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Research Article

What has high fertility got to do with the low birth weight problem in Africa?

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What has high fertility got to do with the low birth weight problem in Africa?

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Abstract

BACKGROUND
There has been much concern about adverse individual and societal consequences of high fertility in sub-Saharan Africa. One concern is that children of high birth orders may have low birth weight. However, the evidence for such an effect is not strong.

OBJECTIVE
Our objective is to investigate whether a woman's high parity status might increase her risks of having a baby with low birth weight.

METHODS
Pooling 60 Demographic and Health Surveys data-sets from 32 sub-Saharan countries, we selected children of mothers who had at least two births of order two or higher within the five years preceding the surveys. We modeled the probability of having a child with low birth weight and controlled for all mother-specific, household, or community characteristics that are constant over the period of analysis, by including fixed-effects for the mother. We also controlled for salient factors including sex, maternal age, preceding birth interval, and whether prenatal care was received.

RESULTS
We found no adverse effect of increasing parity on the odds of having a child with low birth weight at normative ranges; such effects only manifest at extremely high parities - nine or more children. At moderately high parities, the chance of low birth weight is actually lower than at very low parities.

CONCLUSIONS
While high fertility may lead to various adverse outcomes for African families, low birth weight appears not to be among these outcomes. Other factors, such as adolescent childbearing, poverty, and inadequate prenatal care may be more important determinants of low birth weight in Africa.

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1. Introduction

An infant's birth weight is determined by the amount of growth during pregnancy and the eventual gestational age – factors which are related to the infant's own genetic makeup, the mother's genetic makeup, her lifestyle, and her overall health (UNICEF 2004; Wilcox 2001). Very small neonates, particularly those weighing less than 2.5 kilograms (5.5 pounds) at birth, are characterized by poor health outcomes in later life. In particular, a child born with low birth weight is less prepared to fight infections due to its weaker immune system and is therefore more predisposed to infectious diseases such as diarrhea and respiratory infections (Ballot et al. 2010). For this and other reasons, children with low birth weight also tend to have high mortality. In addition, surviving low birth weight babies have higher risks of chronic diseases, inhibited cognitive development, and cardiac and metabolic disorders in adulthood; all of which may reduce their economic productivity (Bryce and Requejo 2008; Black, Devereux, and Salvanes 2005; Barker 2004; Black, Morris, and Bryce 2003; Barker et al. 2002; Wilcox 2001; Godfrey and Barker 2001; Ashworth 1998; Barker 1992; Low, Handley-Derry, and Burke 1992).

The number of children the mother has had is one of several sociodemographic factors that have been suggested to be related to the birth weights of her children. Studies in different populations consistently show elevated risks of low birth weight among first-born children than for the second-born children (Wilcox 2001; Wilcox, Chang and Johnson 1996). The findings are more mixed with respect to the risks at higher parities. For example, Seidman and colleagues (1991) found no adverse effects of high parity (five or more children) in Israel, while the conclusion from an investigation of 22 million mothers in the "Natality data file" gathered by the National Center for Health Statistics in the US was that increasing parity was associated with preterm deliveries, but less with small-for-gestational-age deliveries (Aliyu et al. 2005). When estimating the effect of parity, one obviously has to control for characteristics of the woman, her household, and the community that influence both fertility and the children's birth weight. Most commonly, earlier studies have taken into account factors such as maternal education or other socioeconomic indicators like age, race, ethnicity, marital status, and smoking habits. Health conditions and lifestyle preferences are among the potential joint determinants of fertility and birth weight that have been more difficult to statistically control. In this paper, we improve on previous literature on parity effects by controlling for all constant characteristics of the mother, her household (including the average level of socioeconomic resources during the relevant period), and the community, as well as some time-varying factors, in a fixed-effects regression framework. Our focus is on sub-Saharan Africa, which presents a context of high fertility and socioeconomic disadvantage. Fifteen percent of newborns in the region have low birth weight according to a conservative estimate (Blanc and Wardlaw 2005; UNICEF 2004). In deprived settings like sub-Saharan Africa, the daily physical labor, poor nutrition, poor sanitation, and inadequate health care availability and access generally result in mothers having poor health and inadequate pregnancy care (UNICEF 2004). Poor mothers in these settings are also exposed to indoor air pollutants through the use of poorer quality cooking fuel (Mishra et al. 2004). Nonetheless, there are only a few studies (often localized) from this region about the importance of parity for birth weights (Ozumba and Igwebe 1992; Oni 1986; Simpkiss 1968), none of them using this type of approach. We use pooled data on children born in the five years preceding 60 Demographic and Health Surveys (DHS) from 32 sub-Saharan African countries.

We proceed with an overview of the determinants of birth weight, describe the data and our analytical approach, present the results, and conclude with a discussion of the main findings.

