Pre-pregnancy body mass and weight gain during pregnancy in India & sub-Saharan Africa

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Abstract

Despite being wealthier, Indian children are significantly shorter and smaller than African children. These differences begin very early in life, suggesting that they may in part reflect differences in maternal health. By applying reweighting estimation strategies to the Demographic and Health Surveys, this paper reports the first representative estimates of pre-pregnancy BMI and weight gain during pregnancy for India and sub-Saharan Africa. I find that 42.2% of pre-pregnant women in India are underweight, compared with 16.5% of pre-pregnant women in sub-Saharan Africa. Levels of pre-pregnancy underweight for India are almost 7 percentage points higher than the average fraction underweight among women 15 to 49 years old. This difference in part reflects a previously unquantified relationship among age, fertility and underweight; childbearing is concentrated in the narrow age range in which Indian women are most likely to be underweight. Further, because weight gain during pregnancy is low, averaging about 7 kilograms for a full term pregnancy in both regions, the average woman in India *ends* pregnancy weighing less than the average woman in sub-Saharan Africa *begins* pregnancy. Poor maternal health among Indian women is of global significance because India is home to one fifth of the world's births.

Significance: Because India–home to one fifth of all births–has no monitoring system for maternal health, basic facts about maternal nutrition are unknown. Using statistically adjusted nationally representative survey data, this paper presents the first estimates of pre-pregnancy body mass and weight gain during pregnancy in India and compares them to sub-Saharan Africa. 42.2% of Indian women are underweight when they begin pregnancy, compared to 16.5% of African women. In both regions, women gain little weight during pregnancy, but because of pre-pregnancy deficits Indian women end pregnancy weighing less than African women do at the beginning. Deficits in maternal nutrition could help explain the "Asian enigma," the puzzle of why Indian children are much smaller than their relative wealth predicts.

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1 Introduction

Children in India are significantly shorter and smaller than children in sub-Saharan Africa. Because Indian children are much richer, on average, than African children, scholars have described anthropometric differences between Indians and Africans as an "Asian enigma" [1]-[4]. Although there are likely many reasons why Indian children are shorter than African children [5]-[6], and why Indian children are shorter than economic indicators predict, demographic and health surveys show that physical differences between Indian and African children begin very early in life, suggesting that the Asian enigma may in part reflect differences in maternal health. That Indian women have worse health during pregnancy than African women is also consistent with an anomalously high rate of neonatal mortality in India, as well as high rates of low birth weight, even among relatively privileged groups [7]. Poor maternal health and nutrition among Indian women is of global significance because India is home to one sixth of the world's population and one fifth of the world's births.

In recent decades, India has experienced rapid economic growth and significant reductions in poverty. Despite this economic success, however, measures of women's nutrition remain exceptionally poor. The latest Demographic and Health Survey (DHS), in 2005, showed that 35.5% of women aged 15-49 are underweight, suggesting that maternal health and nutrition are extremely also poor. India's high rate of underweight among women is worrisome in light of mounting evidence that nutrition during pregnancy is important not only for neonatal survival, but also for birth weight [8]-[9], which is associated with height and health in childhood and adulthood [10]-[13], as well cognition and productivity [14]-[17].

Pre-pregnancy body mass and weight gain during pregnancy are useful measures of maternal nutrition. These factors interact to determine birth weight: on average, women with lower pre-pregnancy body mass need to gain more weight during pregnancy in order to deliver infants of the same birth weight as women who start pregnancy with higher body mass [18], [19]. The Institute of Medicine guidelines for women in the United States recommend higher weight gain during pregnancy for women with a pre-pregnancy body mass index (BMI), or ratio of weight in kilograms to height in meters squared, of less than 18.5 [19].

What are average pre-pregnancy BMI and weight gain during pregnancy in India, and how do these figures compare to those in sub-Saharan Africa? These basic nutrition facts are unknown because no representative longitudinal monitoring systems exist for these regions. This paper's primary contribution is to produce the first representative estimates of pre-pregnancy BMI and weight gain during pregnancy for India and sub-Saharan Africa.

To estimate pre-pregnancy BMI, I adjust the BMIs of non-pregnant women for selection into pregnancy based on observable characteristics of pregnant women. I find that in India, 42.2% of pre-pregnant women are underweight; this figure is about 7 percentage points higher than the average fraction underweight among women 15 to 49 years old. These estimates constitute a significant contribution to the literature because they show that commonly cited figures for *average* women's nutrition in India [1], [20], [21] significantly underestimate the fraction of *pre-pregnant* women who are underweight and overestimate average pre-pregnancy BMI. About half of the difference between the prevalence of women's underweight and the prevalence of pre-pregnancy underweight can be attributed to previously unquantified age patterns of fertility and undernutrition that are likely due to pronounced sex and age hierarchies in Indian households. Such hierarchies have been documented and studied by demographers, sociologists and anthropologists [22]-[24]. In contrast, in the much poorer African sample, only 16.5% of pre-pregnant women are underweight.

Empirical distributions of the weights of pregnant women show that Indian women do not compensate for low pre-pregnancy body mass by gaining adequate weight during pregnancy. Indeed, on average, women in India *end* pregnancy weighing less than women in sub-Saharan Africa *begin* pregnancy.

Women in both India and sub-Saharan Africa gain only about 7 kilograms, on average, for a full term pregnancy. Two different methods confirm these results. Such a small weight gain is only about half of the minimum recommended gain for underweight women in the United States, for whom national guidelines recommend gaining between 12.5 and 18 kilograms during pregnancy. It is only about 60% of the minimum recommended gain for normal weight women, for whom the guidelines recommend gaining between 11.5 and 16 kilograms [19].

