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Original Research Article

Intergenerational Effects of Early Life Nutrition: Maternal Leg Length Predicts Offspring Placental Weight and Birth Weight Among Women in Rural Luzon, Philippines

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Objectives: Leg length is the component of stature most sensitive to early life nutrition; as such, it provides an opportunity to retrospectively evaluate the relationship between a woman's infancy and early childhood nutrition and offspring birth weight (BW). Here we explore the relationship between maternal leg length and offspring BW in a rural Philippine community, while also investigating the potential role of placental size as a pathway.

Methods: Anthropometric and questionnaire data were obtained among pregnant women (ages 17–42 years) at a birthing clinic in Antipolo City, Philippines (n = 80). Offspring BW and placental weight were collected upon delivery.

Results: Maternal leg length, but not trunk length, was a positive predictor of infant BW. This relationship was strengthened after adjusting for gestational age and maternal body mass index (BMI). Further adjustment for placental weight attenuated the relationship between leg length and BW, while placental weight was unrelated to maternal trunk length. The relationship between maternal BMI and BW was also attenuated after adjustment for placental weight.

Conclusion: Maternal leg length is the component of stature that most strongly predicts offspring placental weight and BW in this sample. These findings suggest that fetal nutrition and growth in the present generation are influenced, in part, by the mother's own early life growth conditions. Our results add to evidence that fetal nutrition tracks the mother's past nutritional experiences, while also suggesting that ensuring favorable growth conditions during infancy and early childhood may benefit not only the present generation, but future offspring. Am. J. Hum. Biol. 26:652–659, 2014.

The link between fetal nutrition and health across the lifecourse is now well established. Studies report that being born small not only predicts elevated risk of cardiometabolic disease, but also leads to deficits in human capital as indicated by body size, strength, educational attainment, and wages (Barker, 1999, 2006; Victora et al., 2008; Whincup et al., 2008). In parallel, experimental work in animal models has established that the development of biological systems is sensitive to conditions in the prenatal and early postnatal environments, confirming that many of these relationships are causal rather than simply correlational (McMullen and Mostyn, 2009). From a policy perspective, the finding that fetal nutrition has long-term effects on important health and human capital outcomes has heightened interest in the potential benefits to future generations of supplementing the diets of pregnant women. What is less acknowledged in this literature is the fact that nutritional interventions targeting pregnant women often have modest or even negligible effects on birth outcomes, and by implication, fetal nutrition. For instance, providing balanced protein-energy supplements to women during pregnancy has generally been found to have minimal impact on offspring birth weight (BW) (Kramer and Kakuma, 2003; Matthews et al., 1999).

Several lines of evidence point to the mother's chronic or early life nutritional history as important determinants of offspring BW, suggesting potential intergenerational nutritional benefits of interventions targeting young girls during their growing years (Victora et al., 2008). For instance, it has long been appreciated that fetal growth rate of the mother is often a stronger predictor of offspring BW than is the father's BW (Coutinho et al., 1997; Hypponen and Power, 2004; Kuzawa and Eisenberg, 2012; Lunde et al., 2007; Magnus et al., 2001), which has been interpreted as evidence for intergenerational effects of the mother's nutritional experiences as a fetus (Emanuel, 1986; Ounsted et al., 1986; but see Leon, 2008). Less is known about the importance of the mother's nutrition and growth after birth, but evidence is consistent with a lingering, intergenerational impact of nutrition at this age. In Guatemala, girls who were given a high protein/energy supplement during childhood gave birth to babies significantly larger than offspring of women fed a less nutritious supplement (Behrman et al., 2009).