2. Determinants of birth weight and estimation strategy

Birth weights below 3000g are considered sub-optimal, with the lower extreme end, below 2500g (5.5lb), having the most documented adverse health outcomes. On the upper end of the birth weight distribution, birth weights over 4000g are associated with increased maternal morbidity, complicated labor, and maternal death. Outcomes at the lower end of the birth weight scale most likely reflect intrauterine growth deprivation or conditions leading to preterm delivery, while the upper end reflects unusual fetal growth. Thus, there is an optimum birth weight range associated with trouble-free delivery, where neonatal survival is maximized and maternal death is minimized. Undeniably, the child’s genetic makeup affects the birth weight. In addition, the intrauterine environment is a critical determinant, as demonstrated for example in studies where embryos have been transferred to different mothers (Rice and Thapar 2010; Brooks et al. 1995).

The following factors, operating through these genetic and “environmental” channels, have been shown to be related to the birth weight: the sex of child - for the same gestational age boys tend to be heavier than girls (Kramer 1987); maternal age – infants born to adolescents and women above 35 years tend to be smaller (Sharma et al. 2008; Khoshwood 2005); maternal birth weight (Simon et al. 2006); maternal weight (Rice and Thapar 2010; Mahanty et al. 2006; Godfrey and Barker 1997; Brooks et al. 1995); maternal nutrition - cumulatively, and during pregnancy (Stephenson and Symonds 2002; Prentice et al. 1983); cigarette smoking (Magee, Hattis, and Kivel 2004); ethnicity (Blanc and Wardlaw 2005; Cogswell and Yip 1995); and socioeconomic conditions operating partly through some of the factors already mentioned (Cramer 1995). To elaborate on the latter effect, it has been shown in sub-Saharan Africa as well as other developing parts of the world, that poverty, low education, and women's lack of autonomy are related to limited or late initiation of obstetric care, irregular or incomplete immunization (e.g. against Tetanus infection), poor nutrition, and micronutrient supplementation during pregnancy (Spangler and Bloom 2010; Fotso, Ezeh, and Essendi 2009; Magadi, Agwandad, and Obare 2007; Onah, Ikeako, and Iloabachie 2006; Magadi, Madise, and Diamond 2001; Prentice et al. 1983). In addition, the length of the earlier birth intervals (those who have had many children are likely to have had them in short intervals) is important. A birth interval below two years tends to be a risk factor for a preterm or low birth weight delivery (Conde-Agudelo, Rosas-Bermudez, and Kafury-Goeta 2006; Smith, Pell, and Dobbie 2003; Zhu 2005; Zhu et al. 2001; Rawlings, Rawlings, and Read 1995).

Furthermore, some studies have shown that birth weights tend to be low at very low parities (Wilcox 2001) and then increase with parity up to a certain level, after which the marginal increases begin to dwindle and eventually give way to declines (Phung et al. 2003; Wilcox, Chang, and Johnson 1996; Cogswell and Yip 1995; Seidman et al. 1988). The exact parity level at which birth weights begin to decline appears to be context-specific and has not been widely studied (see MacLeod and Kiely 1988, for example). A possible reason for this negative effect of birth order on the birth weight is that the mother's health may have been weakened as a result of many pregnancies and years of caring for children. This idea is somewhat medically supported in that it is believed that the growth of the baby during pregnancy is affected by the mother's levels of hormones and insulin-like growth factors; which tend to reduce at very high parities (D'Ercole and Ye 2008; Skalkidou et al. 2003; Beyer 1999; Reece et al. 1994; Panagiotopoulou et al. 1990; Maccoby et al. 1979).

To delineate the effect of parity on low birth weight, one should ideally control for stable- and changing characteristics of the mother, her household and society that are causally behind or co-determined with parity and also potentially affecting the birth weight. Some of these factors—such as the child's sex, the mother's age, the length of earlier birth intervals, and whether or not the mother had prenatal services during the pregnancy—are measured in the DHS surveys and are included in the models. Measured and unmeasured characteristics that are constant can be effectively controlled for in a fixed-effects (within-mother) analysis. Examples are the mother's ethnicity, her birth weight, and her genetic constitution. Many aspects of her socioeconomic situation are also likely to remain relatively stable over time, at least over relatively short segments of her childbearing years. On the other hand, there are some time-varying unobserved factors that we cannot control for, most importantly the mother's weight, lifestyle preferences, health, and nutritional status (which is ultimately related to her health status). Not being able to control for maternal weight and health status is not necessarily a problem, however, as these factors have causal positions that are quite ambiguous. For example, women suffering from certain chronic diseases may not want or be able to have many children. If this is the case, maternal health status should be controlled for. On the other hand, poor health may be the result of having been through many pregnancies and having many children to care for. Likewise, maternal pre-pregnancy and pregnancy-related weight gain may reflect past pregnancy and childcare experiences. In other words, maternal weight and health status may be factors that parity may operate through (at least partially) in affecting the birth weight, and should not necessarily be controlled for.