2 Summary statistics

Table 1 shows that the 2005 Indian GDP per capita was twice the GDP per capita of sub-Saharan Africa, and the Indian population was 1.45 times as large [25]. The 2005 poverty headcount ratio, using the World Bank's $1.25 per day poverty line, was lower in India than sub-Saharan Africa [26]. Further, the 2005 total fertility rate (TFR) in India was considerably lower than in sub-Saharan Africa; the Population Reference Bureau estimates an India TFR of 3.0, compared to 5.6 for sub-Saharan Africa [27].

Table 1 also provides information on the samples used for the analysis. The sample of African countries is restricted to those 29 countries with a DHS that measured women's weights between 2000 and 2010; these are listed in table 2. Sample countries from sub-Saharan Africa represent about 80% of the population of the region and are poorer than the region as a whole.

3 What fraction of pre-pregnant women are underweight?

It is common to cite the fraction of women who are underweight (BMI<18.5) as a proxy for pre-pregnancy undernutrition. However, if women who get pregnant are younger, less educated, or otherwise different from those who do not, and if these differences are correlated with body mass, then average BMI and fraction underweight among non-pregnant women of childbearing age in a representative cross section will give biased estimates of pre-pregnancy nutrition measures.

Are Indian women who become pregnant different from those who do not, in ways that correlate with nutrition? Figure 1 plots the fraction of non-pregnant women who are underweight at each age, as well as the fraction of women who are pregnant at each age. The Indian data, in red, show a statistically significant ($P < 0.001$) negative relationship between age and the probability of being underweight: women in their early 20s are almost 15 percentage points more likely to be underweight than 40 year old women. The early 20s are also the time when Indian women are most likely to be pregnant, leading to a concentration of childbearing during a nutritionally vulnerable period. This finding coincides with a prior literature that suggests that young Indian women have particularly low social status early in their marriages [23]. This has negative consequences for their own health and the health of their children [22].

The Indian data contrast sharply with those for sub-Saharan Africa. The solid blue curve in figure 1 shows a quadratic relationship between age and underweight ($P < 0.001$) among African women. African women in their early 20s are about 25 percentage points less likely to be underweight than Indian women in the same age range. In sub-Saharan Africa, fertility levels, shown with dashed curves, are much higher and childbearing is spread out between the ages of about 17 and 35, rather than being concentrated in the early 20s.

To estimate pre-pregnancy BMI and fraction underweight, I construct a non-parametric reweighting function to compute what the BMIs of non-pregnant women would be if they had the same distribution of observable characteristics as pregnant women. Table 3 presents means and cluster bootstrapped confidence intervals resulting from statistical reweighting. For comparison, the first rows of panel A and B show average BMI and fraction underweight for non-pregnant women aged 15 to 49. The second rows of these panels show the results of reweighting by only the age structure of pregnant women, in years. Age reweighting makes a difference for India: BMI adjusted for the age profile of pregnancy is 0.7 points lower than that of the average woman, and the adjusted fraction underweight is 3.5 percentage points higher than the unadjusted fraction. Adjustment for the age pattern of pregnancy in sub-Saharan Africa shows that non-pregnant women with the same age distribution as pregnant women have similar average anthropometric outcomes as non-pregnant women.

The third rows of panels A and B of table 3 show the results of an extended statistical reweighting, which splits the sample of non-pregnant women in each region into mutually exclusive bins in order to account for differences between pregnant and non-pregnant women in age, education, urban/rural residence, the number of living children, the age of the youngest living child, whether she has at least one living son, and whether one or more of her children has died in the past five years. These factors were chosen for inclusion in the reweighting function because demographers have linked them to fertility [28]-[34], and they are also plausibly correlated with body mass. Summary statistics for these covariates, as well as linear probability regressions showing that they predict pregnancy are shown in tables **??** and **??**.

The results of the extended reweighting of fraction underweight in panel B of table 3 show that 42.2% of pre-pregnant women in India are underweight, cluster bootstrapped 95% CI = [0.410, 0.432], compared with 16.5% in sub-Saharan Africa, cluster bootstrapped 95% CI = [0.157, 0.174]. The average pre-pregnant woman in India is about 7 percentage points more likely to be underweight than the average woman between the ages of 15 and 49. In sub-Saharan Africa, in contrast, the average fraction underweight and the fraction of pre-pregnant women who are underweight are very similar.

Only those non-pregnant women who are not using modern contraception at the time of the interview are used to compute the results of the extended reweighting. Because the Indian DHS collected data on contraceptive use histories, it is possible to check the assumption of a zero failure rate of contraception by statistically reweighting over the characteristics described above, as well as an indicator for whether non-pregnant women are using modern contraception. The results, shown in table 3, change very little, which is expected considering that only 4% of pregnant women in the Indian sample were using modern contraception in the month of conception. This specification is not shown for the African sample because only 9 of the 29 surveys collected contraceptive use histories. In those countries where contraceptive use histories were collected, only 5% of pregnant women were using modern contraception in the month of conception.

The *Materials and methods* section provides further details about the reweighting functions used to generate the results in table 3.

4 Do Indian women compensate for low pre-pregnancy body mass with weight gain during pregnancy?

Prior research on weight gain during pregnancy in India studies small samples of women, which are not intended to be representative of the population [35]-[37]. In order to estimate average weight gain for full term pregnancies in the population, this paper uses two strategies: the first compares the weights of women in early pregnancy with those of women in late pregnancy, and the second compares the weights of non-pregnant women, adjusted for selection, with weights of women in late pregnancy.

Before turning to model-based estimates of weight gain during pregnancy, figure 2 plots distributions of weights of pregnant and pre-pregnant women in India and sub-Saharan Africa. Everywhere in the weight distribution, Indian women *end* pregnancy weighing less than African women do when they *begin* pregnancy. Each red or blue curve in figure 2 shows an empirical cumulative distribution (CDF) of weight in kilograms (panel A) or BMI (panel B) for women at 3, 6 or 9+ months of gestation. If, except for differences in gestational age, women who report early pregnancy are similar to those who report late pregnancy, then the horizontal distance between CDFs of the same color provides a visual description of weight gain during the second and third trimesters.

