAR, Niger, and Senegal, a larger negative effect for Kenya, a new negative effect for Zimbabwe, and an increased positive effect for Senegal.

In and of themselves, the socioeconomic variables had important significant effects on mean HAZ. Both mother's and husband's educational levels had positive effects of roughly similar magnitude, with secondary or higher education having the strongest influence, as did mother's and husband's occupational levels, with the professional/managerial/clerical/technical level, having the strongest impact. Having a possession score of 2 or more, i.e. having 2 or more appliances, and having a flush toilet, each added about 0.20 SD to mean HAZ.

At the final step, the health service utilization variables were added to the model. These did not appreciably change the effects of measles vaccination from the previous model. The effects of child age were unchanged, as were the effects of the other demographic variables (with the exception of the urban residence effect, which declined slightly). The only socioeconomic factor effects which changed were parental education, which declined slightly, and the effect of having a pit latrine, which disappeared. Two of the country effects did change noticeably once the service utilization variables were added, including Madagascar, which acquired a negative coefficient, and Niger, whose negative effect on mean HAZ was diminished. There were only two significant effects of the service utilization variables: having a medically trained antenatal care provider inreased mean HAZ by 10 percent relative to having no one or someone not medically trained, and delivering in a private facility increased mean HAZ by 20 percent relative to delivering at home or in a public facility. The delivery attendant and the number of antenatal visits had no effect at all.

5.4. *Multivariate analysis of the effects of measles vaccination and other factors on height-for-age, separate age groups*

Similar regression analyses were performed on separate age groups of children, and then the

final models for each of the age groups were compared to the final model for all the age groups combined. The results are presented in Table 5, where the first column contains the adjusted effects of measles and all other factors on mean HAZ for all ages combined. (This column is the same as the final column in Table 4.) Detailed results of the intermediate steps of the regression analyses for the separate age groups are contained in the Appendix.

The effects of measles vaccination was seen to be quite different across child age groups. The overall negative effects of not being vaccinated or being vaccinated at later than one year seen when children of all ages are combined, were not observed at every age group. The negative effect of -0.14 of not being vaccinated was seen at 12-17 months, but not again until 36-47 months, and then twice as strongly at 48-59 months.

Unexpectedly, as noted above, when children of all ages were considered together the effect of being vaccinated at later than one year had twice as strong a negative effect on mean HAZ than not being vaccinated at all. When age groups were analyzed separately, there was no effect of vaccination at later than one year through the second year of life, but a negative effect of from -0.26 to -0.28 SD from the age of 24 months onward. Being vaccinated at an unknown date had no effect on mean HAZ except among the oldest children, where the effect was -0.12 SD.

The effects of maternal age at the birth of the child appeared primarily after the age of two years. Young maternal age had a negative effect, while older maternal age had a positive effect, on mean HAZ, relative to mothers who were 20-34 years old.

Among the other demographic variables, birth order had no effect when age groups were examined separately. The negative effect of having dead siblings seen when all children were combined appeared at only ages 12-17 months and 24-29 months - probably occurring by chance alone. The positive effect of living in an urban area appeared from 12 through 23 months, then at 36-47 months. With regard to gender, the negative effect of being male was seen quite markedly at 12-17 months of age (-0.23), and then at 48-59 months, at about half the strength (-0.11). Being born a singleton had a very strong advantage on mean HAZ compared with being born a multiple birth through the age of 3 years. The negative effect of the mother being in a polygamous union had a sporadic appearance across age groups, with probably little age related significance.

The effects of countries on mean HAZ appeared to be stronger in the younger ages, particularly in the second year of life (12-23 months). Five countries had negative effects for the 12-17 month old group, all but three countries had negative effects for the 18-23 month old group, and these effects became worse moving from the 12-17 to the 18-23 month groups in CAR, Ghana, Madagascar, Zambia, and Zimbabwe. Zambia had strong and consistent negative effects in every age group. CAR, Ghana and Kenya had negative effects in some of the later age groups. The only positive country effects on mean HAZ were observed in Senegal in the 12-17 month group, in the 36-47 month group, and in all ages combined, and in Madagascar when all ages were combined.

Parents' educational levels and occupations had positive effects on long term growth.

Maternal education of secondary schooling or higher had the strongest and most consistent effect on mean HAZ across all the age groups. Husband's secondary education or higher had almost as strong an effect, although not as consistently among the age groups. Husband's occupation of professional, managerial, clerical or technical level had a positive effect overall, but especially so in the third year of life, when mean HAZ increased by 0.28 SD; maternal occupation of professional or managerial level also had a positive effect, particularly strong (-.46) at age 30-35 months.

Among the remaining socioeconomic variables, a possession score of 2 or more had a positive effect on mean HAZ over all ages combined, but was absent in the earlier ages (12-29 months) and yet quite strong in the later ages, from 30-59 months. Having a flush toilet, however, had a consistent, positive effect on mean HAZ across all the ages groups.

Finally, among the service utilization factors, some positive effects of using modern services emerged when all children were analyzed together, including having a medically trained antenatal care provider, delivering in a private facility and making 4 or more antenatal visits. These effects were sporadic across age groups. Unexpectedly, making 1 or more antenatal visits had a negative effect on mean HAZ among the 36-47 month age group, but this is probably due to random error.

6. DISCUSSION

This study of nearly 27,000 children from 1 to 5 years of age from 10 African countries has revealed a number of important findings. First, almost 40 percent of the children are suffering from chronic malnutrition, manifested in linear growth faltering. Second, only three fourths of children who should have been immunized were, and of those, just three-fourths (or 55 percent of all the children studied) were vaccinated between 8 and 12 months, a time frame around the recommended vaccination age of 9 months which would be considered acceptable by most.[2] Third, the absence of measles vaccination, which in most children ultimately results in MV infection, has significant adverse effects on long term growth, appearing mainly after the age of 2 years, even after controlling for demographic, socioeconomic and service utilization factors. Fourth, late vaccination, which characterized 20 percent of all the vaccinated children in this study, appears to afford no protection at all, as many of these children were probably infected prior to receiving measles vaccine.

Bivariate analyses of stunting and measles vaccination status were conducted. Both variables were examined according to a number of bio-demographic, socioeconomic and service utilization factors which affect each of them independently. The highest rate of stunting was observed among the 18-23 month old children. This is not surprising given that this period is an extremely vulnerable

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[2] We have characterized the four month window from 8-12 months as an acceptable, age-appropriate period for children to receive measles vaccination for several reasons. This window begins outside the period of natural immunity but prior to the second year, when most cases of measles will occur (Assad, 1993). In addition, this is the window during which most children become immunized against measles.

one for most children, both because they are being weaned from the breast and because of the high rates of diarrhea, acute respiratory infection (ARI), malaria and other infectious diseases during this time. In-depth studies of child nutritional status in several African countries have documented peak rates of stunting in the second year of life and generally the first two years of life as the period when children are most vulnerable to malnutrition (Macro International Inc. et al., 1996a-d). The relatively high rates of stunting in the third and fourth years probably reflect deficits acquired during the first two years (Lutter et al., 1989). Among the countries studied, stunting ranged from a low of 27 to a high of 48 percent, which is similar to that found throughout Africa (Sommerfelt and Arnold, 1996; Macro International Inc. et al., 1996).

When stunting was examined by measles vaccination status, children who were not vaccinated at all, or vaccinated late, were considerably more stunted than those vaccinated at one year or less, or those vaccinated at an unknown age. This finding implies that late vaccination may often occur after measles infection and thus is as ineffective on long term growth as no vaccination at all. In addition, it suggests that most vaccinations occurring at unknown dates probably occurred at the correct time, like the majority of vaccinations. The fact that no difference was seen between the unvaccinated children and those vaccinated late raises the strong possibility that the latter group received their vaccinations after having had measles, their mothers perhaps thinking (reasonably) that immunization would prevent the disease from recurring.

Positive associations were seen between rates of stunting and high birth order, having a dead sibling, living in a rural area and polygamy. These results reflect the unfortunate but familiar associations between malnutrition and poverty. Short birth intervals, being part of a multiple birth and being male, which were also associated with higher rates of stunting, in contrast reflect biological and possibly sociological influences on nutrition: short birth intervals are more likely to lead to shortened durations of breastfeeding and less maternal time available for child care; being part of a multiple birth is indicative of low birth weight which is typically associated with malnutrition; being male and more stunted is reflective of the tendency seen elsewhere for boys to have higher rates of infectious diseases than girls in early childhood (Selwyn et al., 1990; Arnold, 1996) .

Against the socioeconomic factors, stunting was higher among children whose parents had little or no education or were farmers, where household possessions were few in number, and from households where pit latrines were used or, worse, where there were no toilets. Once again, these results reflect the overall association between malnutrition and poverty, as measured by such characteristics as parental education, occupation, household possessions and type of toilet facility. Although the type of toilet facility is, like the other socioeconomic factors, a proxy for household income, its impact on nutritional status also occurs through its association with disease, as poor sanitation puts infants and young children at risk of increased incidence and duration of illness, particularly diarrhea (Haggerty et al., 1994; Stanton and Clemens 1987).

When stunting was examined by health service utilization characteristics, more stunting occurred when the child's mother did not use modern antenatal services, reflected by her antenatal care provider, her delivery attendant, the birth location and the frequency of antenatal care visits.

Good antenatal care can help prevent low birth weight, and poor fetal and maternal health, as well as provide mothers with valuable information about child care, health, nutrition and when and where to seek help for birth complications. However, these associations probably more strongly reflect the mother's overall propensity to use modern health care services, both before and after birth, which, for the child, would impact upon the severity and frequency of his/her illnesses and consequent health and nutritional status.

Overall, about three quarters of the children studied had received a measles vaccine, including those vaccinated at one year or less, at later than one year, or at an unknown age. Children of mothers who were 20 to 34 years old at their birth, who were the first or second born, who had no dead siblings, who lived in urban areas, and who came from non-polygamous families had the highest rates of vaccination. The associations between vaccination and birth order, birth interval, number of dead siblings and urban-rural residence reflect the association between poverty and child health, in a similar way this association was seen with stunting. In addition, children of the youngest mothers may have lower rates of immunization because their mothers lack the resources and/or necessary knowledge about preventive child health care, while children of older mothers may be vaccinated less frequently because their mothers have several other children to care for and lack the time or resources necessary to obtain adequate health care.