Although prospectively-collected or experimental data on the early postnatal nutritional experiences of pregnant mothers are rare, other methods have allowed retrospective evaluation of the potential long-term impacts of early life nutrition. In particular, leg length (LL) is more sensitive to early life nutrition than are other components of stature growth, making it a useful retrospective index of early life nutrition (Bogin et al., 2002; Gunnell, 2002; Krogman, 1972; Leitch, 1951; Li et al., 2007; Scammon, 1930; Scrimshaw and B'Ehar, 1965; Tanner, 1978; Wadsworth, 2002). Evidence for this comes from studies that directly measure early nutrition in low-income populations (Bogin et al., 2002; Frisancho et al., 2001), while

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improvements in socioeconomic conditions have also been shown to primarily reflect increases in leg growth (Bogin and Keep, 1999; Floyd, 2008; Sanna and Soro, 2000).

Although relatively few, studies have demonstrated the importance of mother's LL as a predictor of offspring BW (Lawlor et al., 2003; Martin et al., 2004). In the 1958 British Birth Cohort, for instance, the mother's LL was found to be a stronger predictor of offspring BW than was her trunk length (TL) (Lawlor et al., 2003). Working with the Boyd Orr Survey, Martin et al. (2004) similarly found that a woman's LL measured during her own childhood was the strongest anthropometric predictor of future offspring BW, even after adjusting for the mother's adult stature. Because LL is particularly nutritionally sensitive, these findings support the hypothesis that a mother's own infancy or early childhood nutrition can have lingering intergenerational effects on offspring fetal nutrition and growth. We are aware of no study that has investigated these relationships in a population in which nutritional stress is more common.

Here we explore the intergenerational impacts of maternal nutritional history as an influence on offspring BW in a sample of women living in rural Luzon, the Philippines. Participants include women served by a mission hospital, and among whom adult stature is relatively low compared to reference norms. We have two aims in this study. First, we test the hypothesis that a mother's adult LL will be a stronger predictor of her offspring's BW than will her TL, as would be consistent with an intergenerational effect of infancy and early childhood nutrition. Second, because the placenta is a likely candidate pathway linking a mother's early nutrition with offspring fetal nutrition (Rutherford, 2013), we also evaluate the potential role of placental size as a mediator of these relationships.

PARTICIPANTS AND METHODS

Participants were recruited from the Shalom Birthing Clinic in Antipolo City, Philippines. Located in the mountains 15 miles from metropolitan Manila, the clinic is mainly used by local women in need of inexpensive pre- to postnatal care. During clinic visits, women were invited to participate if they were in their last trimester of pregnancy and had an expected delivery date during the project period (delivery dates June 26th, 2012–August 4, 2012). Eligible women were told about the study and were invited to participate by an American registered nurse fluent in English and Tagalog. This study was conducted under conditions of written informed consent. All study protocols were approved by the Institutional Review Board at Northwestern University, and with formal permission from the Shalom Birthing Clinic.

Data collection

Despite its location in the rural mountains, the missionary-run birthing clinic serves about 100 patients daily. While most mothers visit the clinic for routine check up and prenatal exams, the clinic also sees ~4 new births in a given day. Because of its low cost—the entire cost for delivery including pre- and postnatal care is 500 pesos, equivalent to about $12 U.S. dollars—low socioeconomic status, along with proximity to clinic, are common characteristics of the mothers who regularly use the clinic. Mothers in the area can also choose to attend other public and private hospitals for shorter wait times and even to hire midwives for delivery, which is quite common in rural areas of the Philippines. Most women attend the clinic alone, while a few are accompanied by their children and mothers.

Questionnaires were used to obtain information about pregnancy and socioeconomic factors like the mother's age, parity, marital status, education level, and employment status, and whether or not she smoked during pregnancy. Upon delivery, the mother's height and weight were obtained using standard techniques (Lohman et al., 1988). First, standing height of the mother was measured, without shoes, using a stadiometer to the nearest millimeter. Seated height was measured several days after giving birth, on a stool that was placed on the same stadiometer. The mothers were asked to sit straight with their entire back touching the vertical pole of the stadiometer and were given foot rests of appropriate height in case their feet did not touch the ground. Trunk length was then obtained as seated height minus the height of the stool, which was 46 cm. Leg length was calculated as seated height minus TL following Lawlor et al. (2003). In addition, information on gestational age and pregnancy hemoglobin levels were obtained from medical records. Gestational age was assessed based upon the woman's self-reported last menstrual period (LMP) following Naegele's Rule. Each newborn's weight was measured twice at birth, to the nearest 0.1 kg, after the baby had been dried but before breastfeeding. The placenta was also collected at birth, and its untrimmed weight was measured on a separate scale to the nearest 50 g. In all cases, the mother's postpartum weight was measured within a day of delivery.