The black curves in figure 2 show estimated CDFs of pre-pregnancy weight and BMI, computed using the extended reweighting function on the sample of non-pregnant, non-contracepting women discussed in the previous section. For Indian women, the estimated pre-pregnancy CDFs are very close to the empirical distributions for women at 3 months gestation. For African women, the CDFs of estimated pre-pregnancy weight and BMI are slightly to the left of the 3 month distributions. The larger gap between the pre-pregnancy distribution and the 3 mo distribution for sub-Saharan Africa suggests that African women may gain more weight in the first trimester than Indian women. Figure 3 presents additional estimates of pre-pregnancy weight distributions that were calculated by modeling the association between body weight and gestational age, individual characteristics, and their interactions in cross sections of pregnant women.

Panel C of table 3 presents several estimates for mean pre-pregnancy weight, computed using the same methods described above for pre-pregnancy BMI and underweight. Panel D of table 3 shows estimated means and confidence intervals for weight gain during pregnancy for India and sub-Saharan Africa. The confidence intervals on weight gain for all four estimation strategies overlap within and across regions, demonstrating that despite very different pre-pregnancy BMIs, women in India and sub-Saharan Africa gain similar amounts of weight during pregnancy.

Estimates labeled "method one" are computed using OLS regressions of weight in kilograms on month of gestation for women three or more months pregnant. These regressions estimate average monthly weight gain. Linear modeling of these data is appropriate because weight gain during pregnancy is known to follow a linear pattern at these gestational ages [38]-[40]. Assuming that first trimester gain is 10% of second and third trimester gain [19], average weight gain for a full term pregnancy is estimated as $1.1 \times 6 \times \hat{\beta}$, where $\hat{\beta}$ is the coefficient on month of gestation from the regression.

Table 3 presents two ways of estimating weight gain during pregnancy using OLS regression. The first row of panel D, labeled "method one, no controls," shows estimated weight gains using uncontrolled regressions of weight on month of gestation. The second row, labeled "method one, extended controls," shows estimated weight gains using coefficients from regressions that control for factors related to selection into reported month of gestation, including age, years of schooling, number of living children, urban residence, and wealth quintile interacted with country. Dummy variables for the interaction of DHS sample region with month of interview are also included. Table **??** shows the regression table associated with the "method one" estimates from panel D of table 3, as well as weight gain estimates from additional regression specifications.

Estimates labeled "method two" in panel D of table 3 compute weight gain by comparing the weights of pregnant women who report 9+ months of gestation with the weights of non-pregnant women, adjusted for selection into pregnancy using the extended reweighting function used to compute pre-pregnancy BMI and fraction underweight. To account for the fact that women who report 9+ months of pregnancy will continue to gain weight until they deliver, these differences are adjusted upward by $\frac{1}{2}\hat{\beta}$, where $\hat{\beta}$ is average monthly gain estimated from the controlled regression described above. In panel D of table 3, the results labeled "method two, reweight with pregnant women" use the characteristics of pregnant women in the reweighting function; the results labeled "method two, reweight with women who delivered last year" use characteristics, from the time of conception, of women who delivered a live infant in the year prior to the survey. The results of these two strategies would differ if rates of terminated pregnancies (due either to miscarriage or abortion) or pre-term births are high, and if characteristics that correlate with terminated pregnancies and pre-term births also correlate with weight. However, table 3 shows that the results are similar.

The results in table 3 suggest that Indian and African women gain similar amounts of weight during pregnancy; the confidence intervals for all eight weight gain estimates overlap. Women in both regions gain only about 7 kilograms during pregnancy, which is far less than what is recommended for women in the United States with similar pre-pregnancy body mass. The estimation of these means and confidence intervals, as well as the strengths and weaknesses of each approach, are discussed further in the *Materials and methods* section.

5 Discussion

This paper provides the first estimates of pre-pregnancy BMI, fraction underweight and weight gain during pregnancy for India, the country with the highest number of births in the world and serious challenges for population health, and for sub-Saharan Africa, a region which is significantly poorer.

By a novel application of reweighting estimation strategies, I find that 42.2% of pre-pregnant women in India are underweight, which is more than 25 percentage points higher than the comparable figure for sub-Saharan Africa. Women in both regions gain very little weight during pregnancy, but because of pre-pregnancy deficits, women in India *end* pregnancy weighing even less than women in sub-Saharan Africa *begin* it. Since pre-pregnancy BMI interacts with weight gain to produce birth weight, one would expect Indian infants to be born at significantly lower birth weights than African infants, a prediction which is supported by differences in anthropometric outcomes very early in life measured in the DHS. Because birth weight is a determinant of height, these differences in *in utero* nutrition may help explain "the Asian enigma" that Indians are shorter than Africans, despite their relatively better economic circumstances.

This study also found that in India, the prevalence of underweight among pre-pregnant women is higher than estimates for the average woman. About half of the gap between average underweight and pre-pregnancy underweight is explained by a previously unquantified relationship among age, the prevalence of underweight, and pregnancy, shown in figure 1.

These results suggest that further research is needed to understand why health during pregnancy in India is so poor and how it might be improved. Strong economic arguments exist as to why India should invest in pregnancy to improve infant health [14], [41]. However, to the extent that poor health during pregnancy is caused by low intra-household status among young women, which imposes a heavy burden of manual labor and restricts food intake [23], government intervention may prove extremely difficult. Indeed, prior literature on maternal health care has observed that the coincidence of childbearing with the restricted mobility and low intra-household status of young women limits their use of health services [23], [44].

Although certainly important, discrimination against young women is not the only reason why maternal health is so poor. Indeed, India's most recent DHS shows that the prevalence of underweight is 25% among men aged 40-50; these are the household members with the highest intra-household status. Exposure to infectious disease, poor sanitation, and poor diets all contribute to low body mass among both men and women. In the context of strong intra-household inequalities, investments in public goods that improve the disease environment similarly for everyone may be particularly useful.