3. Methods

3.1 Sample selection

Pooling 60 DHS data-sets from 32 sub-Saharan countries (see appendix for a list of the surveys), we selected children of mothers who had at least two births of order two or higher within the five years before the surveys. We excluded first births since our goal is to assess the impact of high fertility, which we define as childbearing beyond three births. Unfortunately, the birth weight is only reported for less than one-third of these births. This is primarily because of the large number of births that occur in homes and traditional informal clinics. When we leave out the mothers who did not have two children with reported birth weight in the five-year interval (as well as the few who had twins), we are left with 68,744 children (29% of the initial sample). Their characteristics are obviously not representative of all children in their countries (Blanc and Wardlaw 2005; Boerma et al. 1996). In particular, they are likely to come from socioeconomically advantaged families. The implications for our estimates are discussed later. Using births in the last five years of surveys did not seem to result in disproportionally selecting births of short birth intervals. The average time since last birth among the children born within the interval was 32 months, which is not particularly short by African standards (Rafalimanana and Westoff 2001). Birth weights tended to “heap” or cluster in multiples of 500g in most data-sets. In the sample, 5.6 percent of the births were heaped at exactly 2500g. Therefore, we estimated models for two outcomes, having a birth weight below 2500 g and having a birth weight less than or equal to 2500g.

3.2 Estimation

The fixed-effects logit model is as follows:

$$\log\left(\frac{P_{ij}}{1-P_{ij}}\right)=\beta M_{ij}+\delta X_{ij}+\mu_i$$

where P_{ij} is the probability that the child i (index of the child within the five-year observation window) of mother j has low birth weight, M_{ij} is a vector of birth order dummies (to allow for a flexible pattern in the relationship between birth order and birth weight rather than, for example, a linear effect), and X_{ij} is a vector of other related factors. β and δ are the corresponding coefficients. The X vector includes the sex of the child, maternal age at birth, preceding birth interval (in months*)*, and whether or not the mother had prenatal services during the pregnancy. The latter may generally reflect access to health facilities, which has implications both for fertility and birth weight. One might argue that the variable is also to some extent influenced by parity and thus a causally-intermediate factor. However, this is not a critical issue, as its inclusion had only minor impact on the parity-effect estimates (not shown in the tables). The unobserved constant mother-level characteristics are represented by μ_j. Only mothers with at least one child with low birth weight and at least one child without low birth weight are included in the model, because the others would not contribute to the likelihood estimation. This reduced the estimation sample to 5,385 infants when low birth weight is defined as less than 2500g and 8,227 infants when it is defined as less than or equal to 2500g.

Table 1: Percent distribution of variables in pooled sample of births in the five years before DHS surveys

	Entire sample with birth weight data	Sample with at least one LBW child (LBW < 2500g)	Sample with at least one LBW child (LBW≤ 2500g)
Wealth index			
Poorest	10.58	11.23	10.11
Poorer	13.39	13.00	14.48
Middle	15.57	15.97	16.30
Richer	21.79	20.98	21.49
Richest	38.67	38.81	37.62
Total	100.00	100.00	100.00
Education			
No school	30.45	35.10	34.93
Primary	44.23	44.70	44.67
Secondary and higher	25.31	20.21	20.40
Total	100.00	100.00	100.00
Parity			
2-4	66.77	62.51	62.57
5-6	19.23	22.36	21.58
7+	14.10	15.13	15.85
Total	100.00	100.00	100.00
Place of residence			
urban	43.11	45.55	43.71
Rural	56.89	54.45	56.29
Sex of child			
Boy	50.56	48.23	48.45
Girl	49.44	51.77	51.55
Prenatal care			
Had at least one prenatal visit	63.88	51.74	52.29
Had no prenatal visit	36.12	48.26	47.71
Maternal age at birth			
Under 20	7.65	5.78	5.92
20 - 34	80.44	80.44	80.92
35+	11.91	13.78	13.16
Mean age at birth	27.40 (5.8)*	27.98 (5.85)	27.88 (5.82)
Birth Interval			
More than or equal to 24 months	75.70	72.50	72.40
Less than 24 months	24.30	27.50	27.60
Mean birth interval (months)	32.09 (14.5)	32.27 (17.09)	32.09 (16.77)
Delivered at health facility	87.47	86.30	86.11
Proportion low birth weight	8.36 (< 2.5kg) 13.97 (≤ 2.5kg)	48.69	48.95
Number	68,744	5385	8227

Note: *Values in brackets are standard deviations.

4. Results

Table 1 provides the descriptive information on the demographic and socioeconomic characteristics, as well as the prevalence of low birth weight for the entire sample of children with birth weights and the two fixed-effects sub-samples. The distribution of the two fixed effects samples differed slightly from the general sample in a few areas. The children in the fixed effects samples had mothers who were slightly less educated (35 percent had no formal schooling compared to 30 percent in the entire sample). These mothers were also of higher parities and were less likely to have had prenatal care during pregnancies. By design, the proportion of children with low birth weight in the fixed effects sub-samples was much higher (48 and 49 percent in the samples with low birth weight defined as < 2500g and ≤ 2500g respectively) than in the whole sample, where it ranged from 8 percent to 14 percent depending on the definition applied.

