

**Is birth weight a good predictor of child mortality in developing countries? Results
from recent national surveys in sub-Saharan Africa**

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Abstract

Low birth weight has been found to be the strongest predictor of infant mortality, especially in the neonatal period. However, less attention has been paid to the relationship between low birth weight and the risk of dying before age 5. To fill this gap, we exploit recent national survey data to explore whether low birth weight is associated with increased risk of child mortality in sub-Saharan Africa. Specifically, we apply a multivariate piecewise constant hazard model with gamma-shared frailty to the Demographic and Health Survey data for Benin (2006), Congo Brazzaville (2005), Congo Democratic Republic (2007), Lesotho (2004), Namibia (2006), Swaziland (2006), and Zimbabwe (2005/06). In all countries, life table estimates of the risk of dying before age 5 indicate that low birth weight is associated with a higher probability of dying not only in infancy but also during childhood. The results of the multivariate hazard model confirm that, in all countries, after controlling for potential confounding factors, low birth weight is a very strong predictor of mortality risk during the first five years of life. We find also strong evidence of the differential impact of birth weight status on the risk of dying before age 5 based on exposure time (less than 1 month of age, 1-11 months, more than 12 months). Of the other covariates included in the model, only the number of visits at a prenatal clinic is systematically negatively associated with the risk of dying before age 5.

Key Words: Birth weight, Child mortality, Sub-Saharan Africa, Frailty model.

Introduction

More than 20 million infants worldwide are born with low birth weight, that is, weighing less than 2500 grams (5.5. pounds) at birth. The majority (95.6 percent) of low birth weight children are found in developing countries, and low birth weight levels in sub-Saharan Africa are around 15 percent (United Nations Children's Fund and World Health Organization 2004: 1). The goal of reducing low birth weight incidence by at least one third between 2000 and 2010 was thus one of the major goals in the Declaration and Plan of Action adopted by the United Nations General Assembly Special Session on Children in 2002.

The reduction of low birth weight forms also an important contribution to the Millennium Development Goal (MDG) for reducing child mortality, which remains a major health challenge in sub-Saharan Africa (Ahmad, Lopez and Inoue 2000; Black, Morris and Bryce 2003; Bryce and Requejo 2008; Jones et al. 2003; Lee 2003; WHO 2005). The relationship between low birth weight and infant mortality has indeed been recognized for several decades (Ashworth 1998; Black et al. 2008; de Onis, Blossner and Villar 1998). Low birth weight has been found to be the strongest predictor of infant mortality, especially in the neonatal period (Susser, Marolla and Fleiss 1972; United Nations Children's Fund and World Health Organization 2004).

Little attention has been paid to the relationship between low birth weight and the risk of dying before age 5, for two main reasons. First, in less developed countries reliable data on low birth weight remain limited, because a large proportion of babies are born at home and without a skilled attendant, and in these circumstances they are rarely weighed. Even when babies are weighed at birth, their weight is not always measured accurately, or recorded, reported and tabulated correctly (United Nations Children's Fund and World Health Organization 2004: 3). In household surveys, the availability of information on birth weight importantly decreases with birth order, so that children born further away from the survey date generally have more incomplete information on birth weight. The second reason for the limited number of studies linking low birth weight to child mortality is that after the neonatal period it may be difficult to disentangle genetic from environmental factors that affect a child's chances of survival. To fill this gap, in this paper we exploit several recent national surveys to evaluate whether low birth weight is associated with increased risk of child mortality in sub-Saharan Africa.

Data and methods

Data sources, measurement of birth weight and country selection

We use data from the most recent Demographic and Health Surveys (DHS) from the following seven countries in sub-Saharan Africa, which were carried out between 2004 and 2006: Benin, Congo (Brazzaville), Congo Democratic Republic, Lesotho, Namibia, Swaziland, and Zimbabwe. The DHSs are nationally-representative, self-weighting probability samples of women aged 15–49 years. They use standardized questionnaires across countries to collect information on the sampled respondents' basic socio-demographic characteristics, as well as on their birth histories and on their children's health. The sampling design and survey implementation procedures for each country are described in detail in the individual country survey reports (Central Statistical Office [Swaziland], and Macro International Inc. 2008; Central Statistical Office [Zimbabwe] and Macro International Inc. 2007; Centre National de la Statistique et des Études Économiques [Congo] et ORC Macro 2006; Institut National de la Statistique et de l'Analyse Économique [Bénin] et Macro International Inc. 2007; Ministère du Plan et Macro International 2008; Ministry of Health and Social Services [Namibia] and Macro International Inc. 2008 ; Ministry of Health and Social Welfare [Lesotho], Bureau of Statistics [Lesotho], and ORC Macro 2005).