6 Materials & methods

6.1 Data

This paper uses data from the Demographic and Health Surveys (DHS), which are publicly available from *www.dhsprogram.com.* For sub-Saharan Africa, I construct a dataset that includes all countries in which a survey collected data on women's weights and pregnancy duration between 2000 and 2010. If a country had more than one such DHS in this time window, the survey that took place closest to 2005 is chosen. A list of 29 countries and survey years included in the sub-Saharan Africa sample is presented in table 2. Anthropometry data are missing for 4.3% of pregnant women and 4.6% of non-pregnant women in the India sample, and for 2.4% of pregnant women and 2.4% of non-pregnant women in sub-Saharan Africa sample; these observations are dropped from the analysis.

6.2 Design weights

Design weights are used to compute all results. For India, I use the women's sampling weights provided by the DHS. For sub-Saharan Africa, I construct a weight, s_{ic}, for each woman i in country c. $s_{ic} = \frac{pop_{c,2005}}{\Sigma_c pop_{c,2005}} \times \frac{w_i}{\Sigma_{i \in c} w_i}$, where $pop_{c,2005}$ is the population of country c in 2005 from the Penn World Tables [25]. w_i is the sampling weight for woman i within a given survey.

6.3 Estimation of pre-pregnancy indicators

This paper applies a non-parametric reweighting function similar to that described by DiNardo et al., 1996 [42] and Geruso, 2012 [43]. The reweighting function used to generate many of the results reported in table 3, Ψ, is defined as $\Psi(\mathbf{x}) = \frac{f(\mathbf{x}|P=1)}{f(\mathbf{x}|P=0)}$, where $\mathbf{x}$ is a single set of indicators for the intersections of categorical indicators assigned from observable characteristics that are correlated with pregnancy and body size. With the exception of education and urban residence, which are assigned for all women based on what is true at the time of survey, pregnant women are assigned characteristics based on what was true in the month of conception, and non-pregnant women are assigned characteristics based on what is true when they are surveyed. In panels A, B, and C of table 3, the results in the second row reweight only by age in years, and non-pregnant women who are using modern contraception are dropped from the reweighting procedure. The results of the extended reweighting likewise omit contracepting women, and include a larger set of characteristics in the reweighting function: dummy variables for age groups (15-19, 20-24, 25-30, 30-40, 40-50); education level (primary or less, some secondary or more); residence (urban, rural); age of the youngest child (no living children, youngest child is less than one year old, youngest child is between one and two years old, youngest child is older than two years old); presence of a living son; number of living children (1, 2, 3, 4 or more); whether any of the woman's children died in the five years before the interview. Table **??** presents summary statistics for these covariates for pregnant and non-pregnant women. Table **??** shows linear probability regressions of an indicator for being 3 or more months pregnant on these covariates. The results in the last rows of panels A, B and C of table 3 include non-pregnant women who are using modern contraception and add to the extended reweighting function an indicator for the use of modern contraception at the time of conception.

The probability of reporting pregnancies of one or two months gestation is low relative to the probability of reporting pregnancies of other months of gestation. Table **??** shows the fraction of women reporting pregnancies of each gestational age. To avoid biasing the results due to selection into reporting of early pregnancies, only women reporting three months or more since their last menstrual period are included in the sample of pregnant women used to compute the reweighting function. Throughout the paper, month of gestation is calculated based on the respondent's reported time since her last menstrual period, which is asked of all respondents, and is rounded up or down to the nearest month if reported in weeks. Where data on time since last menstrual period is missing, the response to a question asked only of pregnant women ("How many months pregnant are you?") is used.

Mean pre-pregnancy BMI, $\overline{BMI}$, is $\frac{\Sigma_i BMI_i \times \Psi(\mathbf{x}_i)}{n_0}$ where i indexes non-pregnant women and n_0 is the number of non-pregnant women in the sample. For India, the results in panels A, B and C of table 3 for the age-only reweighting and the extended reweighting without contraceptive users drop less than 1% of the sample of pregnant women due to lack of support in the distribution of non-pregnant women. For the extended reweighting that includes contraceptive users, 2% of the sample of pregnant women are dropped prior to calculating the reweighting function. For sub-Saharan Africa, no pregnant women are dropped to compute the results of the age-only reweighting; for the extended reweighting, about a tenth of a percent of the sample of pregnant women is dropped.

To compute the bootstrapped confidence intervals reported in panels A, B and C of table 3, I re-sample clusters from the original data sources (DHS primary sampling units), stratifying within urban residence and state for the India sample and urban residence and country for the African sample.

6.4 Estimation of weight gain during pregnancy

Method one. Estimates labeled "method one" in panel D of table 3 present average weight gain for a full term pregnancy estimated as $1.1 \times 6 \times \hat{\beta}$, where $\hat{\beta}$ is the coefficient on month of gestation from an OLS regression of weight on month of gestation for women three or more months pregnant. This method for computing weight gain assumes that women in both regions gain an additional 10% of their second and third trimester weight gain in the first trimester. Table **??** presents estimates of weight gain in pregnancy computed using several different estimates of $\hat{\beta}$ from OLS regressions of the form:

$$weight_i = \alpha + \beta month_i + \Gamma C_i + \varepsilon_i, \tag{1}$$

where $weight_i$ is the weight in kilograms of pregnant woman i. $month_i$ is month of gestation, calculated as described above. Controls, C_i, are added to the regression in stages to correct for possible selection into gestational age reporting, which could bias $\hat{\beta}$ negatively if disadvantaged women fail to report early pregnancies, or positively if disadvantaged women are more likely to miscarry or terminate the pregnancy. Column 3 of table **??** controls for age fixed effects, years of schooling fixed effects, number of living children fixed effects, an urban fixed effect, and dummy variables for the interaction of wealth quintile with country. Column 3 also adds controls for place interacted with month of interview. Places are countries in the Africa sample and states in the India sample. Columns 4 and 5 restrict the regression to women reporting 4-9 months and 3-8 months of pregnancy respectively, in order to test whether the results are sensitive to omitting the months that are most likely affected by pregnancy underreporting and prematurity, respectively. The results are not sensitive to these re-specifications. 95% confidence intervals of weight gain for method one results in panel D of table 3 and in table **??** are calculated as $1.1 \times 6 \times (\hat{\beta} \pm 1.96 \times se_{\hat{\beta}})$.