Table 2: Fixed-effects logistic regression model predicting the occurrence of low birth weight among pooled DHS samples of children born in the preceding five years before the surveys

	Sample with LBW defined as birth weight < 2500g	Sample with LBW defined as birth weight ≤ 2500g
Parity		
Second	1.00	1.00
Third	0.94	0.91
Fourth	0.80	0.78*
Fifth	0.77	0.73*
Six	0.82	0.79
Seventh	1.04	0.93
Eighth	0.95	0.95
ninth	1.26	1.29
Tenth	1.69	1.74*
Age at birth		
Maternal age 20-34	1.00	1.00
Maternal age < 20	1.34†	1.25†
Maternal age ≥35	1.14	1.17
Sex of child		
Girl Child	1.00	1.00
Boy child	0.70***	0 .67***
Preceding birth interval		
More than or equal to 24 months	1.00	1.00
Less than 24 months	1.03	1.05
Prenatal Care		
Had no prenatal care	1.00	1.00
Had prenatal care	0.92	0.95
Number of births	5385	8227
Number of mothers	2548	3905

Note: † p < 0.10 ; * p<0.05; ** p<0.01; *** p<0.001.

The coefficients for the birth order dummy variables in the fixed-effects regressions in Table 2 show that the odds of low birth weight decrease with parity (significant only when low birth weight includes 2500g) and then increase at parities beyond eight (also significant only with this definition). We also note that the effects of the control variables were in the expected direction. Boys had significantly less risk of low birth weight than girls. Births during adolescence had significantly higher risks than between ages 20 and 34. When a mother had at least one prenatal visit during the pregnancy and birth intervals greater than 24 months, she had lower risks of having a child with low birth weight.

Can we generalize from these results?

As mentioned earlier, children with reported birth weights are not representative of all children in these countries. This could have the consequence that the effects of parity that we estimate are different from those we would have found if all children could be included. More specifically, such a bias would arise if the effect of parity on birth weight varies with certain factors that also affect the chance of being weighed. One such factor could be the socio-economic resources in the household. The relatively rich may, to a larger extent, be able to raise many children without experiencing the deterioration of the mother's health that might reduce the birth weight of later children, and they would also be more likely to give birth in hospitals and thus have their children weighed. In that case, we would see a less adverse effect of very high parity in our analysis than the one existing in the general population. To get an impression of the importance of these selection problems, we estimate the fixed effects models separately for various sub-samples of women who have different chances of having their children weighed at birth.

This analysis step includes three slightly different versions. In one, we consider rich and poor women. As mentioned, there are relatively many poor among those who are not included in our sample. In other words, if we could have included all children, we would have had a larger proportion of poor than we actually have in our sample, and the estimates would have been influenced by the greater number of poorer women. When we group the women into those among the 50% richest and those among the 50% poorest[3], we see that there are more beneficial effects of moderately high parity and less adverse effects of very high parity among the latter according to the fixed effects model (3rd and 4th column of Table 3). This pattern is contrary to what was suggested

[3] We calculated the relative wealth status of the mothers from household possessions and amenities using the conventional method of principal components analysis (see Rustein and Johnson 2004, Filmer and Pritchett 2001). The items included in the calculation were electricity, radio, television, refrigerator, motorcycle, car, bicycle, floor material, types of toilet facility and type of drinking water.

above, and we do not see any obvious explanation. Selection might, for example, be involved: the very few who have many children in spite of being rich may have certain characteristics that also lead to low birth weights. Whatever the explanation, however, the conclusion is that with a more representative sample, the estimates would have been more like what we see among the poorer women. In other words, it seems that we underestimate the advantage at moderate parities and overestimate the disadvantage at very high birth orders. (This argument hinges on the assumption that the difference between the top 50% richest and bottom 50% in our sample is representative of the difference between the rich and the poor in the entire population, i.e. that the same factors affect the chance of having a child weighed among the rich as among poor, or that – if there are such differences – the factors also have different effects on the birth weight.) The second version of our attempt to shed light on the selection problem, which considers the rural-urban distinction (5th and 6th column), leads to a similar conclusion: the over-representation of urban women in our sample seems to cause overestimation rather than underestimation of the adverse effect of high parity.

Table 3: Fixed effects regression results showing odds of low birth weight (<2500g) by "probability missing, W", relative wealth, and place of residence

Variables	W < 0.50	W ≥ 0.50	Poorer 50%	Richer 50%	Urban	Rural
Parity						
Two	1.00	1.00	1.00	1.00	1.00	1.00
Three	0.97	0.95	0.99	0.93	0.92	0.95
Four	1.15	0.69*	0.69	0.90	1.02	0.63*
Five	1.32	0.62*	0.60†	0.92	1.00	0.57*
Six	1.99	0.58*	0.59	1.05	1.41	0.49*
Seven	5.78**	0.57†	0.52	1.62	2.27*	0.51†
Eight	11.13**	0.42*	0.28*	1.94	3.00*	0.36*
Nine	9.59**	0.60	0.32	2.94	3.90*	0.46
Ten	12.82**	0.83	0.49	3.21*	5.61**	0.54
Maternal age 20-34	1.00	1.00	1.00	1.00	1.00	1.00
Maternal age < 20	1.49	1.019	1.29	1.45†	1.54†	1.21
Maternal age ≥35	1.11	1.571	1.15	1.35†	0.98	1.26
Girl	1.00	1.00	1.00	1.00	1.00	1.00
Boy	0.65***	0.71***	0.71***	0.69***	0.68***	0.71***
Birth interval ≥24 months	1.00	1.00	1.00	1.00	1.00	1.00
Birth Interval <24 months	1.00	1.12	1.03	1.03	1.01	1.04
Had no prenatal care	1.00	1.00	1.00	1.00	1.00	1.00
Had some prenatal care	0.74*	0.93	1.00	0.86†	0.81*	1.04
N	1725	3660	1838	3547	2453	2932

Note: † p < 0.10 ; * p<0.05; *** p<0.001; Regression equation for generating "probability missing" include, wealth index, educational level, and rural/urban place of residence.