Against the socioeconomic variables, rates of measles vaccination were highest among children whose parents had the highest levels of education, who had professional, managerial or clerical jobs, where households possessed several appliances, and where there were flush toilets. Although maternal educational level is highly correlated with household income, which positively affects child health, many studies have shown that even after holding household income constant, maternal education has a positive effect on child health (Moore, 1990). The mechanism of this relationship is not clear, but is probably related to the fact that the educated mother can read, is more likely to use modern health services, and has greater overall exposure to beneficial information on child health.

Surprisingly, the highest percentages of children reported to be vaccinated but without a known vaccination date (i.e. without a health card) were those displaying the same characteristics as the children most often vaccinated in the first year of life, i.e they had no dead siblings, lived in urban areas, were singletons at birth, had non-polygamous parents, were from the highest socioeconomic levels as measured by their parents' educational levels, occupations, possession scores, and type of toilet, and who had mothers whoused modern antenatal health services. These findings do not imply that mothers from the highest socioeconomic levels were more forgetful of their health cards at the time of the survey. On the contrary, more children of the highest socioeconomic strata were vaccinated overall, which includes more vaccinations in the first year of life as well as at "unknown" dates. The parallellism of rates of vaccination in the first year, and vaccination at unknown dates, with regard to socioeconomic characteristics, reinforces the hypothesis proposed above that most of the children whose vaccination dates are unknown were in fact vaccinated in the first year of life.

The goal of this study was to examine and describe the influence of measles vaccination on

child nutritional status, using cross-sectional data. Clearly, long term nutritional status is influenced by numerous factors, measles vaccination being only one of them. Since many of the factors that influence the likelihood of a child being vaccinated also independently influence growth, and therefore confound the relationship between measles and mean HAZ, multivariate (OLS regression) analysis was used to estimate the effect of measles vaccination status on mean HAZ, alone, and after taking account of other related factors, including child age, demographic characteristics (mother's age at child's birth, birth interval and order, urban-rural residence, child sex, single/multiple birth, polygamous union), country, socioeconomic factors (parents' education and occupations, possession score, type of toilet) and health service utilization variables (antenatal care provider, delivery attendant and location, number of antenatal visits), the effects of which could also be estimated. Because it was felt that the adjusted effects of independent factors on mean HAZ might also vary according to a child's age and stage of development, separate regression analyses were also conducted on children grouped into six age categories, using the same modelling approach.

When measles vaccine was considered without any other factors, not being vaccinated or being vaccinated late each decreased mean HAZ by about the same amount, almost one half a SD, relative to being vaccinated at one year or less. These results presented the first evidence that receiving vaccine too late is much less useful. These effects were unchanged by adding child age, although clearly child age had its own independent effects, the most negative seen in the 18-23 month group. When demographic factors were added to the model in the next step, the effects of measles vaccine were diminished, by about the same magnitude both for not being vaccinated and for being vaccinated late, again reinforcing the notion that late vaccine is as ineffective as no vaccine. The demographic factors had independent effects on mean HAZ. Young maternal age at the child's birth decreased mean HAZ relative to maternal age of 20-34 years, and being 35 years or older had a positive effect. Young mothers often enter into pregnancy physically immature or undernourished, increasing their chances of having a low birth weight child who will ultimately be disadvantaged in growth compared with normal birth weight infants. In addition, young mothers lack the knowledge and experience of older mothers concerning child care and child feeding. Older mothers may have more child rearing experience, more acquired "know-how" concerning good child care practices, and/or more older siblings to help around the home, thereby freeing up some of their time to care for the young children. Birth intervals smaller than 3 years, birth order beyond first or second, being a male child, having dead siblings, or being the child of a polygamous woman all had negative effects. Short birth intervals and high birth orders reflect low socioeconomic status as well as the adverse biological consequences of short birth spacing and high fertility: each takes a nutritional and health toll on the mother, as well as on children who may be weaned too early because of the mothers pregnancy or may be cared for less well because of the mothers lack of time. Being a singleton at birth had a strong positive effect, reflecting the nutritional advantage of higher birth weight, and living in urban areas, reflecting socioeconomic advantage, was also positive relative to living in rural areas.

When the country factor was added to the model, the effects of measles vaccine, child age, and the demographic factors did not change meaningfully. However, several of the countries did have a significant effect on mean HAZ, indicating that something unique about those countries not accounted for by the previous factors in the models, did influence child growth. Relative to

Cameroon (used as a reference country for convenience), Zambia had a strong negative effect, lowering mean HAZ by two-thirds of a standard deviation. Central African Republic and Niger had substantial but smaller negative effects, and Uganda, Ghana, and Kenya also had negative effects. Numerous political, economic, social, and cultural differences contribute to the wide variation in stunting across these countries. Differences in nutrition and child survival programs in particular could have marked effects.

Adding the socioeconomic factors did, as expected, decrease the effects of measles vaccination on mean HAZ. However, while these factors decreased the effect of not being vaccinated by about a third, the effect on vaccination at later than one year was only slight, from -0.28 to -0.23 SD. This pattern suggests there is an important difference between the unvaccinated and the vaccinated-late group. It leads one to believe that the vaccinated-late group in fact represent children who had MV infection, and were vaccinated afterward, probably because their mothers believed (erroneously) that vaccination after illness could prevent the measles from recurring. On the other hand, in the unvaccinated group, because it includes both children who got measles, as well as some children who did not, the effects on mean HAZ are reduced moreso because socioeconomic factors play a greater relative role. In the vaccinated-late group, socioeconomic factors have much smaller effects, in all likelihood because the adverse effects of measles infection and its morbid sequelae on growth overshadow these effects.

In terms of other effects of the socioeconomic variables, there was no effect on child age, preceding birth interval, sex, or single/multiple birth. These findings imply that child age, birth interval, sex, single/multiple birth have independent, socio-biological affects on mean HAZ. The effect of young maternal age at birth was reduced by a third. The effects of birth order and number of dead siblings were also diminished, reinforcing the notion that these variables do, in fact, act as proxies for socioeconomic status. The effect of urban versus rural residence declined largely, which is not surprising since urban-rural residence is typically used to proxy socioeconomic status. The effects on countries were variable, including diminished negative effects for CAR, Niger, and Senegal, a larger negative effect for Kenya, a new negative effect for Zimbabwe, and an increased positive effect for Senegal. It is very plausibe that socioeconomic conditions in some countries play a stronger role than in others. These can include the effects of structural adjustment, social policies and programs, political conditions, currency fluctuations, and so on. It would appear that some important socioeconomic conditions in Senegal may be specifically benefitting nutritional status.

In and of themselves, the socioeconomic variables had important significant effects on mean HAZ. Both mother's and husband's educational levels had positive effects of aboutthe same size, with secondary or higher education having the strongest influence, as did mother's and husband's occupational levels, with the highest job categories having the strongest impact. Having a high possession score, and having a flush toilet, each increased mean HAZ significantly. Once again, these associations reinforce the well known association between poverty and malnutrition.

At the final step, the health service utilization variables were added to the model. These did not appreciably change the effects of measles vaccination from the previous model. The effects of

child age were unchanged, as were the effects of most other demographic and socioeconomic variables, with the exceptions of parental education, which declined slightly, and having a pit latrine, which disappeared. In terms of influencing country effects, Madagascar acquired a negative effect and Niger's negative effect was reduced. The absence of a greater influence of service utilization factors on the other factors indicates that service utilization factors are independent factors exerting a unique kind of influence on growth compared with the bio-demographic and socioeconomic variables considered.

There were only two significant effects on mean HAZ of the service utilization variables themselves: having a medically trained antenatal care provider and delivering in a private facility increased mean HAZ by 10 and 20 percent, respectively, relative to their reference categories. Women who use modern antenatal care services are more likely to be of higher socioeconomic status, may be more educated, and also are more likely to use health care services generally, which for the child would be reflected in less illness and improved nutritional status.

Because it was felt that the effects of measles vaccination could differ according to the age of the child, the multivariate analyses were repeated on separate child age groups, and then the results of the full models with all factors included for each of the age groups were compared with the results for the all-child analyses. The negative effects on mean HAZ of not being vaccinated or being vaccinated late, when all the ages were combined, did not appear at every age group. The negative effect of not being vaccinated was seen at 12-17 months, but not again until the fourth and fifth years, and the effect in the fifth year was strongest. By the fourth and fifth years of life most of the unvaccinated children will have been infected with measles; in addition to the adverse effect of measles, repeated episodes of other illnesses that thwart catch-up growth will have occurred, accumulating in stunted growth. During the second and third years of life, fewer cases of measles have occurred. In addition, during this time many other events that affect nutritional status occur, including weaning from the breast, high rates of other infectious diseases, including diarrhea, ARI, and malaria, and more independent exploration on the part of the child which exposes her to pathogens. These events may predominate during this period and overshadow the effect of the presence or absence of measles infection.

Unexpectedly, as noted above, when children of all ages were considered together the effect of being vaccinated at later than one year had twice as strong a negative effect on mean HAZ than not being vaccinated at all. When age groups were analyzed separately, there was no effect of late vaccination through the second year of life, but significant negative effects appeared from the age of 24 months onward.

The earlier and stronger negative effect of late vaccination, compared with no vaccination, provides evidence that the children vaccinated late are at a greater nutritional disadvantage than those not vaccinated. As hypothesized above, the most likely explanation for this finding is that the children who were vaccinated late, actually were infected with measles and received immunization after infection. The fact that this effect is predominant in older age groups who have had more time to be infected supports this theory. While some of the children in the unvaccinated group may never have

been infected, perhaps more of the children who were vaccinated late were infected, with the morbid consequences reflected in poor linear growth and worse stunting than among the unvaccinated children. These findings highlight the critical importance of receiving vaccine in a timely fashion, and of educating mothers and health workers about the benefits of vaccine early in life and the ineffectiveness of vaccine given after infection has occurred. The results also suggest that in the absence of data on measles infection, data on prevalence of late vaccinations may act as a proxy for measles infection.