The selection of the countries to be included in the analysis was guided by the availability of information on birth weight.¹ The DHS questionnaire collects information on birth weight for up to three of the respondent's children who were born in the five years preceding the survey. For each of these children, the DHS records the mother's report of the child's weight at birth (numerical weight in grams or pounds) as well as her assessment of the child's size when born. The proportion of children with missing information on numerical birth weight varies quite considerably across countries and can be quite high, especially for children born the furthest away from the date of the survey (see Appendix Table 1). For the purposes of the present analysis, we chose to include only countries where the proportion of children with missing information on numerical birth weight is 45 percent or less. In addition, because not in all countries information for the respondent's three most recent births was collected, we limit the analysis to the two most recent births during the five years preceding the survey. Focusing on recent births has the additional advantage of reducing the problems associated with period effects of child mortality and ensuring that maternal and household characteristics relate to current conditions. The number

¹ The DHSs do not permit missing data on survival or age at death.

of children included in the analysis thus ranges from 2772 in Swaziland to 15999 in Benin (Table 1).

[Table 1 about here]

Treatment of missing information on birth weight

Studies based on birth weight data collected from surveys in developing countries have demonstrated that biases are likely to result from restricting estimates of the frequency of low birth weight or its determinants to the selected subsample of women who report birth weight information. They also indicate, however, that the use of subjective assessment of birth weight such as the relative size of the infant at birth from the full sample of respondents, along with numerical birth weight where available, can reduce these biases (Blanc and Wardlaw 2005; Boerma et al. 1996; Magadi et al. 2006; Robles and Goldman 1999: 926; Rutstein 2008).

We follow this approach and we draw from the mother's assessment of the child's size at birth to infer the numerical birth weight if the latter is missing. To do so, for mothers who reported both the child's numerical birth weight and self-assessed size at birth, in Figure 1 and Appendix Table 2 we compare the mean numerical birth weight by the different categories of the mother's assessment of the child's size at birth. This comparison suggests that, if the mother reports that the child's size was very small at birth, in all countries included the analysis this systematically corresponds to a low numerical birth weight (less than 2500 grams). We thus classify children with missing numerical birth weight but who are assessed to have been very small at birth as low birth weight children.

[Figure 1 about here]

Methods

We first calculate the probability of dying before age 5 by age at death and country using the life table method. We stratify the findings by birth weight and we compare them graphically by using the logrank test statistics. We measure birth weight by distinguishing children with normal weight (more than 2500 grams) from those with low birth weight (less than 2500 grams).

Next, we evaluate the association between birth weight (measured as indicated above) and the risk of dying before age 5 controlling for other potential confounding factors. The dependent variable is the risk of death in childhood (0–59 months), measured as duration from birth to the age at death (in months) or censored. Since not all children had the chance to survive to the

oldest age under investigation by the time of the interview, we use an event history model to account for right-censoring in the estimation of exposure time in the multivariate analysis. Specifically, we use a proportional hazard model with a piecewise constant baseline hazard by dividing the child's first five years into three exposure periods (0-1 months, 1-11 months, and 12-59 months²) and assuming that the baseline hazard is constant within each period.

The standard piecewise exponential model is built on the assumption of independence of observations, but the DHS children file has a hierarchical structure with children nested within mothers (Gyimah 2007). Some women contribute more than one child to the sample (across the countries included in our analysis, 18 % to 34 % of women count more than one child), thus violating the independence assumption. Children of the same mother are expected to be more alike, at least in part because of shared genetic and environmental factors. Without accounting for the within-mother correlation, the standard piecewise exponential model is misspecified and parameter estimates can be inconsistent, standard errors can be wrong, and estimates of duration dependency can be misleading. To account for this dependence, an appropriate solution is to estimate a model with shared frailty (Sastry 1997b).³ This assumes that children of the same mother share an unobservable random covariate that acts multiplicatively on the hazard.⁴ The estimated parameter relating to the distribution of unobserved heterogeneity (θ) is interpreted as the variance of the frailty distribution (Cleves, Gould and Gutierrez 2004; Jenkins 1995; Jenkins 1997; Sastry 1997a). If the variance estimate is significantly different from zero, it can be concluded that there are unmeasured and unmeasurable factors shared by siblings that affect the risk of death, and thus that siblings' survival risks are correlated (Omariba 2005).

The control variables included in the analysis are a number of demographic and socioeconomic factors traditionally known to affect child mortality (Hobcraft, McDonald and Rutstein 1985; Rafalitanana and Westoff 2000; Rutstein 2000). These are: the child's birth order and sex, the

² These intervals conform to established conventions and assure that there are enough cases in each of them.