The third version can be seen as a generalization of the two others. We first estimated a model for the chance that a mother does not have her child weighed at birth. This model included the following variables: her relative wealth position, educational level, and whether she lives in an urban area or not. Using the estimated coefficients, we predicted the chance W of not having the child weighed for each mother included in our fixed-effects analysis (that is for those whose children were actually weighed). We then estimated the fixed-effects models for subgroups of women with different levels of W to see if there were different estimates at lower levels of W than at higher levels. The results are shown in the 2nd and 3rd columns of Table 3 for two groups, $W < 0.5$ and $W \geq 0.5$. We see that, when there is a high chance of not having a child weighed, there are stronger advantages at moderately high parities or birth orders and less adverse effects of very high parity. Therefore, if more children could have been included in our analysis, the estimates would have moved in this direction, just as concluded based on the distinctions between rich and poor and between urban and rural.

5. Discussion and conclusions

In this study, we explored the relationship between a woman's parity and her chances of having a child with low birth weight. The data were based on a pooled sample of births of mothers who had multiple births in the five years preceding African DHS surveys. Our fixed-effects regression models controlled for all stable characteristics of the mother, including the average amount of socioeconomic resources over the five-year observation period, as well as some time-varying or child-specific factors. The results show a pattern of decreasing risk of low birth weight deliveries comparing birth orders 3-8 to second births, followed by an increase at higher birth orders. This was seen most clearly when low birth weight was defined to include 2500g. A decline at moderate parities has also been reported in earlier studies, though there is always doubt about whether these studies adequately controlled for joint determinants of fertility and birth weight.

In principle, the fixed-effects estimates may be biased. Unobserved time-varying characteristics of the mother, her household or the community that lead her to have, say, a 9th child, and also increase the chance of a low birth weight, could be responsible for the observed adverse effects at very high parities. An example may be the deterioration of health institutions over the five year period, which has implications for contraceptive services and prenatal care. Alternatively, if there are time-varying factors producing both high fertility and *high* birth weights, the true effect of very high birth order would be even more adverse than suggested by our estimates. Furthermore, our sample is not representative of the populations considered as birth weights were recorded for a relatively small fraction of births in these populations. Our attempts to understand the implications of the selective nature of the birth weight data on our estimates suggest that we may have overestimated the adverse effects of very high parities and underestimated the advantage at more moderate levels.

There are very few women in sub-Saharan Africa who have nine or more children, so unless the estimates are strongly biased downwards by unobserved time-varying factors, it seems that the low birth weight problem in sub-Saharan Africa is not a consequence of the prevalent high fertility in the region. On the contrary, the large proportion of births of moderately high orders in sub-Saharan Africa may serve to reduce the average chance of low birth weight in these populations. In other words, while high fertility may well lead to various adverse outcomes for African families and societies (which has been the impetus for many population policies over the years), low birth weight appears not to be among these outcomes.

Poverty and low levels of education, which have been shown to be important determinants in other contexts (Janevic et al. 2010, Collins et al. 2009; Conley and Bennett 2001), are probably more important reasons for the high prevalence low birth weights in Africa. Additional risk factors, not only caused by lack of socioeconomic resources, are the use of inferior energy sources for indoor cooking (Mishra et al. 2004), early childbearing, and inadequate access to prenatal health services (though the better access in urban areas seems to be more than outbalanced by various disadvantages, leading to a higher prevalence of low birth weight in cities than in rural areas in sub-Saharan Africa; Ezeh, Kodzi, and Emina 2010). Expansion of health services, especially to poor women, would reduce the incidence of low birth weight babies in the region, and such efforts would also serve to improve the quality and coverage of data on birth outcomes.

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References

Aliyu, M., Salihu, H.M., Keith, L.G., Ehiri, J.E., Islam, A., and Jolly, P. (2005). High parity and fetal morbidity outcomes. *Obstetrics* & *Gynecology* 105(5): 1045-1051. doi:10.1097/01.AOG.0000157444.74674.75.

Ashworth, A. (1998). Effects of intrauterine growth retardation on mortality and morbidity in infants and young children. *European Journal of Clinical Nutrition* 52(Suppl 1): S34-41.

Ballot, D.E., Chirwa, T.F., and Cooper, P. (2010). Determinants of survival in very low birth weight neonates in a public hospital in Johannesburg. *BMC Pediatrics* 10(1): 1-11. doi:10.1186/1471-2431-10-30.