Being vaccinated at an unknown date had no effect on mean HAZ except among the oldest children, where the effect was -0.12 SD. It is likely that most of the children in this group were vaccinated at one year or less. The negative effect during the fifth year may reflect the fact that some of these children were vaccinated late, and/or were infected at some point earlier in time.

The effects of maternal age at the birth of the child appeared primarily after the age of two years. Then, young maternal age has a negative effect, while older maternal age has a positive effect, as is seen when all children are combined. Interestingly, no effects of maternal age at birth were seen from 12 to 23 months. It is possible that so many other factors influence child health and nutritional status powerfully at this age, that any effects of maternal age may be overshadowed.

There were other interesting findings in the comparison of multivariate results among the age groups. One was the disappearance of the positive effect of urban living at 24 to 35 months of age. This does not imply that urban residence does not impact children at these ages, but rather that other factors are probably affecting growth more strongly during this time and masking the effect of urban living. With regard to gender, the negative effect of being male was seen quite markedly at 12-17 months of age, and then at 48-59 months, at about half the strength. At the early age, 12-17 months, boys are probably experiencing the adverse effect of more frequent episodes of infectious disease, which has been observed in many DHS surveys in Africa (Arnold, 1992) and elsewhere (Selwyn et al., 1990). Being born a singleton had a very strong advantage on mean HAZ compared with being born a multiple birth through the age of 3 years. This finding indicates that multiple birth children can catch up in growth and do so mostly in the fourth and fifth years.

The effects of countries on mean HAZ appeared to be stronger in the younger ages, particularly in the second year of life (12-23 months). Five countries had negative effects for the 12-17 month old group, all but three countries had negative effects for the 18-23 month old group, and the effects got worse moving from the 12-17 to the 18-23 month groups in several countries. These results underscore the great vulnerability of children in the second year of life, and the importance of social and economic programs and policies which may effect them. This age group should indeed be a special target of programs and policies designed to improve their health and nutrition status and to eliminate risk factors for diseases prevalent at this age. The positive country effects on mean HAZ from Senegal, seen in two age groups and in all ages combined, and from Madagascar, seen in the age-combined analysis, warrant further study in order to better understand the mechanisms and efforts which are conferring these benefits and potentially reinforce and replicate them.

Among the remaining socioeconomic variables, a high possession score had a positive effect on mean HAZ over all ages combined, was absent in the earlier ages (12-29 months) and yet was quite strong in the later ages, after 30 months. This finding may reflect, once again, the relatively weaker effect of socioeconomic factors compared to disease and weaning factors during the earlier ages, especially 18-23 months, and a greater impact of socioeconomic factors in the later months. Nevertheless, having a flush toilet had a strong, consistent and positive effect on mean HAZ across all the ages groups. The flush toilet not only represents higher income status but also lower risk of disease due to inadequate water and sanitation at all ages.

The results of this study imply that in many countries measles immunization programs may need to be scrutinized more closely. Only three fourths of the vaccinated children in this study were vaccinated from 8 to 12 months. Of all the children who should have been immunized, only 55 percent were vaccinated within this age window. Twenty percent of children are vaccinated too late, which in most cases means they will be infected with measles. Failure to receive measles immunization is associated with increased rates of stunting, manifested most obviously from the age of 2 years onward. Measles infection has significant adverse effects on long term growth, independent of the many important demographic and socioeconomic factors that also affect growth in early childhood. These consequences are primarily due to the morbid sequelae typical of severe measles.

In measles immunization programs, special efforts should be made to educate parents and health workers on the importance of correct timing of measles vaccine. Measles program managers should evaluate their programs to determine true coverage rates of children, as well as the proportion of children being vaccinated at the appropriate age. Many children are vaccinated beyond the first year of life, and most of these late vaccinations are ineffective in preventing measles. Only a small proportion of children in this study were vaccinated prior to 8 months, and whether such early vaccinations are effective in preventing measles warrants study.

TABLES AND FIGURES

Table 1. List of Countries, DHS Survey Fieldwork Dates, Age Range and Total Number of Children Studied

		DHS Survey		Used in This Analysis	
Country	DHS Survey Date of Fieldwork	Age Range of Chidren (Months)	Number of Children	Age Range of Children (Months)	Number of Children
Cameroon	Apr-Sep 1991	0-59	3189	12-59	1735
Central African Republic	Sep-Mar 1994/95	0-35	2577	12-35	1552
Ghana	Sep-Dec 1993	1-35	2024	12-35	1153
Kenya	Feb-Aug 1987	0-59	4752	12-59	3842
Madagascar	May-Nov 1992	0-59	5012	12-59	3766
Niger	Mar-Jun 1992	0-59	5717	12-59	3621
Senegal	Nov-Aug 1992/93	0-59	5124	12-59	2883
Uganda	Apr-Jul 1995	0-47	4775	12-47	3238
Zambia	Jan-May 1992	0-59	6211	12-59	3794
Zimbabwe	Jul-Nov 1994	0-35	2221	12-35	1351
				Total	26,935

Table 2. List of Variables Used in Analysis of Effects of Measles Vaccination and Other Factors on Height-for-Age, Among Children 12-59 Months of Age, in Selected Sub-Saharan Countries

DEPENDENT VARIABLE:

Height-for-Age Z Score

INDEPENDENT VARIABLES:	**CATEGORIES:**
Main independent factor of interest:	
Measles vaccination status	Not vaccinated Vaccinated at age ≤ 12m Vaccinated at age >12 m Vaccinated, date unknown
Other independent factors of interest:	
Demographic variables:	
Child Age group	12-17 mos. 18-23 mos. 24-29 mos. 30-35 mos. 36-47 mos. 48-59 mos.
Mother's age at birth of child	13-19 yrs. 20-34 yrs. 35+ yrs.
Preceding birth interval	7-23 mos. 24-35 mos. 36+ mos. First born
Birth order	1, 2 3, 4 or 5 6+
Number of dead siblings	0 1+
Urban-rural residence	Urban Rural
Sex of child	Male Female
Single/multiple birth	Single Multiple
Polygamous union	Polygamous Non polygamous
Country	Cameroon Central African Republic Ghana Kenya

Table 2. List of Variables Used in Analysis of Effects of Measles Vaccination and Other Factors on Height-for-Age, Among Children 12-59 Months of Age, in Selected Sub-Saharan Countries

	Madagascar Niger Senegal Uganda Zambia Zimbabwe
Socio-economic variables:	
Mother's education	None Primary Secondary +
Husband's education	None Primary Secondary+
Husband's occupation	Professional, managerial, clerical or technical Other (non-agricultural) Agriculture
Mother's occupation	Professional, managerial or clerical Other Agriculture
Possession score	0 1 2+
Type of toilet	Flush Improved or traditional pit latrine None
Service utilization variables:	
Antenatal care provider	Medically trained Not medically trained/none
Delivery attendant	Medically trained Not medically trained/none
Place of delivery	Home Public facility Private facility
Number of antenatal visits	0 1-3 visits 4+ visits

Table 3. Percentage Distribution of Stunting and Measles Vaccination Among Children 12-59 Months of Age, from Ten Countries in Africa, According to Background Characteristics

Characteristic	Percent Stunted[1]	Vaccination Status: A Not Vaccinated	B Vaccinated at ≤12 months	C Vaccinated at > 12 months	D Vaccinated Date Unknown	(B+C+D) Total Percent Vaccinated	Total Number of Children[3]
Measles vaccination status:							
Not vaccinated	43.4	-	-	-	-	25.6	6819
Vaccinated at age ≤12m	32.00	-	-	-	-	39.6	10549
Vaccinated at age >12 m	44.10	-	-	-	-	9.9	2640
Vaccinated, date unknown	33.70	-	-	-	-	25.0	6653
	p<0.0001						
Child's age group:							
12-17 mos.	31.70	36.4	46.0	3.6	14.0	63.6	4646
18-23 mos.	44.30	28.8	43.8	9.1	18.3	71.2	4123
24-29 mos.	36.30	25.8	40.8	11.4	22.0	74.2	4239
30-35 mos.	39.40	22.8	39.9	12.2	25.0	77.2	3767
36-47 mos.	36.80	20.6	36.3	11.5	31.5	79.4	5669
48-59 mos.	32.10	19.7	31.6	11.8	36.9	80.3	4491
	p<0.0001		p<0.0001			p<0.0001	
Mother's age at birth of child:							
13-19 yrs.	40.70	27.0	38.7	10.3	24.1	73	7743
20-34 yrs.	35.60	24.6	40.7	9.8	24.9	75.4	18835
35+ yrs.	36.70	29.0	35.1	9.8	26.1	71	3723
	p<0.0001		p<0.0001			p<0.0001	
Preceding birth interval:							
7-23 mos.	39.30	29.3	33.5	10.8	26.3	70.7	4934
24-35 mos.	39.10	27.0	29.1	10.6	23.2	73	4828
36+ mos.	33.80	25.5	29.7	9.2	25.7	74.5	9238
First born	33.60	19.4	46.1	8.9	25.7	80.6	7935
	p<0.0001		p<0.0001			p<0.0001	

Table 3. Percentage Distribution of Stunting and Measles Vaccination Among Children 12-59 Months of Age, from Ten Countries in Africa, According to Background Characteristics

Characteristic	Percent Stunted[1]	Vaccination Status: A Not Vaccinated	B Vaccinated at ≤12 months	C Vaccinated at > 12 months	D Vaccinated Date Unknown	(B+C+D) Total Percent Vaccinated	Total Number of Children[3]
Birth order:							
1, 2	34.50	21.4	44.3	9.2	25.1	78.6	9516
3, 4 or 5	36.40	25.6	39.7	10.3	24.4	74.4	9871
6+	39.30	30.8	33.4	10.2	25.5	69.2	7548
	p<0.0001		p<0.0001			p<0.0001	
Number of dead siblings:							
0	34.00	21.0	43.8	9.3	25.8	79	17334
1+	41.20	33.8	31.9	10.9	23.4	66.2	9601
	p<0.0001		p<00001			p<0.0001	
Urban-rural residence:							
Urban	25.80	16.4	48.1	7.9	27.7	83.6	9144
Rural	42.1	30.3	35.2	10.9	23.6	69.7	17791
	p<0.0001		p<0.0001			p<0.0001	
Sex of child:							
Male	37.60	26.2	38.8	9.9	25.1	75	13572
Female	35.50	25.0	40.4	9.9	24.8	73.8	13363
	p<0.0001		p<0.04			p=0.02	
Single/multiple birth:							
Single	36.20	25.6	39.4	9.9	25.1	77.1	26285
Multiple	50.30	22.9	46.6	10.1	20.4	74.4	650
	p<0.0001		p<0.0001			NS	
Polygamous union:							
Polygamous	39.40	34.4	32.1	11.6	21.9	65.6	5939
Non polygamous	35.600	23.6	41.3	9.6	25.4	76.4	19104
	p<0.0001		p<0.0001			p<0.0001	