Method two. It is useful to validate weight gain estimates from method one using a second method. Estimates produced using method one may overestimate weight gain during pregnancy if women gain less than 10% of second and third trimester gain in the first trimester. The black curve representing the distribution of weights among pre-pregnant women in India in figure 2 suggests that, for India, this may be true. However, if gestational ages are misreported, then the coefficients on gestational age would be attenuated, and method one would underestimate weight gain in pregnancy. Method two estimates average gain as the difference between average pre-pregnant weight computed using the non-parametric reweighting method described above for BMI and the average weight of women in late pregnancy. This method does not make assumptions about first trimester gain, nor does it potentially suffer from attenuation bias. However, method two will only produce unbiased estimates of weight gain in pregnancy insofar as the non-parametric reweighting accounts for all important endogeneity in selection into pregnancy. Figure **??**, which plots the estimated pre-pregnancy weight distribution from the non-parametric reweighting of non-pregnant women against estimates of the distribution of pre-pregnant weight based on correcting the weights of individual pregnant women for gestational age, observable characteristics, and their interactions, provides evidence that the distributions resulting from the non-parametric reweighting are good estimates of the pre-pregnancy distributions.

Method two estimates average gain as $(\overline{W}_9 - \overline{W}_0) + \frac{1}{2}\hat{\beta}_1$, where $\overline{W}_9$ is the average weight of women reporting 9+ months of gestation; $\overline{W}_0$ is an estimate of pre-pregnancy weight from the non-parametric reweighting; and $\hat{\beta}$ is the average estimated monthly gain from the controlled regression described for method one. The inclusion of a half a month of linear weight gain assumes that pregnant women who report 9+ months since their last menstrual period are, on average, at the midpoint of the final month of pregnancy. Average pre-pregnancy weight is computed using the extended reweighting function described above, dropping contraceptive users. The first row of "method two" results in panel D of table 3 reweights over characteristics of pregnant women; the second row of "method two" results reweights over characteristics, from the time of conception, of women who delivered a live birth in the year before the survey.

Sampling error contributes to the variance of both $\overline{W}_9$ and $\overline{W}_0$, and to the estimation of $\hat{\beta}$. Therefore, to calculate 95% confidence intervals for this estimate of weight gain, I bootstrap the entire calculation, stratifying within urban residence and state for the India sample and urban residence and country for the African sample. I cluster at the primary sampling unit level.

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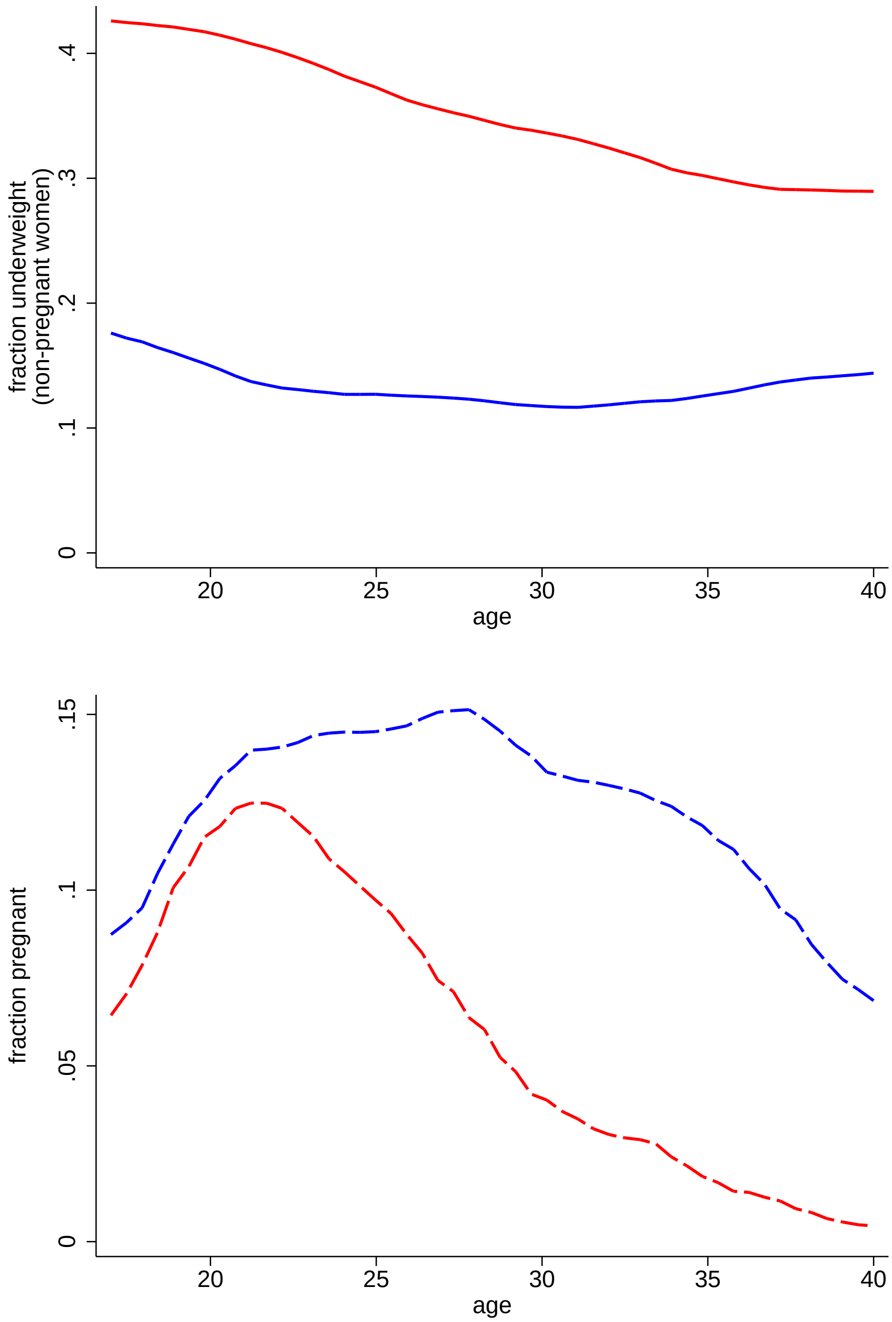

Figure 1: Underweight by age (among non-pregnant women) and pregnancy by age in India and sub-Saharan Africa.