Barker, D.J.P. (1992). *Fetal and Infants origins of disease*. London: BMJ Books.

Barker, D.J.P. (2004). Developmental origins of adult health and diseases. *Journal of Epidemiology and Community Health* 58(2):114-115. doi:10.1136/jech.58.2.114.

Barker, D.J.P., Eriksson, J.G., Forsen, T., and Osmond, C. (2002). Fetal origins of adult disease: Strength of effect and biological basis. *International Journal of Epidemiology* 31(6): 1235-1239. doi:10.1093/ije/31.6.1235.

Beyer, C. (1999). Estrogen and the developing mammalian brain. *Anatomy and Embryology* 199(5): 379-390. doi:10.1007/s004290050236.

Black, R.E., Morris, S.S., and Bryce, J. (2003). Where and why are 10 million children dying every year? *The Lancet* 361(9376): 2226-2234. doi:10.1016/S0140-6736(03)13779-8.

Black, S.E., Devereux, P.J., and Salvanes, K.G. (2005). From the Cradle to the Labor Market? The effect of Birth weight on adult outcomes. IZA Discussion Paper Series. (Number 1864).

Blanc, A.K. and Wardlaw, T. (2005). Monitoring low birth weight: An evaluation of international estimates and an updated estimation procedure. *Bulletin of the World Health Organization* 83(3): 178-185. doi:10.1590/S0042-96862005000300010.

Boerma, T.J., Weinstein, K.I., Rutstein, S.O., and Sommerfelt, E. (1996). Data on birth weight in developing countries: Can surveys help? *Bulletin of the World Health Organization* 74(2): 209-216.

Brooks, A.A., Johnson, M.R., Steer, P.J., Pawson, M.E., and Abdalla, H.I. (1995). Birth weight: Nature or nurture? *Early Human Development* 42(1): 29-35. doi:10.1016/0378-3782(95)01637-I.

Bryce, J. and Requejo, J.H. (2008). Countdown to 2015. Tracking progress in maternal, newborn and child survival: The 2008 Report. New York: UNICEF.

Cogswell, M.E. and Yip, R. (1995). The influence of fetal and maternal factors on the distribution of birth weights. *Seminars in Perinatology* 19(3): 222-240. doi:10.1016/S0146-0005(05)80028-X.

Collins, J.W., Wambach, J., David, R.J., and Rankin, K.M. (2009). Women's lifelong exposure to neighborhood poverty and low birth weight: A population-based study. *Maternal and Child Health Journal* 13(3): 326-333. doi:10.1007/s10995-008-0354-0.

Conde-Agudelo, A., Rosas-Bermudez, A., and Kafury-Goeta, A.C. (2006). Birth Spacing and Risk of Adverse Perinatal Outcomes. *Journal of American Medical Association* 295(15): 1809-1823. doi:10.1001/jama.295.15.1809.

Conley, D. and Bennett, N.G. (2001). Birth weight and income: Interactions across generations. *Journal of Health and Social Behavior* 42(4): 450-465. doi:10.2307/3090189.

Cramer, J.C. (1995). Racial and ethnic difference in birth weight: The role of income and financial assistance. *Demography* 32(2): 231-247. doi:10.2307/2061742.

D'Ercole, J.A. and Ye, P. (2008). Expanding the mind: Insulin-Like Growth Factor I and brain development. *Endocrinology* 149(12): 5958-5962. doi:10.1210/en.2008-0920.

Ezeh, A.C., Kodzi, I., and Emina, J. (2010). Reaching the urban poor with family planning services. *Studies in Family Planning* 41(2): 109-116. doi:10.1111/j.1728-4465.2010.00231.x.

Filmer, D. and Pritchett, L.H. (2001). Estimating wealth effects without expenditure data – or tears: An application to education enrollments in states of India. *Demography* 38(1): 115-132. doi:10.1353/dem.2001.0003.

Fotso, J.-C., Ezeh, A., and Essendi, H. (2009). Maternal health in resource-poor urban settings: How does women's autonomy influence the utilization of obstetric care services? *Reproductive Health* 6(9): 1-8. doi:10.1186/1742-4755-6-9.

Godfrey, K.M. and Barker, D.J. (1997). Maternal birthweight and diet in pregnancy in relation to the infant's thinness at birth. *British Journal of Obstetrics and Gynecology* 104(6): 663-667. doi:10.1111/j.1471-0528.1997.tb11975.x.

Godfrey, K.M. and Barker, D.J. (2001). Fetal programming and adult health. *Public Health Nutrition* 4(2b): 611-624. doi:10.1079/PHN2001145.

Janevic, T., Stein, C.R., Savitz, D.A., Kaufman, J., Mason, S.M., and Herring, A.H. (2010). Neighborhood deprivation and adverse birth outcomes among diverse ethnic groups. *Annals of Epidemiology* 20(6): 445-451. doi:10.1016/j.annepidem.2010.02.010.

Khoshwood, B. (2005). Risk of low birth weight associated with advanced maternal age among four ethnic four ethnic groups in United States. *Maternal and Child Health Journal* 9(1): 3-9. doi:10.1007/s10995-005-2446-4.