Table 3. Percentage Distribution of Stunting and Measles Vaccination Among Children 12-59 Months of Age, from Ten Countries in Africa, According to Background Characteristics

Characteristic	Percent Stunted[1]	Vaccination Status: A Not Vaccinated	B Vaccinated at ≤12 months	C Vaccinated at > 12 months	D Vaccinated Date Unknown	(B+C+D) Total Percent Vaccinated	Total Number of Children[3]
Mother's education:							
None	39.20	35.7	29.7	11.0	23.5	64.3	12411
Primary	38.60	20.1	45.6	9.8	24.6	79.9	10543
Secondary +	22.80	8.7	54.3	6.5	30.5	91.3	3981
	p<0.0001		p<0.0001			p<0.0001	
Husband's education:							
None	38.90	37.5	28.1	11.2	23.2	62.5	9615
Primary	40.80	23.8	42.6	10.4	23.1	76.2	8965
Secondary+	28.20	12.1	50.6	7.7	29.5	87.9	6589
	p<0.0001		p<0.0001			p<0.0001	
Husband's occupation:							
Professional, managerial, clerical or technical	23.40	11.2	50.8	7.7	30.3	88.8	3025
Other (non-agricultural)	32.30	19.4	44.6	9.0	27.1	80.6	11637
Agriculture	44.70	37.1	30.1	11.8	21.0	62.9	11057
	p<0.0001		p<0.0.0001				
Mother's occupation:							
Professional, managerial or clerical	16.40	7.0	52.2	5.1	35.7	93	
Other	34.40	23.2	41.3	9.5	26.0	76.8	19182
Agriculture	44.90	34.2	33.4	11.6	20.8	65.8	6962
	p<0.0001		p<0.0001			p<0.0001	

Table 3. Percentage Distribution of Stunting and Measles Vaccination Among Children 12-59 Months of Age, from Ten Countries in Africa, According to Background Characteristics

Characteristic	Percent Stunted[1]	Vaccination Status: A Not Vaccinated	B Vaccinated at ≤12 months	C Vaccinated at > 12 months	D Vaccinated Date Unknown	(B+C+D) Total Percent Vaccinated	Total Number of Children[3]
Possession score:							
0	46.5	37.7	30.8	10.6	20.8	62.3	7418
1	41.1	30.0	35.0	11.0	24.1	70	7654
2+	27.3	15.1	48.1	8.8	28.0	84.9	11679
	p<0.0001		p<0.0001			p<0.0001	
Type of toilet:							
Flush	20.2	7.5	54.2	6.0	32.3	92.5	3771
Improved or traditional pit latrine	37.1	22.5	42.3	10.1	25.1	77.5	14090
None	42.6	37.9	29.2	11.3	21.7	62.1	9074
	p<0.0001		p<0.0001			p<0.0001	
Antenatal care provider:							
Medically trained	35.0	18.8	45.7	9.8	25.7	81.2	19768
Not medically trained/none	41.0	44.3	22.6	10.2	22.9	55.7	7167
	p<0.0001		p<0.0001			p<0.0001	
Delivery attendant:							
Medically trained	28.8	15.3	48.7	8.5	27.4	84.7	11943
Not medically trained/none	42.7	33.7	32.2	11.0	23.0	66.3	14992
	p<0.0001		p<0.0001			p<0.0001	
Place of delivery:							
Home	43.20	34.3	32.0	11.0	22.7	65.7	14454
Public facility	29.50	15.8	47.9	8.7	27.5	84.2	10120
Private facility	26.00	13.8	50.5	8.3	27.4	86.2	2339
	p<0.0001		p<0.0001			p<0.0001	

Table 3. Percentage Distribution of Stunting and Measles Vaccination Among Children 12-59 Months of Age, from Ten Countries in Africa, According to Background Characteristics

		Vaccination Status					
		A	B	C	D	(B+C+D)	
Characteristic	Percent Stunted[1]	Not Vaccinated	Vaccinated at ≤12 months	Vaccinated at > 12 months	Vaccinated Date Unknown	Total Percent Vaccinated	Total Number of Children[3]
Number of antenatal visits:							
0	39.50	44.5	22.0	9.7	23.8	55.5	6631
1-3 visits	36.30	24.9	40.3	10.8	24.0	75.1	8638
4+ visits	35.10	15.4	49.0	9.3	26.3	84.6	11666
	p<0.0001		p<0.0001			p<0.0001	
Overall	36.6	25.6	39.6	9.9	25.0	74.4	26935

[1] Level of significance determined by Chi-square test.
[2] Includes all children having had measles vaccine, either as recorded on a health card or reported by mother
[3] Total numbers of children per characteristic differ slightly due to small numbers of cases with missing values for the characteristic. Total number of children included in analysis of HAZ-scores=26,935. Total number of children included in analysis of measles vaccination=26,661.

Table 4. Adjusted Effects of Measles Vaccination and Other Factors on Height-for-Age, Children 12-59 Months of Age [1]

Independent Factor	Effects Adjusted For: Measles Vaccine, No Other	Child age	Demographic Factors	Country	Socio-economic Factors	Health Service Utilization
Measles vaccination status:						
Not vaccinated	-0.41	-0.42	-0.27	-0.24	-0.16	-0.13
Vaccinated at age ≤12m	0	0	0	0	0	0
Vaccinated at age >12 m	-0.43	-0.41	-0.30	-0.28	-0.23	-0.22
Vaccinated, date unknown	-	-	-	-	-	-
Child's age group:						
12-17 mos.		0	0	0	0	0
18-23 mos.		-0.40	-0.40	-0.39	-0.39	-0.39
24-29 mos.		-0.17	-0.17	-0.16	-0.16	-0.16
30-35 mos.		-0.28	-0.28	-0.28	-0.28	-0.28
36-47 mos.		-0.24	-0.21	-0.22	-0.22	-0.22
48-59 mos.		-0.14	-0.13	-0.14	-0.15	-0.15
Mother's age at birth of child:						
13-19 yrs.			-0.32	-0.27	-0.18	-0.18
20-34 yrs.			0	0	0	0
35+ yrs.			0.15	0.12	0.14	0.13
Preceding birth interval:						
7-23 mos.			-0.18	-0.18	-0.18	-0.16
24-35 mos.			-0.17	-0.15	-0.12	-0.11
36+ mos.			-	-	-	-
First born			0	0	0	0
Birth order:						
1, 2			0	0	0	0
3, 4 or 5			-0.08	-0.07	-	-
6+			-0.15	-0.14	-0.06	-0.06
Number of dead siblings:						
0			0	0	0	0
1+			-0.16	-0.12	-0.08	-0.07
Urban-rural residence:						
Urban			0.46	0.50	0.18	0.14
Rural			0	0	0	0
Sex of child:						
Male			-0.08	-0.08	-0.08	-0.08
Female			0	0	0	0
Single/multiple birth:						
Single			0.50	0.49	0.48	0.50
Multiple			0	0	0	0
Polygamous union:						
Polygamous			-0.09	-0.09	-0.06	-0.06
Non polygamous			0	0	0	0
Country:						
Cameroon				0	0	0
Central African Republic				-0.52	-0.37	-0.31
Ghana				-0.21	-0.20	-0.18
Kenya				-0.19	-0.24	-0.22
Madagascar				-	-	-0.14
Niger				-0.37	-0.10	-0.06

Table 4. Adjusted Effects of Measles Vaccination and Other Factors on Height-for-Age, Children 12-59 Months of Age[1]

	Effects Adjusted For:					
Independent Factor	Measles Vaccine, No Other	Child age	Demographic Factors	Country	Socio-economic Factors	Health Service Utilization
Senegal				-	0.12	0.15
Uganda				-0.28	-0.21	-0.20
Zambia				-0.68	-0.68	-0.65
Zimbabwe				-	-0.16	-0.16
Mother's education:						
None					0	0
Primary					0.10	0.07
Secondary +					0.27	0.23
Husband's education:						
None					0	0
Primary					0.13	0.12
Secondary+					0.22	0.19
Husband's occupation:						
Professional, managerial, clerical or technical					0.18	0.16
Other (non-agricultural)					0.06	0.05
Agriculture					0	0
Mother's occupation:						
Professional, managerial or clerical					0.18	0.17
Other					0.05	0.06
Agriculture					0	0
Possession score:						
0					0	0
1					-	-
2+					0.19	0.17
Type of toilet:						
Flush					0.22	0.20
Improved or traditional pit latrine					0.05	-
None					0	0
Antenatal care provider:						
Medically trained						0.10
Not medically trained/none						0
Delivery attendant:						
Medically trained						-
Not medically trained/none						0
Place of delivery:						
Home						0
Public facility						-
Private facility						0.21
Number of antenatal visits:						
0						0
1-3 visits						-
4+ visits						-

[1] Effects represent R^2 coefficients from OLS regression analysis of 26,935 children age 12-59 months with Mean HAZ=-1.62, from DHS surveys in 10 sub-Saharan countries.