Epanechnikov kernel-weighted local polynomial regressions. Data from India are shown in **red**; data from sub-Saharan Africa are shown in **blue**. Underweight women have a BMI<18.5.

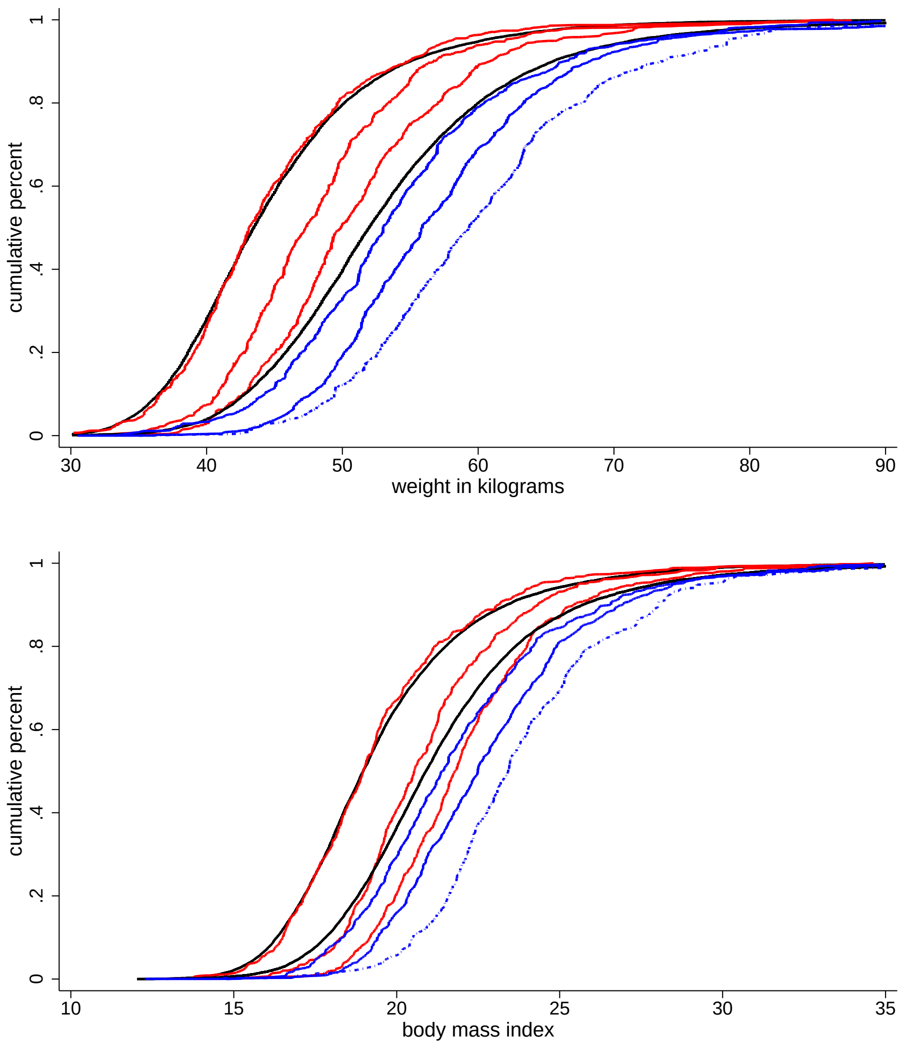

Figure 2: Estimated CDFs for pre-pregnant women and empirical CDFs for 3, 6, and 9+ months gestation.

Estimated CDFs for pre-pregnant women are shown in **black** for in India (left) and sub-Saharan Africa (right). These are estimated using the extended reweighting function described in the *Materials and methods* section. **Red** curves represent empirical CDFs for Indian women at 3, 6, and 9+ months gestation (left to right). **Blue** curves present empirical CDFs for African women at 3, 6, and 9+ months gestation.