Kramer, M.S. (1987). Determinants of low birth weight: Methodological assessment and meta-analysis. *Bulletin World Health Organization* 65: 663-737.

Low, J., Handley-Derry, M., and Burke, S. (1992). Association of intrauterine fetal growth retardation and learning deficits at age 9 to 11. *American Journal of Obstetrics and Gynecology* 167(6): 1499-1505.

Maccoby, E.E., Doering, C.H., Jacklin, C.N., and Kraemer, H. (1979). Concentration of sex hormones in umbilical cord blood: Their relation to sex and birth order of infants. *Child Development* 50(3): 632-642. doi:10.2307/1128928.

MacLeod, S. and Kiely, J.L. (1988). The effect of maternal age and parity on birthweight: A population-based study in New York City. *International Journal of Gynecology and Obstetrics* 26(1): 11-19. doi:10.1016/0020-7292(88)90191-9.

Magadi, M., Madise, N., and Diamond, I. (2001). Factors Associated with unfavourable birth outcomes in Kenya. *Journal of Biosocial Science* 33(2): 199-225. doi:10.1017/S0021932001001997.

Magadi, M.A., Agwandad, A.O., and Obare, F.O. (2007). A comparative analysis of the use of maternal health services between teenager and older mothers in sub-Saharan Africa: Evidence from the Demographic and Health Surveys. *Social Science and Medicine* 64(6): 1311-1325. doi:10.1016/j.socscimed.2006.11.004.

Magee, B.D., Hattis, D., and Kivel, N.M. (2004). Role of smoking in low with weight. *Journal of Reproductive Medicine* 49(1): 23-27.

Mahanty, C., Prasad, R., Reddy, S., Ghosh, J.K., Singh,T.B., and Das, B.K. (2006). Maternal anthropometry as predictors of low birth weight. *Journal of Tropical Pediatrics* 52(1): 24-29. doi:10.1093/tropej/fmi059.

Mishra, V., Dai, X., Smith, K., and Mika, L. (2004). Maternal exposure to biomass smoke and reduced birth weight in Zimbabwe. *Annals of Epidemiology* 14(10): 740-747. doi:10.1016/j.annepidem.2004.01.009.

Onah, H.E., Ikeako, L.C., and Iloabachie, G.C. (2006). Factors associated with the use of maternal services in Enugu, Nigeria. *Social Science and Medicine* 63(7): 1870-1878. doi:10.1016/j.socscimed.2006.04.019.

Oni, G.A. (1986). The effects of maternal age, education and parity on birth weight in a Nigerian community. The comparison of results from bivariate and multivariate analyses. *Journal of Tropical Pediatrics* 32(6): 295-300. doi:10.1093/tropej/32.6.295.

Ozumba, B.C. and Igwegbe, A.O. (1992). The challenge of grandmultiparity in Nigerian obstetric practice. *International Journal of Gynecology and Obstetrics* 37(4): 259-264. doi:10.1016/0020-7292(92)90326-E.

Panagiotopoulou, K., Katsouyanni, K., Petridou E., Garas, Y., Tzonou, A., and Trichopoulos, D. (1990). Maternal age, parity, and pregnancy estrogens. *Cancer Causes and Control* 1(2): 119-124. doi:10.1007/BF00053162.

Phung, H., Bauman, A., Nguyen T.V., Young L., Tran, M., and Hillman, K. (2003). Risk factors for low birth weight in a socio-economically disadvantaged population: Parity, marital status, ethnicity and cigarette smoking. *European Journal of Epidemiology* 18(3): 235-243. doi:10.1023/A:1023384213536.

Prentice, A.M., Whitehead, R.G., Watkinson, M., Lamb, W.H., and Cole, T.J. (1983). Prenatal dietary supplementation of African women and birth-weight. *The Lancet* 321(8323): 489-492. doi:10.1016/S0140-6736(83)92188-8.

Rafalimanana, H. and Westoff, C.F. (2001). Gap between Preferred and Actual Birth Intervals in Sub-Saharan Africa: Implications for Fertility and Child Health. Calverton, Maryland: ORC Macro (DHS Analytical Studies No. 2).

Rawlings, J.S., Rawlings V.B., and Read, J.A. (1995). Prevalence of low birth weight and preterm delivery in relation to the interval between pregnancies among white and black women. *The New England Journal of Medicine* 332: 69-74. doi:10.1056/NEJM199501123320201.

Reece, A.E., Wizniter, A., Le, E., Homko, C.J., Behrman, H., and Spencer, E.M. (1994). The relation between human fetal growth and fetal blood levels of insulin-like growth factors I and II, their binding proteins, and receptors. *Obstetrics and Gynecology* 84(1): 88-95.

Rice, F. and Thapar, A. (2010). Estimating the relative contributions of maternal genetic, paternal genetic intrauterine factors to offspring birth weight and head circumference. *Early Human Development* 86(7): 425-432. doi:10.1016/j.earlhumdev.2010.05.021.

Rustein, S.O. and Johnson, K. (2004). The DHS wealth index. Calverton, Maryland: ORC Macro (DHS Comparative reports No 6).