Table 5. Combined, Adjusted Effects of Measles Vaccination and Other Factors on Height-for-Age, by Child Age[1]

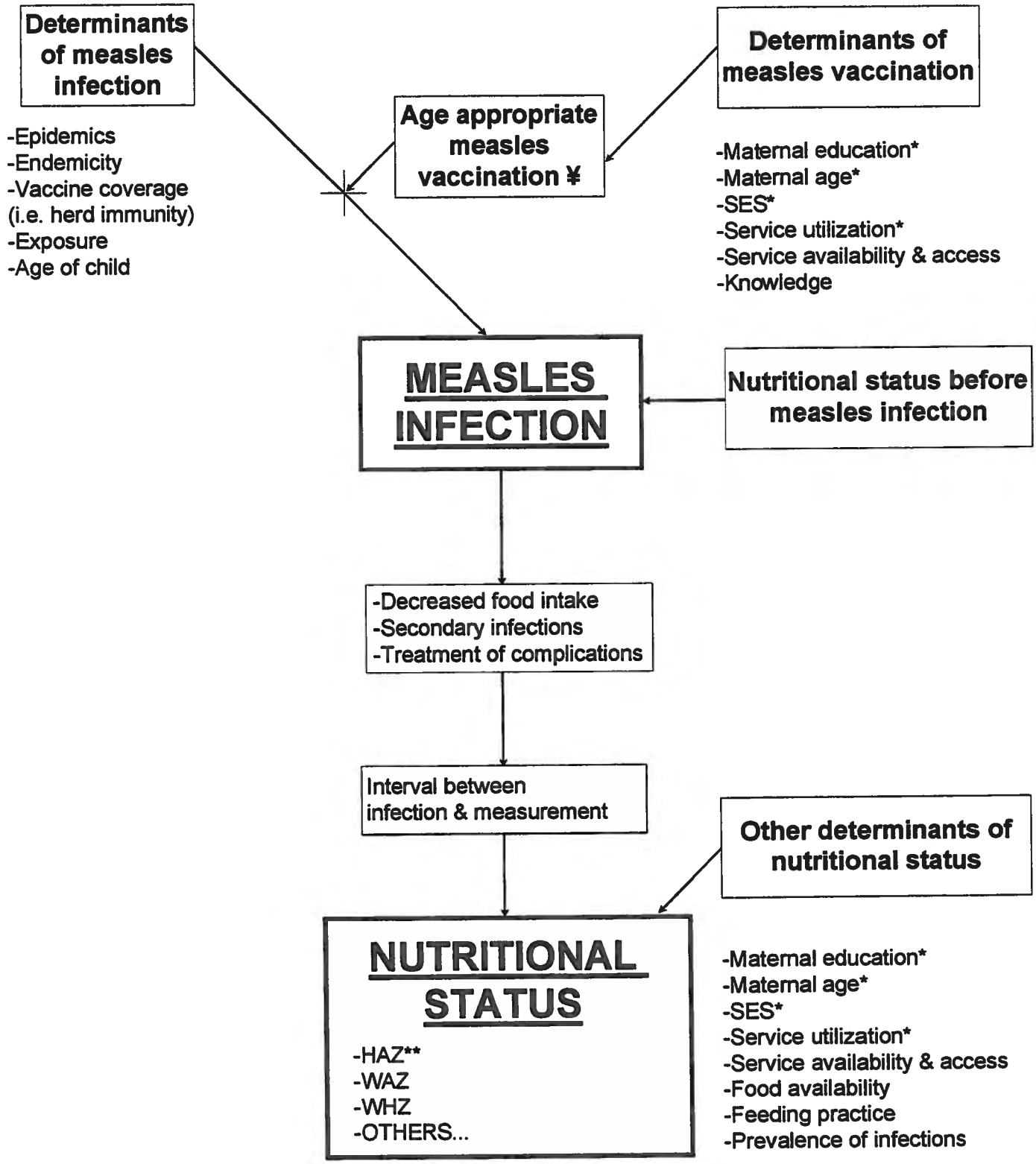
Independent Factor	Child Age						
	12-59m (n=26,935)	12-17m (n=4,646)	18-23m (n=4,123)	24-29m (n=4,239)	30-35m (n=3,767)	36-47m (n=5,669)	48-59m (n=4,491)
Measles vaccination status:							
Not vaccinated	-0.13	-0.14	-	-	-	-0.16	-0.26
Vaccinated at age ≤12m	0	0	0	0	0	0	0
Vaccinated at age >12 m	-0.22		-	-0.26	-0.26	-0.28	-0.28
Vaccinated, date unknown	-	-	-	-	-	-	-0.12
Child's age group:							
12-17 mos.	0	NA	NA	NA	NA	NA	NA
18-23 mos.	-0.39	NA	NA	NA	NA	NA	NA
24-29 mos.	-0.16	NA	NA	NA	NA	NA	NA
30-35 mos.	-0.28	NA	NA	NA	NA	NA	NA
36-47 mos.	-0.22	NA	NA	NA	NA	NA	NA
48-59 mos.	-0.15	NA	NA	NA	NA	NA	NA
Mother's age at birth of child:							
13-19 yrs.	-0.18	-	-	-0.3	-	-0.15	-0.3
20-34 yrs.	0	0	0	0	0	0	0
35+ yrs.	0.13	-	-	0.15	-	0.16	0.19
Preceding birth interval:							
7-23 mos.	-0.16	-	-	-	-0.25	-0.2	-0.26
24-35 mos.	-0.11	-	-	-	-0.2	-	-0.18
36+ mos.	-	-	-	-	-	-	-
First born	0	0	0	0	0	0	0
Birth order:							
1, 2	0	0	0	0	0	0	0
3, 4 or 5	-	-	-	-	-	-	-
6+	-0.06	-	-	-	-	-	-
Number of dead siblings:							
0	0	0	0	0	0	0	0
1+	-0.07	-0.13	-	-0.18	-	-	-
Urban-rural residence:							
Urban	0.14	0.15	0.22	-	-	0.24	-
Rural	0	0	0	0	0	0	0
Sex of child:							
Male	-0.08	-0.23	-	-	-	-	-0.11
Female	0	0	0	0	0	0	0
Single/multiple birth:							
Single	0.5	0.82	0.47	1.09	0.63	-	-
Multiple	0	0	0	0	0	0	0
Polygamous union:							
Polygamous	-0.06	-	-	-	-0.13	-	-0.16
Non polygamous	0	0	0	0	0	0	0
Country:							
Cameroon	0	0	0	0	0	0	0
Central African Republic	-0.31	-0.32	-0.5	-	-0.49	-	-
Ghana	-0.18	-	-0.31	-	-0.5	-	-
Kenya	-0.22	-0.3	-0.49	-	-0.3	-	-0.15
Madagascar	0.14	-	-	-0.29	-	-	-

Table 5. Combined, Adjusted Effects of Measles Vaccination and Other Factors on Height-for-Age, by Child Age[1]

Independent Factor	Child Age						
	12-59m (n=26,935)	12-17m (n=4,646)	18-23m (n=4,123)	24-29m (n=4,239)	30-35m (n=3,767)	36-47m (n=5,669)	48-59m (n=4,491)
Niger	-0.06	-	-	-	-	-	-
Senegal	0.15	0.26	-	-	-	0.19	-
Uganda	-0.2	-0.37	-0.31	-	-	-	-
Zambia	-0.68	-0.59	-0.68	-0.68	-0.75	-0.67	-0.61
Zimbabwe	-0.16	-	-0.4	-	-	-	-
Mother's education:							
None	0	0	0	0	0	0	0
Primary	0.08	-	-	-	-	-	-
Secondary +	0.23	-	0.24	0.32	0.22	0.25	0.39
Husband's education:							
None	0	0	0	0	0	0	0
Primary	0.12	-	0.18	-	-	0.17	-
Secondary+	0.18	-	0.29	-	0.21	0.27	-
Husband's occupation:							
Professional, managerial, clerical or technical	0.16	0.18	-	0.28	0.28	-	-
Other (non-agricultural)	0.05	-	-	-	0.12	-	-
Agriculture	0	0	0	0	0	0	0
Mother's occupation:							
Professional, managerial or clerical	0.17	-	-	-	0.46	-	-
Other	0.06	-	-	-	-	-	-
Agriculture	0	0	0	0	0	0	0
Possession score:							
0	0	0	0	0	0	0	0
1	-	-	-	-	-	-	-
2+	0.17	-	-	-	0.21	0.32	0.28
Type of toilet:							
Flush	0.2	0.23	0.21	0.25	0.22	-	0.28
Improved or traditional pit latrine	-	-	-	-	-	-	-
None	0	0	0	0	0	0	0
Antenatal care provider:							
Medically trained	0.1	-	-	0.23	-	0.18	-
Not medically trained/none	0	0	0	0	0	0	0
Delivery attendant:							
Medically trained	-	-	-	-	-	-	-
Not medically trained/none	0	0	0	0	0	0	0
Place of delivery:							
Home	0	0	0	0	0	0	0
Public facility	-	-	-	-	-	-	-
Private facility	0.21	0.33	-	0.3	-	-	-
Number of antenatal visits:							
0	0	0	0	0	0	0	0
1-3 visits	-	-	-	-	-	-0.19	-
4+ visits	0.04	-	-	-	-	-0.19	-