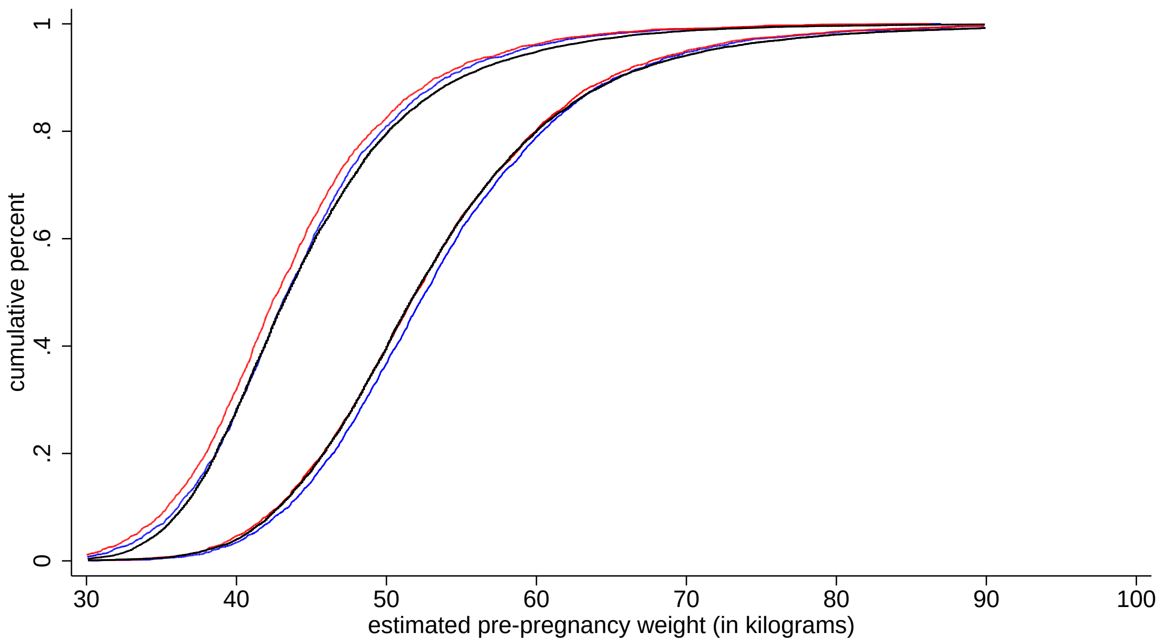

Figure 3: Three estimates of pre-pregnancy weight for India (left) and sub-Saharan Africa (right)

This figure shows six distributions of estimated pre-pregnancy weight. The three distributions for India are to the left of those for sub-Saharan Africa. The distributions in **black** are estimated using the extended non-parametric reweighting, which adjusts the body weights of non-pregnant women for selection into pregnancy. This method is described in the *Materials and methods* section. Distributions shown in **red** and **blue** are estimated from a cross-section of women who are 3+ months pregnant. I first regress body weight on month of gestation, and all the indicator variables used in the extended non-parametric reweighting, and their interactions with month of gestation. For each woman who has completed the first trimester, I compute the effect of gestational age on her body weight based on her own characteristics, month gestation and the interactions of these variables. To estimate an individual pre-pregnancy weight, I subtract from her body weight the product of her gestational age and her estimated effect. The **blue** distributions assume that no weight is gained in the first trimester, and the **red** distributions assume that 10% of an individual's estimated second and third trimester gain is gained in the first trimester.

Table 1: Summary statistics

	2005 population (in millions)[a]		2005 GDP per capita (in international dollars)[a]		poverty headcount ratio at $1.25 per day PPP[b]	
	region	sample	region	sample	region	sample
India	1,091	1,091	2,492	2,492	41.6%	41.6%
sub-Saharan Africa	752	597	1,480	990	52.8%	56.8%

	2005 total fertility rate[c]	number of countries		sample size women 15-49[d]	
	region	region	sample	non-pregnant, not contracepting	3+ months pregnant
India	3.0	1	1	69,543	5,055
sub-Saharan Africa	5.6	47	29	148,964	17,601

[a]Computations made using data from the Penn World Tables [25], using real GDP per capita. [b]2005 World Development Indicators [26] data are used. These estimates use purchasing power parity (PPP) figures from the 2005 International Comparison Program. The estimate for sub-Saharan Africa sample countries is computed using country-level poverty headcount ratio data from the years, between 2001 and 2007, that is closest to 2005. Data for Zimbabwe are missing. [c]Estimates are taken from the Population Reference Bureau [27]. [d]Sample sizes of women whose anthropometry was measured are shown.

Table 2: Countries included in the sub-Saharan Africa sample

country	**year of DHS survey**
Benin	2006
Burkina Faso	2003
Burundi	2010
Cameroon	2004
Chad	2004
Democratic Republic of Congo	2007
Ethiopia	2005
Gabon	2000
Ghana	2003
Guinea	2005
Kenya	2003
Lesotho	2004
Liberia	2007
Madagascar	2003
Malawi	2004
Mali	2006
Mozambique	2003
Namibia	2006
Niger	2006
Nigeria	2003
Rwanda	2005
São Tomé and Princípe	2008
Senegal	2005
Sierra Leone	2008
Swaziland	2006
Tanzania	2004
Uganda	2006
Zambia	2007
Zimbabwe	2005

Table 3: Estimates of pre-pregnancy BMI, fraction underweight and weight, and weight gain during pregnancy for India & sub-Saharan Africa

	India		**sub-Saharan Africa**	
	mean	95% CI	mean	95% CI
Panel A: Body mass index				
non-pregnant women, 15-49 years	20.47	[20.41, 20.53]	21.90	[21.82, 21.98]
pre-pregnant women, reweighted by age (CU dropped)	19.81	[19.73, 19.90]	21.75	[21.66, 21.84]
pre-pregnant women, extended reweighting (CU dropped)	19.54	[19.46, 19.62]	21.49	[21.39, 21.59]
pre-pregnant women, extended reweighting (CU included)	19.57	[19.50, 19.63]	.	.
Panel B: Fraction underweight ($BMI < 18.5$)				
non-pregnant women, 15-49 years	0.355	[0.349, 0.360]	0.152	[0.147, 0.158]
pre-pregnant women, reweighted by age (CU dropped)	0.390	[0.382, 0.399]	0.146	[0.140, 0.153]
pre-pregnant women, extended reweighting (CU dropped)	0.422	[0.410, 0.432]	0.165	[0.157, 0.174]
pre-pregnant women, extended reweighting (CU included)	0.418	[0.410, 0.432]	.	.
Panel C: Weight (in kilograms)				
non-pregnant women, 15-49 years	47.31	[47.17, 47.46]	54.58	[54.38, 54.81]
pre-pregnant women, reweighted by age (CU dropped)	45.81	[45.62, 46.02]	54.29	[54.05, 54.52]
pre-pregnant women, extended reweighting (CU dropped)	44.92	[44.71, 45.19]	53.45	[53.22, 53.74]
pre-pregnant women, extended reweighting (CU included)	45.04	[44.87, 45.21]	.	.
pre-pregnant women, extended reweighting, using women who delivered last year (CU dropped)	44.85	[44.69, 45.02]	53.08	[52.84, 53.33]
Panel D: Weight gain for a full term pregnancy (in kilograms)				
method 1, no controls	7.13	[6.48, 7.77]	6.47	[5.95, 6.99]
method 1, extended controls	7.00	[6.35, 7.64]	6.27	[5.88, 6.66]
method 2, reweight with pregnant women	6.88	[6.18, 7.69]	7.44	[6.32, 8.44]
method 2, reweight with women who delivered last year	6.95	[6.23, 7.76]	7.84	[6.73, 8.93]

CU stands for contraceptive users.