Seidman, D.S., Dollberg, S., Stephenson, D., and Gale, R. (1991). The effects of high parity and socioeconomic status on obstetric and neonatal outcome. *Archives of Gynecology and Obstetrics* 249(3): 119-127. doi:10.1007/BF02391578.

Seidman, D.S., Ever-Hadani, P., Stevenson, D., Slater, P., Harlap, S., and Gale, R. (1988). Birth order and weight re-examined. *Obstetrics and Gynecology* 72(2): 158-162.

Sharma, V., Katz, J., Mullany, L.C., Khatry, S.K., LeClerq, S.C., Shrestha, S.R., Darmstadt, G.L., and Tielsch, J.M. (2008). Young maternal age and the risk of mortality in Rural Nepal. *Archives of Pediatrics & Adolescent Medicine* 162(9): 828-835. doi:10.1001/archpedi.162.9.828.

Simon, D.M., Vyas, S., Prachand, N.G., David, R.J., and Collins, J.W.Jr. (2006). Relation of maternal low birth weight to infant growth retardation and prematurity. *Maternal and Child Health Journal* 10(4): 321-327. doi:10.1007/s10995-005-0053-z.

Simpkiss, M.J. (1968). Birth weight, maternal age, parity among the African population of Uganda. *British Journal of Preventive and Social Medicine* 22(4): 234-237. doi:10.1136/jech.22.4.234.

Skalkidou, A., Petridou, E., Papathoma, E., Savanos, H., Kedikoglou, S., Chrousos, G., and Trichopoulos, D. (2003). Determinants and consequences of major insulin-like growth factor components among full-term healthy neonates. *Cancer Epidermiology Biomakers Prevevention* 12: 860-865.

Smith, G.C., Pell, J.P., and Dobbie, R. (2003). Interpregnancy interval and risk of preterm birth and neonatal death: Retrospective cohort study. *British Medical Journal* 327(7410): 313. doi:10.1136/bmj.327.7410.313.

Spangler, S.A. and Bloom, S. (2010). Use of biomedical obstetric care in rural Tanzania: The role of social and material inequalities. *Social Science and Medicine* 71(4): 760-768. doi:10.1016/j.socscimed.2010.05.025.

Stephenson, T. and Symonds, M.E. (2002). Maternal nutrition as a determinant of birth weight. *Arch Dis Child Fetal Neonatal Ed* 86: F4-F6. doi:10.1136/fn.86.1.F4.

United Nations Children's Fund and World Health Organization (2004). Low Birthweight: Country, regional and global estimates. UNICEF.

Wilcox, A.J. (2001). On the importance – and the unimportance – of birthweight. *International Journal of Epidermiology* 30(6): 1233-1241. doi:10.1093/ije/30.6.1233.

Wilcox, A., Chang, A.M., and Johnson, I.R. (1996). The effects of parity on birth weight using successive pregnancies. *Acta Obstetricia et Gynecologica Scandinavica* 75(5): 459-463. doi:10.3109/00016349609033354.

Zhu, B.P. (2005). Effects of interpregnancy interval on birth outcomes: Findings from three recent US studies. *International Journal of Gynecology and Obstetrics* 89(1): S25-S33. doi:10.1016/j.ijgo.2004.08.002.

Zhu, B.P., Haines, K.M., Le, T., McGrath-Miller, K., and Boulton, M.L. (2001). Effect of the Interval Between Pregnancies on Perinatal Outcomes among White and Black Women. *American Journal Obstetrics and Gynecology* 185(6): 1403-1410. doi:10.1067/mob.2001.118307.

Appendix

Selected DHS surveys in pooled data-set

Country	Year of survey	Country	Year of survey
Benin	1996	Madagascar	2008
Benin	2001	Malawi	2000
Benin	2006	Malawi	2004
Burkina-Faso	1998-99	Mali	1995-96
Burkina-Faso	2003	Mali	2001
Cameroon	1998	Mali	2006
Cameroon	2004	Mozambique	1997
Central African Republic	1994-95	Mozambique	2003
Chad	1996-97	Namibia	2000
Chad	2004	Namibia	2006-07
Comoros	1996	Niger	1998
Congo	2007	Niger	2006
Congo-Brazzaville	2005	Nigeria	2003
Cote D'Ivoire	1994	Nigeria	2008
Cote D'Ivoire	1998	Rwanda	2000
Ethiopia	2000	Rwanda	2005
Ethiopia	2005	Senegal	2005
Gabon	2000	Sierra-Leone	2008
Ghana	1998	Swaziland	2006
Ghana	2003	Tanzania	1996
Ghana	2008	Tanzania	1999
Guinea	1999	Tanzania	2004
Guinea	2005	Togo	1998
Kenya	1999	Uganda	2000-01
Kenya	2003	Uganda	2006
Kenya	2008-09	Zambia	2001
Lesotho	2004	Zambia	2007
Liberia	2007	Zimbabwe	1994
Madagascar	1997	Zimbabwe	1999
Madagascar	2003	Zimbabwe	2005