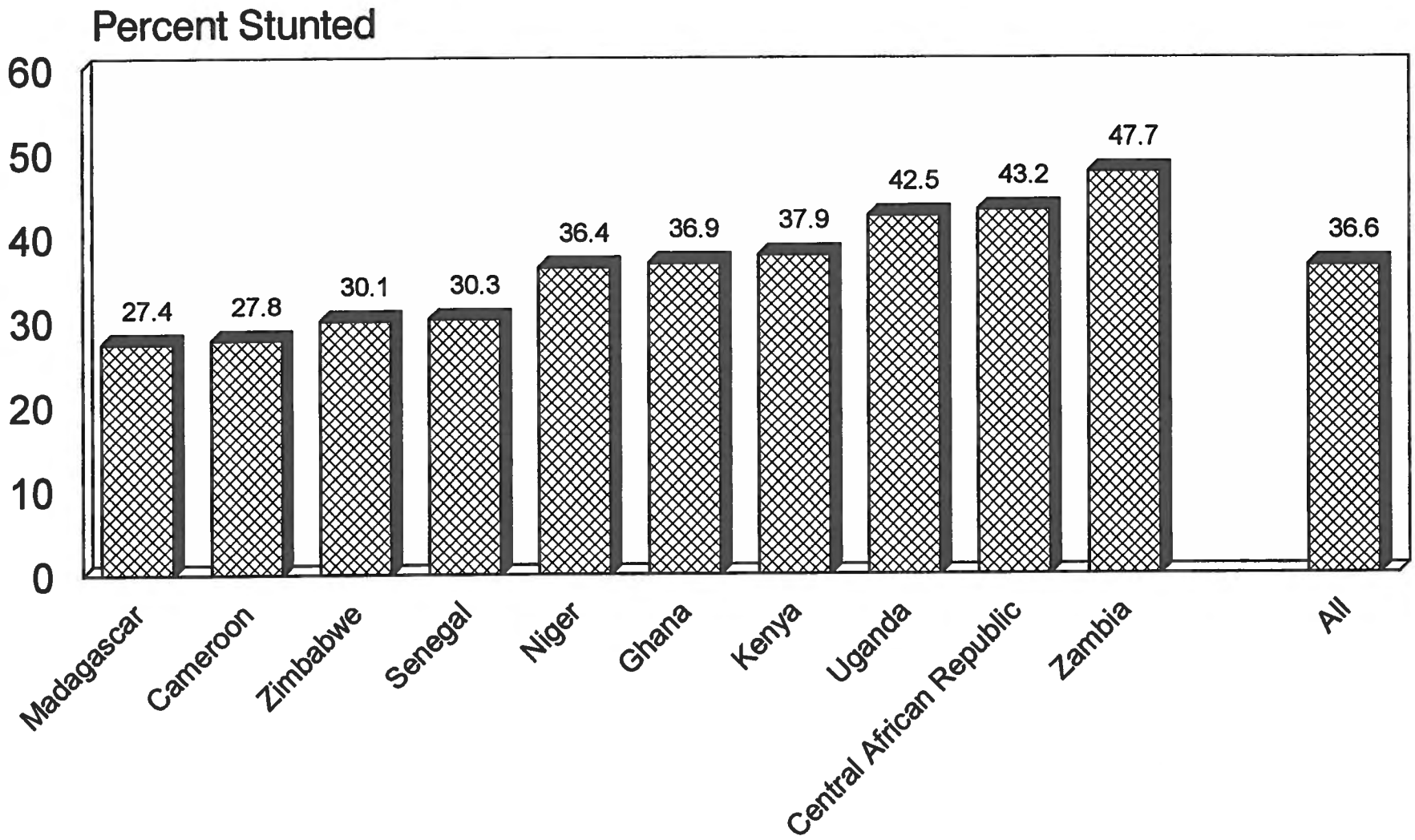
[1] Effects represent R^2 coefficients from OLS regression analysis of all children age 12-59 months of age from 10 sub-Saharan countries, and then separately of children according to age group.

Figure 1. Conceptual framework for the relationship between measles infection and nutritional status.



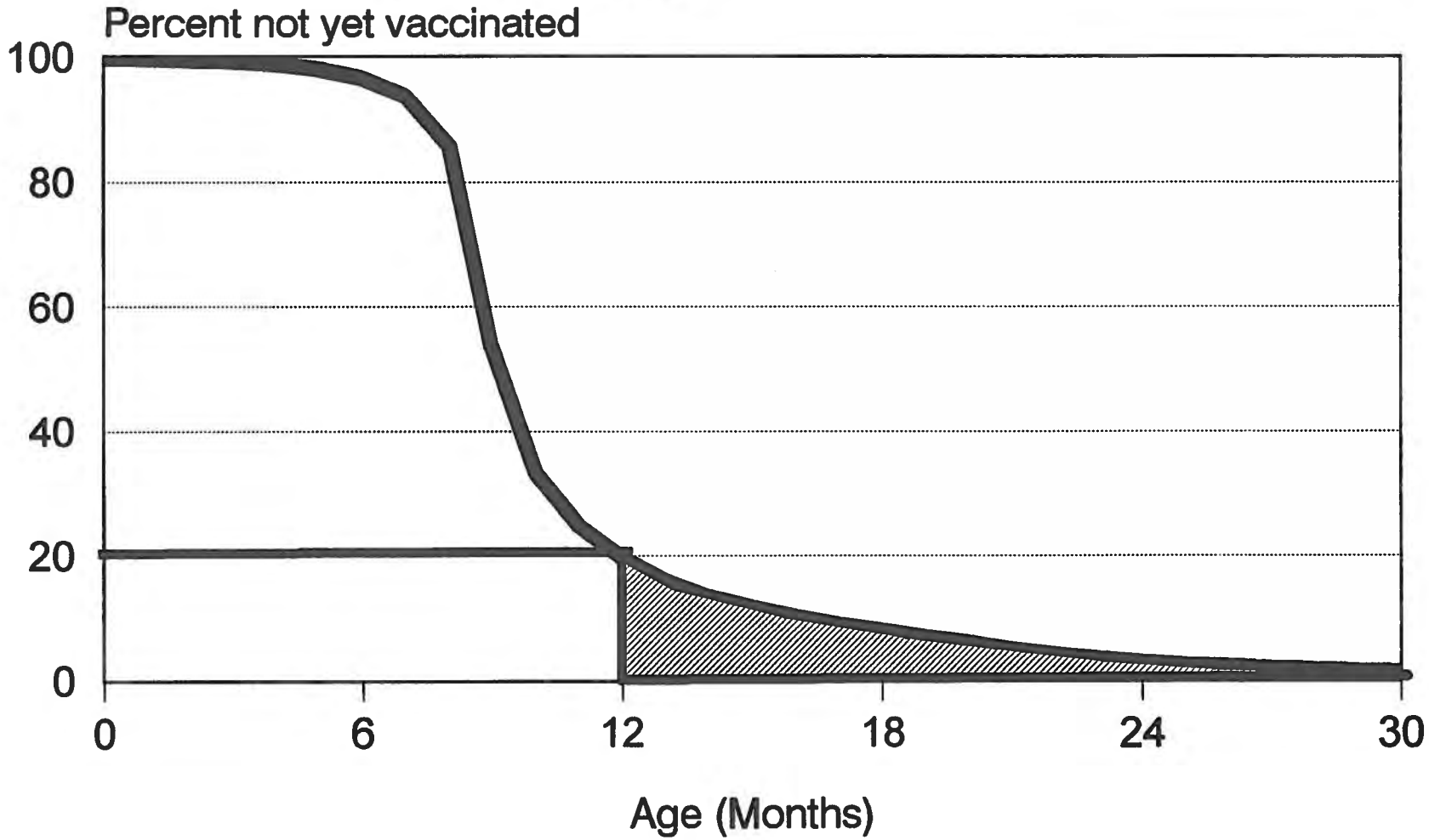
¥ Independent variable of interest in the analysis.
* Confounding factors controlled for in the analysis
** Dependent variable.

Figure 2
Prevalence of stunting among children 12-59 months of age in selected countries in sub-Saharan Africa



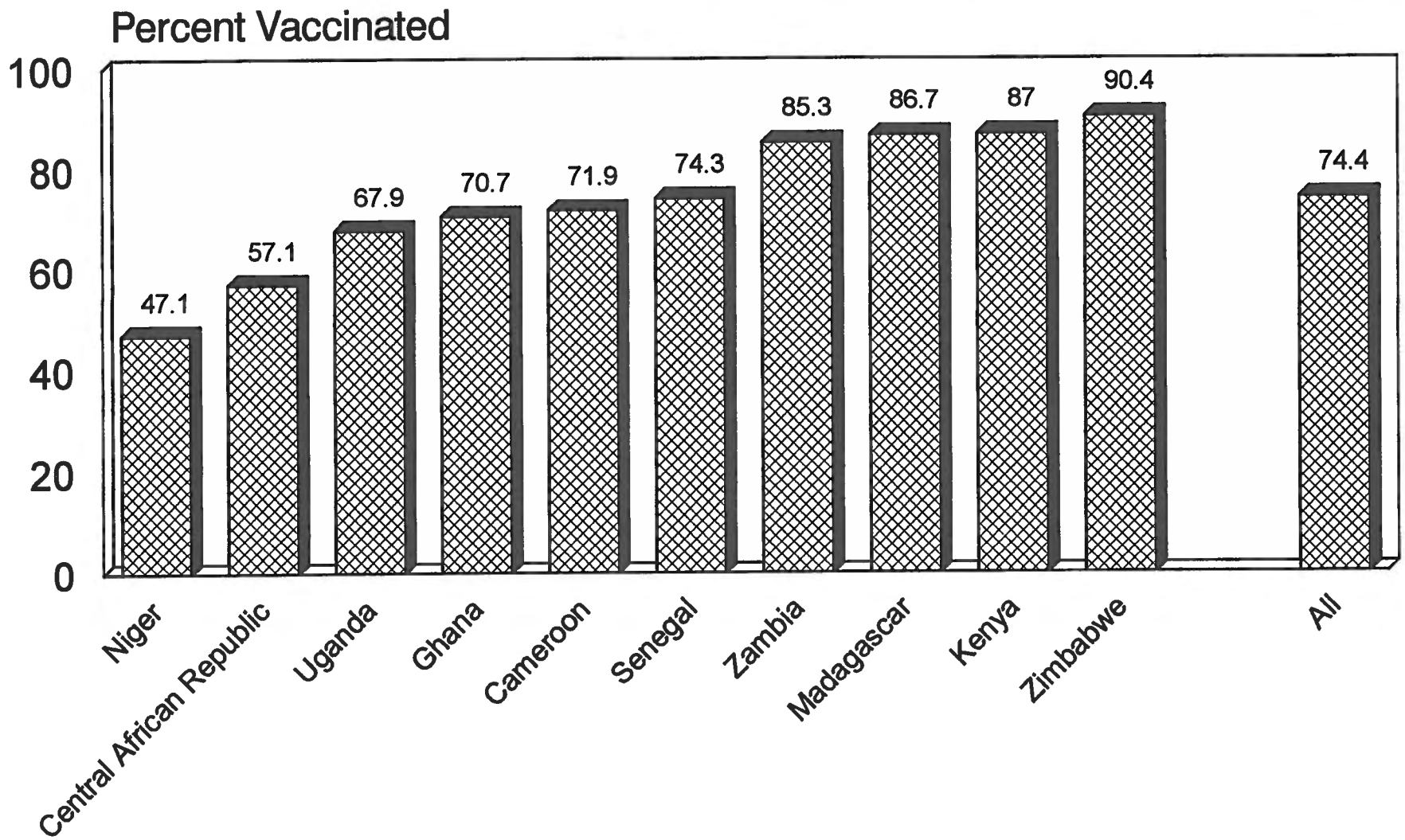
Footnote: Based on n=26,935 children from 10 countries, DHS surveys 1986-1995

Figure 3. Distribution of children not vaccinated for measles by age at vaccination among children 12-59 months of age, in selected sub-Saharan countries.