Table 4: Sample means of covariates used to compute pre-pregnancy estimates

	India		**sub-Saharan Africa**	
	women 3+ months pregnant[a]	non-pregnant, non-contracepting women[b]	women 3+ months pregnant[a]	non-pregnant, non-contracepting women[b]
age group				
15-19	0.228	0.326	0.176	0.245
20-24	0.434	0.221	0.271	0.184
25-29	0.225	0.139	0.253	0.159
30-39	0.106	0.179	0.255	0.232
40-49	0.007	0.136	0.045	0.180
education level				
primary or less	0.608	0.505	0.823	0.753
secondary or more	0.392	0.495	0.177	0.247
residence				
urban	0.240	0.310	0.234	0.298
rural	0.760	0.690	0.766	0.702
age of youngest child				
no living children	0.360	0.475	0.203	0.320
less than 12 months	0.090	0.115	0.055	0.082
between 12 & 23 months	0.240	0.077	0.286	0.058
24 months or more	0.310	0.332	0.460	0.540
sex of children				
has a living son	0.408	0.402	0.626	0.560
number of living children				
none	0.360	0.475	0.203	0.320
one	0.287	0.157	0.204	0.140
two	0.162	0.135	0.178	0.121
three	0.092	0.088	0.134	0.109
four or more	0.099	0.146	0.282	0.311
child death				
any child death in last 5 years	0.095	0.039	0.182	0.112
n	5,055	69,543	17,061	148,964
fraction non-pregnant women contracepting at time of survey[c]	0.385		0.174	

[a]Sample means for women who are 3+ months pregnant are calculated based on what was true in the month of conception. [b]Sample means for non-pregnant, non-contracepting women are calculated based on what was true at the time of the survey. [c]Calculated for non-pregnant women whose weights and heights were measured.

Table 5: Linear probability regressions predicting pregnancy, using covariates from the extended reweighting

	India	sub-Saharan Africa
	pregnant	
age group		
15-19	.	.
	.	.
20-24	0.053***	0.042***
	(0.003)	(0.003)
25-29	0.033***	0.040***
	(0.004)	(0.003)
30-39	-0.044***	-0.001
	(0.003)	(0.003)
40-49	-0.090***	-0.080***
	(0.004)	(0.003)
education level		
primary or less	0.027***	0.024***
	(0.002)	(0.002)
residence		
urban	-0.004*	-0.014***
	(0.002)	(0.002)
age of youngest child		
no living children	. .	.
	. .	.
less than 12 months	0.020***	-0.047***
	(0.005)	(0.003)
between 12 & 23 months	0.154***	0.223***
	(0.006)	(0.005)
24 months or more	0.093***	0.012***
	(0.005)	(0.004)
sex of children		
has a living son	-0.026***	0.001
	(0.004)	(0.003)
number of living children		
none	.	.
	.	.
one	.	.
	.	.
two	-0.024***	0.012***
	(0.004)	(0.003)
three	-0.024***	0.006
	(0.005)	(0.003)
f[illegible]	[illegible]	[illegible]

Table 6: Method one estimates of weight gain during pregnancy, which use early pregnancy as a counterfactual

	(1)	(2)	(3)	(4)	(5)
Panel A: India					
month gestation ($\hat{\beta}_1$)	1.08	1.06	1.06	0.99	1.08
	(0.05)	(0.05)	(0.05)	(0.06)	(0.06)
estimated gain (in kgs)	7.13	7.00	7.00	6.53	7.13
95% CI	(6.48, 7.77)	(6.35,7.64)	(6.35,7.64)	(5.76, 7.31)	(6.35, 7.90)
n	5,055	5,055	5,055	4,316	4,279
Panel B: sub-Saharan Africa					
month gestation ($\hat{\beta}_1$)	0.98	0.94	0.95	1.00	0.92
	(0.04)	(0.03)	(0.03)	(0.04)	(0.04)
estimated gain (in kgs)	6.47	6.20	6.27	6.60	6.07
95% CI	(5.95, 6.99)	(5.82,6.59)	(5.88, 6.66)	(6.08, 7.12)	(5.55, 6.59)
n^a	17,601	17,333	17,333	15,149	15,244
age fixed effects		✓	✓	✓	✓
years of schooling fixed effects		✓	✓	✓	✓
number of children fixed effects		✓	✓	✓	✓
urban		✓	✓	✓	✓
wealth quintile × country		✓	✓	✓	✓
place × month fixed effects			✓	✓	✓
gestational months	3-9	3-9	3-9	4-9	3-8

All coefficients are significant at the 0.001 level. [a] Wealth quintiles are not provided for Gabon; these data are dropped from regressions in columns 2-5.

Table 7: Distribution of gestational ages in the Indian and sub-Saharan African samples

	India		**sub-Saharan Africa**	
	number of women	fraction of pregnant women	number of women	fraction of pregnant women
month of gestation				
1	107	0.019	509	0.026
2	495	0.088	1488	0.076
3	759	0.134	2197	0.112
4	729	0.129	2534	0.129
5	727	0.128	2736	0.139
6	693	0.123	2591	0.132
7	668	0.118	2627	0.134
8	695	0.123	2720	0.138
9+	785	0.139	2250	0.115

Design weights, described in the *Materials and methods* section, are used.