³ The main difference between shared and individual frailty models is the assumption about how frailty is distributed in the data. Shared frailty models assume that similar observations share frailty, even though frailty may vary from group to group.

⁴ This study assumes that frailty follows a gamma distribution. Past research has made extensive use of this distribution because of its flexible shape and analytical tractability (Oakes 1982; Sastry 1996), and because estimates do not seem to be too sensitive to the choice of the distribution for the random effect (Guo and Rodriguez 1992; Omariba et al. 2007; Sastry 1997b; van Poppel et al. 2002). Indeed, a recent study shows that, in a large class of hazard models with proportional unobserved heterogeneity, the distribution of the heterogeneity among survivors converges rapidly to a gamma distribution (Abbring and Van den Berg 2007).

mother's age at birth and education, household wealth, and place of residence. We also include controls for access to health care services as measured by the number of prenatal visits and the place of delivery for the index child. Descriptive statistics for all covariates included in the analysis are presented in Table 2. To test whether birth weight status has a differential impact on the risk of dying by age 5 by duration of exposure, we also include in the model a series of dichotomous variables to capture the interaction between exposure time (0-1 months, 1-11 months, and 12-59 months) and birth weight.

[Table 2 about here]

All analyses were performed using Stata 10.0 (Stata Corporation 2007) by taking into account the DHS complex survey design.

Results

Probability of dying before age 5 by birth weight status

Figure 2 shows the proportion of children surviving at each age (in months) by birth weight status for each country included in the analysis. The figure clearly indicates that low birth weight is associated with a higher probability of dying not only in infancy but also during childhood. Overall, the difference in survival probabilities at age 5 between normal and low birth weight children varies from 2% in Benin to 12 % in Swaziland. In addition, at each age, the proportion surviving is significantly higher among children whose weight is normal, particularly after the first year of life, that is, the neonatal period. This provides a first indication of the differential impact of birth weight by duration of exposure to the risk of dying during childhood. We expand on this point when discussing the results of the multivariate models in the next section.

[Figure 2 about here]

Influence of birth weight status on the risk of dying before age 5

Table 3 shows the results of the multivariate piecewise exponential model with gamma-shared frailty for each country included in the analysis. The model with frailty provides a good fit to the data: in all the models, the null hypothesis that the effect of the frailty (θ) is zero is rejected ($p \leq .05$ in all countries), suggesting that children of the same mother share relevant characteristics and emphasizing the need to account for such dependence between them.

[Table 3 about here]

The main result of the analysis is that, in all countries, low birth weight is a very strong predictor of mortality risk during the first five years of life. In addition, the statistical significance of the interaction between birth weight status and exposure time confirms that the estimate for the influence of birth weight status on the risk of dying before age 5 conceals differences based on exposure time. The interaction terms signify that covariates interact and that the first-order interactions modify the linear relationship measured by main effects. Thus, the results show that the effect of birth weight status on the risk of dying differs by exposure time.

To facilitate the interpretation of the interaction terms in Table 3, Table 4 shows the interaction effects for exposure time and birth weight status (low birth weight, normal birth weight) on the risk of dying before age 5, controlling for the effect of the same covariates as in Table 3. In this table, for all countries the reference category is the risk of dying during the neonatal period (less than 1 month of age) for children with normal birth weight. Consistently with the existing literature, we find that across the countries included in the analysis the risk of dying during the neonatal period for children with low birth weight is 2 to 4 times the risk of dying for children with normal birth weight. Regardless of birth weight status, exposure time has a significantly negative relationship with the risk of dying before age 5 (except for Namibia and Swaziland): generally, mortality declines sharply after the first month of life and continues to gradually decline thereafter through infancy and childhood. However, the magnitude of this effect importantly differs by birth weight status. The risk of dying for normal weight children is 63% to 87% lower during infancy (1-11 months of age) than during the neonatal period (less than 1 month of age). For low birth weight children, during infancy the risk of dying that is lower than in the neonatal period, but it is still 23% to 91% higher than the risk of dying of normal birth weight children during the first month of life. Low birth children recover their mortality disadvantage compared to normal birth weight children only by the end of their fifth year of life. During childhood (1-5 years), the risk of dying for low birth weight children decreases to become only 3% to 25% lower than the risk of dying of normal birth weight children during the neonatal period.

[Table 4 about here]

Of the other covariates included in the model, only the number of visits at a prenatal clinic is systematically negatively associated with the risk of dying before age 5. Children whose mothers

were visited 1-3 times have a risk of dying before age 5 that is 3% to 47% lower than children whose mothers were not visited. If the mother was visited 4 or more times, the risk of dying before age 5 is 32% to 55% lower than if the mother was not visited.

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