Based on n=13,189 children with health cards.
Age at vaccination: Mean=11.2 months, Mode=9.0 months.

Figure 4
Measles vaccination coverage of children 12-59 months of age in selected countries in sub-Saharan Africa



Footnote: Based on n=26,661 children from 10 countries, DHS surveys 1986-1995

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APPENDIX

Table A1. Adjusted Effects of Measles Vaccination and Other Factors on Height-for-Age, Children 12-17 Months[1]

Independent Factor	Effects Adjusted For: Measles Vaccine, No Other Factors	Demographic Factors	Country Factor	Socio-economic Factors	Health Service Utilization Factors
Measles vaccination status:					
Not vaccinated	-0.34	-0.23	-0.21	-0.16	-0.14
Vaccinated at age ≤12m	0	0	0	0	0
Vaccinated at age >12 m	-	-	-	-	-
Vaccinated, date unknown					
Mother's age at birth of child:					
13-19 yrs.		-0.22	-0.16	-0.13	-
20-34 yrs.		0	0	0	0
35+ yrs.		0.16	-	-	-
Birth interval:					
7-23 mos.		-	-	-	-
24-35 mos.		-	-	-	-
36+ mos.		-	-	-	-
First born		0	0	0	0
Birth order:					
1, 2		0	0	0	0
3, 4 or 5		-	-	-	-
6+		-	-	-	-
Number of dead children:					
0		0	0	0	0
1+		-0.18	-0.15	-0.13	-0.13
Urban-rural residence:					
Urban		0.36	0.38	0.19	0.15
Rural		0	0	0	0
Sex of child:					
Male		-0.21	-0.21	-0.22	-0.23
Female		0	0	0	0
Single/multiple birth:					
Single		0.81	0.81	0.78	0.82
Multiple		0	0	0	0
Polygamous union:					
Polygamous		-	-	-	-
Non polygamous		0	0	0	0
Country:					
Cameroon			0	0	0
Central African Republic			-0.48	-0.38	-0.32
Ghana			-	-	-
Kenya			-0.30	-0.33	-0.30
Madagascar			-	-	-
Niger			-0.34	-	-
Senegal			-	0.21	0.26
Uganda			-0.42	-0.38	-0.37
Zambia			-0.61	-0.63	-0.59
Zimbabwe			-	-	-

Table A1. Adjusted Effects of Measles Vaccination and Other Factors on Height-for-Age, Children 12-17 Months[1]

Independent Factor	Effects Adjusted For: Measles Vaccine, No Other Factors	Demographic Factors	Country Factor	Socio-economic Factors	Health Service Utilization Factors
Mother's education:					
None				0	0
Primary				0.13	0
Secondary +				-	-
Husband's education:					
None				0	0
Primary				-	-
Secondary+				-	-
Husband's occupation:					
Professional, managerial, clerical or technical				-	-
Other (non-agricultural)				-	-
Agriculture				0	0
Mother's occupation:					
Professional, managerial or clerical				-	-
Other				-	-
Agriculture				0	0
Possession score:					
0				0	0
1				-	-
2+				-	-
Type of toilet:					
Flush				0.26	0.23
Improved or traditional pit latrine				-	-
None				0	0
Antenatal care provider:					
Medically trained					-
Not medically trained/none					0
Delivery attendant:					
Medically trained					-
Not medically trained/none					0
Place of delivery:					
Home					0
Public facility					-
Private facility					0.33
Number of antenatal visits:					0
0					-
1-3 visits					-
4+ visits					

[1] Effects represent R^2 coefficients from OLS regression analysis of 4,646 children age 12-17 months from, from DHS surveys in 10 sub-Saharan countries, with mean HAZ = -1.44

Table A2. Adjusted Effects of Measles Vaccination on Height-for-Age: Children 18-23 Months[1]

Independent Factor	Effects Adjusted For: Measles Vaccine, No Other Factors	Demographic Factors	Country	Socio-economic Factors	Health Service Utilization Factors
Measles vaccination status:					
Not vaccinated	-0.36	-0.22	-0.20	-0.12	-
Vaccinated at age ≤12m	0	0	0	0	0
Vaccinated at age >12 m	-0.30	-0.19	-0.18	-	-
Vaccinated, date unknown	-	-	-	-	-
Mother's age at birth of child:					
13-19 yrs.		-0.20	-0.17	-	-
20-34 yrs.		0	0	0	0
35+ yrs.		-	-	-	-
Birth interval:					
7-23 mos.		-	-	-	-
24-35 mos.		-	-	-	-
36+ mos.		-	-	-	-
First born		0	0	0	0
Birth order:					
1, 2		0	0	0	0
3, 4 or 5		-	-	-	-
6+		-	-	-	-
Number of dead children:					
0		0	0	0	0
1+		-0.14	-	-	-
Urban-rural residence:					
Urban		0.49	0.51	0.24	0.22
Rural		0	0	0	0
Sex of child:					
Male		-	-	-	-
Female		0	0	0	0
Single/multiple birth:					
Single		0.41	0.46	0.46	0.47
Multiple		0	0	0	0
Polygamous union:					
Polygamous		-	-	-	-
Non polygamous		0	0	0	0
Country:					
Cameroon			0	0	0
Central African Republic			-0.60	-0.55	-0.50
Ghana			-0.32	-0.32	-0.31
Kenya			-0.38	-0.48	-0.49
Madagascar			-	-	-
Niger			-0.52	-0.26	-
Senegal			-	-	-
Uganda			-0.29	-0.30	-0.31
Zambia			-0.63	-0.69	-0.68
Zimbabwe			-0.28	-0.40	-0.40

Table A2. Adjusted Effects of Measles Vaccination on Height-for-Age, Children 18-23 Months [1]

Independent Factor	Effects Adjusted For: Measles Vaccine, No Other Factors	Demographic Factors	Country	Socio-economic Factors	Health Service Utilization Factors
Mother's education:					
None				0	0
Primary				0.12	-
Secondary +				0.26	0.24
Husband's education:					
None				0	0
Primary				0.18	0.18
Secondary+				0.30	0.29
Husband's occupation:					
Professional, managerial, clerical or technical				-	-
Other (non-agricultural)				-	-
Agriculture				0	0
Mother's occupation:					
Professional, managerial or clerical				-	-
Other				-	-
Agriculture				0	0
Possession score:					
0				0	0
1				-	-
2+				-	-
Type of toilet:					
Flush				0.22	0.21
Improved or traditional pit latrine				-	-
None				0	0
Antenatal care provider:					
Medically trained					-
Not medically trained/none					0
Delivery attendant:					
Medically trained					-
Not medically trained/none					0
Place of delivery:					
Home					0
Public facility					-
Private facility					-
Number of antenatal visits:					
0					0
1-3 visits					-
4+ visits					-

[1] Effects represent R^2 coefficients from OLS regression analysis of 4,123 children age 18-23 months from 10 sub-Saharan countries, with mean HAZ = -1.82

Table A3. Adjusted Effects of Measles Vaccination on Height-for-Age, Children 24-29 Months [1]

Independent Factor	Effects Adjusted For: Measles Vaccine, No Other Factors	Demographic Factors	Country	Socio-economic Factors	Health Service Utilization Factors
Measles vaccination status:					
Not vaccinated	-0.46	-0.28	-0.23	-0.14	-
Vaccinated at age ≤12m	0	0	0	0	0
Vaccinated at age >12 m	-0.47	-0.38	-0.34	-0.28	-0.26
Vaccinated, date unknown					
Mother's age at birth of child:					
13-19 yrs.		-0.47	-0.39	-0.29	-0.30
20-34 yrs.		0	0	0	0
35+ yrs.		0.21	0.17	0.17	0.15
Birth interval:					
7-23 mos.		-0.19	-	-	-
24-35 mos.		-0.18	-	-	-
36+ mos.		-	-	-	-
First born		0	0	0	0
Birth order:					
1, 2		0	0	0	0
3, 4 or 5		-	-	-	-
6+		-0.18	-	-	-
Number of dead children:					
0		0	0	0	0
1+		-0.29	-0.24	-0.19	-0.18
Urban-rural residence:					
Urban		0.40	0.46	0.13	
Rural		0	0	0	0
Sex of child:					
Male		-	-	-	-
Female		0	0	0	0
Single/multiple birth:					
Single		1.08	1.03	1.06	1.09
Multiple		0	0	0	0
Polygamous union:					
Polygamous		--	-	-	-
Non polygamous		0	0	0	0
Country:					
Cameroon			0	0	0
Central African Republic			-0.36	-	-
Ghana			-	-	-
Kenya			-	-	-
Madagascar			-	-	0.29
Niger			-0.43	-	-
Senegal			-	-	-
Uganda			-0.24	-	-
Zambia			-0.69	-0.68	-0.68
Zimbabwe			-	-	-

Table A3. Adjusted Effects of Measles Vaccination on Height-for-Age, Children 24-29 Months [1]

Independent Factor	Effects Adjusted For: Measles Vaccine, No Other Factors	Demographic Factors	Country	Socio-economic Factors	Health Service Utilization Factors
Mother's education:					
None				0	0
Primary				-	-
Secondary +				0.38	0.32
Husband's education:					
None				0	0
Primary				-	-
Secondary+				-	-
Husband's occupation:					
Professional, managerial, clerical or technical				0.31	0.28
Other (non-agricultural)				0.13	-
Agriculture				0	0
Mother's occupation:					
Professional, managerial or clerical				-	-
Other				-	-
Agriculture				0	0
Possession score:					
0				0	0
1				-	-
2+				-	-
Type of toilet:					
Flush				0.27	0.25
Improved or traditional pit latrine				-	-
None				0	0
Antenatal care provider:					
Medically trained				-	0.23
Not medically trained/none				0	0
Delivery attendant:					
Medically trained				-	-
Not medically trained/none				0	0
Place of delivery:					
Home				0	0
Public facility				-	-
Private facility				-	0.30
Number of antenatal visits:					
0					0
1-3 visits					-
+ visits					-

[1] Effects represent R^2 coefficients form OLS regression analysis of 4,239 children age 24-29 months from, from DHS surveys in 10 sub-Saharan countries, with mean HAZ = -1.60

Table A4. Effects of Measles Vaccination on Height-for-Age, Children 30-35 Months[1]

Independent Factor	Effects Adjusted For: No Confounders	Demographic Factors	Country	Socio-economic Factors	Health Service Utilization Factors
Measles vaccination status:					
Not vaccinated	-0.43	-0.31	-0.24	-	-
Vaccinated at age ≤12m	0	0	0	0	0
Vaccinated at age >12 m	-0.49	-0.39	-0.34	-0.28	-
Vaccinated, date unknown	-	-	-	-	-
Mother's age at birth of child:					
13-19 yrs.		-0.27	-0.22	-	-
20-34 yrs.		0	0	0	0
35+ yrs.		-	-	-	-
Birth interval:					
7-23 mos.		-0.29	-0.29	-0.27	-0.25
24-35 mos.		-0.26	-0.25	-0.21	-0.20
36+ mos.		-	-	-	-
First born		0	0	0	0
Birth order:					
1, 2		0	0	0	0
3, 4 or 5		-	-	-	-
6+		-	-	-	-
Number of dead children:					
0		0	0	0	0
1+		-	-	-	-
Urban-rural residence:					
Urban		0.49	0.57	0.15	-
Rural		0	0	0	0
Sex of child:					
Male		-	-	-	-
Female		0	0	0	0
Single/multiple birth:					
Single		0.63	0.66	0.62	0.63
Multiple		0	0	0	0
Polygamous union:					
Polygamous		-0.17	-0.17	-0.13	-0.13
Non polygamous		0	0	0	0
Country:					
Cameroon			0	0	0
Central African Republic			-0.76	-0.55	-0.49
Ghana			-0.56	-0.51	-0.50
Kenya			-0.25	-0.31	-0.30
Madagascar			-0.28	-	-
Niger			-0.55	-	-
Senegal			-	-	-
Uganda			-0.32	-	-
Zambia			-0.81	-0.78	-0.75
Zimbabwe			-	-	-

Table A4. Effects of Measles Vaccination on Height-for-Age, Children 30-35 Months[1]

Independent Factor	Effects Adjusted For: No Confounders	Demographic Factors	Country	Socio-economic Factors	Health Service Utilization Factors
Mother's education:					
None				0	0
Primary				-	-
Secondary +				0.26	0.22
Husband's education:					
None				0	0
Primary				0.16	-
Secondary+				0.26	0.21
Husband's occupation:					
Professional, managerial, clerical or technical				0.30	0.28
Other (non-agricultural)				0.14	0.12
Agriculture				0	0
Mother's occupation:					
Professional, managerial or clerical				0.48	0.46
Other				-	-
Agriculture				0	0
Possession score:					
0				0	0
1				-	-
2+				0.24	0.21
Type of toilet:					
Flush				0.23	0.22
Improved or traditional pit latrine				-	-
None				0	0
Antenatal care provider:					
Medically trained					-
Not medically trained/none					0
Delivery attendant:					
Medically trained					-
Not medically trained/none					0
Place of delivery:					
Home					0
Public facility					-
Private facility					-
Number of antenatal visits:					
0					0
1-3 visits					-
4+ visits					-

[1] Effects represent R^2 coefficients from OLS regression analysis of 3,767 children age 30-35 months from, from DHS surveys in 10 sub-Saharan countries, with mean HAZ = -1.64

Table A5. Adjusted Effects of Measles Vaccination and Other Factors on Height-for-Age, Children 36-47 Months[1]

Independent Factor	Effects Adjusted For: Measles Vaccine, No Other Factor	Demographic Factors	Country	Socio-economic Factors	Health Service Utilization Factors
Measles vaccination status:					
Not vaccinated	-0.47	-0.28	-0.28	-0.19	-0.16
Vaccinated at age ≤12m	0	0	0	0	0
Vaccinated at age >12 m	-0.48	-0.35	-0.34	-0.29	-0.28
Vaccinated, date unknown	-	-	-	-	-
Mother's age at birth of child:					
13-19 yrs.		-0.32	-0.27	-0.16	-0.15
20-34 yrs.		0	0	0	0
35+ yrs.		0.16	0.14	0.17	0.16
Birth interval:					
7-23 mos.		-0.22	-0.22	-0.22	-0.20
24-35 mos.		-0.18	-0.16	-0.14	-
36+ mos.		-	-	-	-
First born		0	0	0	0
Birth order:					
1, 2		0	0	0	0
3, 4 or 5		-	-	-	-
6+		-	-	-	-
Number of dead children:					
0		0	0	0	0
1+		-0.16	-0.10	-	-
Urban-rural residence:					
Urban		0.59	0.61	0.29	0.24
Rural		0	0	0	0
Sex of child:					
Male		-	-	-	-
Female		0	0	0	0
Single/multiple birth:					
Single		-	-	-	-
Multiple		0	0	0	0
Polygamous union:					
Polygamous		-	-	-	-
Non polygamous		0	0	0	0
Country:					
Cameroon			0	0	0
Central African Republic			-	-	-
Ghana			-	-	-
Kenya			-	-	-
Madagascar			-	-	0.20
Niger			-0.35	-	-
Senegal			-	-	0.19
Uganda			-0.26	-	-
Zambia			-0.73	-0.71	-0.67
Zimbabwe			-	-	-

Table A5. Adjusted Effects of Measles Vaccination and Other Factors on Height-for-Age, Children 36-47 Months[1]

	Effects Adjusted For:				
Independent Factor	**Measles Vaccine, No Other Factor**	**Demographic Factors**	**Country**	**Socio-economic Factors**	**Health Service Utilization Factors**
Mother's education:					
None				0	0
Primary				-	-
Secondary +				0.28	0.25
Husband's education:					
None				0	0
Primary				0.19	0.17
Secondary+				0.30	0.27
Husband's occupation:					
Professional, managerial, clerical or technical				-	-
Other (non-agricultural)				-	
Agriculture				0	0
Mother's occupation:					
Professional, managerial or clerical				-	-
Other				-	-
Agriculture				0	0
Possession score:					
0				0	0
1				-	-
2+				0.34	0.32
Type of toilet:					
Flush					-
Improved or traditional pit latrine					-
None					0
Antenatal care provider:					
Medically trained					0.18
Not medically trained/none					0
Delivery attendant:					
Medically trained					-
Not medically trained/none					0
Place of delivery:					
Home					0
Public facility					-
Private facility					-
Number of antenatal visits:					
0					0
1-3 visits					-0.19
4+ visits					-0.19

[1] Effects represent R^2 coefficients from OLS regression analysis of 5,667 children age 36-47 months from, from DHS surveys in 10 sub-Saharan countries, with mean HAZ = -1.64

Table A6. Adjusted Effects of Measles Vaccination on Height-for-Age, Children 48-59 Months[1]

Independent Factor	Effects Adjusted For: Measles Vaccine, No Other Factors	Demographic Factors	Country	Socio-economic Factors	Health Service Utilization Factors
Measles vaccination status:					
Not vaccinated	-0.52	-0.30	-0.37	-0.27	-0.26
Vaccinated at age ≤12m	0	0	0	0	0
Vaccinated at age >12 m	-0.44	-0.31	-0.35	-0.29	-0.28
Vaccinated, date unknown	-0.15	-0.10	-0.14	-0.12	-0.12
Mother's age at birth of					
13-19 yrs.		-0.42	-0.38	-0.31	-0.30
20-34 yrs.		0	0	0	0
35+ yrs.		0.18	0.18	0.19	0.19
Birth interval:					
7-23 mos.		-0.26	-0.27	-0.26	-0.26
24-35 mos.		-0.25	-0.24	-0.20	-0.18
36+ mos.		-	-	-	-
First born		0	0	0	0
Birth order:					
1, 2		0	0	0	0
3, 4 or 5		-	-	-	-
6+		-0.23	-0.23	-	-
Number of dead children:					
0		0	0	0	0
1+		-0.12	0.09	-	-
Urban-rural residence:					
Urban		0.41	0.43	-	-
Rural		0	0	0	0
Sex of child:					
Male		-0.10	-0.11	-0.11	-0.11
Female		0	0	0	0
Single/multiple birth:					
Single		-	-	-	-
Multiple		0			
Polygamous union:					
Polygamous		-0.15	-0.18	-0.17	-0.16
Non polygamous		0	0	0	0
Country:					
Cameroon			0	0	0
Central African Republic			-	-	-
Ghana			-	-	-
Kenya			-0.18	-0.25	-0.21
Madagascar			-	-	-
Niger			-0.16	-	-
Senegal			-	-	-
Uganda			-	-	-
Zambia			-0.64	-0.65	-0.61
Zimbabwe			-	-	-

Table A6. Adjusted Effects of Measles Vaccination on Height-for-Age, Children 48-59 Months [1]

	Effects Adjusted For:				
Independent Factor	**Measles Vaccine, No Other Factors**	**Demographic Factors**	**Country**	**Socio-economic Factors**	**Health Service Utilization Factors**
Mother's education:					
None				0	0
Primary				-	-
Secondary +				0.43	0.38
Husband's education:					
None				0	0
Primary				-	-
Secondary+				-	-
Husband's occupation:					
Professional, managerial,				-	-
Other (non-agricultural)				-	-
Agriculture				0	0
Mother's occupation:					
Professional, managerial or				-	-
Other				-	-
Agriculture				0	0
Possession score:					
0				0	0
1				-	-
2+				0.27	0.25
Type of toilet:					
Flush				0.29	0.28
Improved or traditional pit				-	-
None				0	0
Antenatal care provider:					
Medically trained					-
Not medically trained/none					0
Delivery attendant:					
Medically trained					-
Not medically trained/none					0
Place of delivery:					
Home					0
Public facility					-
Private facility					-
Number of antenatal visits:					
0					0
1-3 visits					-
4+ visits					-

[1] Effects represent R^2 coefficients based on OLS regression analysis of 4,491 children age 48-59 months from, from DHS surveys in 10 sub-Saharan countries, with mean HAZ = -1.54