Of the 101 mothers who consented to participate, 89 gave birth during the six-week study period. Two participants were excluded because anthropometric measures were not obtained after giving birth, and one participant withdrew from the study. Four participants were excluded due to anthropometric or BW measures that were deemed unreliable. A pair of twins was also excluded from the study. The final analysis sample thus included the subsample of 80 mothers who delivered singleton offspring during the project period and for whom all variables were available.

All statistical analyses were performed with version 11 of Stata (Stata Corporation, College Station, TX). Maternal height, leg length (LL), and trunk length (TL), infant BW, placental weight, and gestational age were all treated as continuous variables. Additionally, prepregnancy body mass index (BMI) was defined as postpartum weight (kg)/height (meters)^2 and was interpreted as an indicator of the mother's nutritional status during late pregnancy. Descriptive statistics were calculated stratified on tertiles of mother's LL, and one-way ANOVA (continuous variables) and chi-square tests (categorical variables) were used to test for significant differences across levels. Relationships between maternal LL and TL and offspring BW were modeled using multiple regression. Relationships were first evaluated in a base model to which was added a suite of potentially confounding influences. Finally, to evaluate the potential role of the placenta as a pathway linking maternal nutritional history with offspring BW we evaluated coefficients before and after including placental weight in the model. We evaluated the predictors of placental weight using the same set of predictor variables used in models

TABLE 1. Characteristics of mothers and their newborns[a]

	Total sample (N = 80)	Range	Tertiles of leg length: Tertile 1 (n = 27)	Tertile 2 (n = 28)	Tertile 3 (n = 25)	P-value
Mother						
Age (years)[b]	26.8 ± 7.0	(17, 42)	28.0 ± 7.4	28.2 ± 7.3	24.6 ± 6.2	0.176
Married (%)	25.0		33.3	28.6	12.0	0.179
Educational attainment (%)						0.694
Elementary school	6.4		4.0	3.6	12.0	
High school	73.1		72.0	75.0	72.0	
College	20.5		24.0	21.4	16.0	
Standing height (cm)	152.6 ± 5.8	(141.5, 170.5)	147.8 ± 3.7	152.1 ± 3.1	158.4 ± 5.0	0.001
Leg length (cm)	74.0 ± 4.9	(64, 88)	69.4 ± 1.7	73.3 ± 1.1	79.7 ± 4.0	0.001
Trunk length (cm)	78.6 ± 3.1	(70.5, 88)	78.4 ± 3.8	78.8 ± 2.8	78.8 ± 2.8	0.884
Postpartum weight (kg)	51.4 ± 7.9	(37.5, 76.5)	49.2 ± 6.6	51.6 ± 8.6	53.7 ± 8.0	0.121
BMI[c] (kg/m^2)	22.1 ± 3.3	(16.8, 33.6)	22.5 ± 3.1	22.3 ± 3.7	21.4 ± 3.0	0.411
Smoker (%)[d]	9.2		11.5	15.4	0.0	0.150
Hemoglobin (mg/dl)[e]	11.3 ± 0.9	(9, 14)	11.3 ± 1.0	11.2 ± 1.0	11.3 ± 0.8	0.895
Duration of labor (h)	4.1 ± 3.1	(0.5, 12)	4.5 ± 3.1	3.7 ± 2.7	4.03 ± 3.67	0.647
Newborn						
First born (%)[f]	26.6		33.3	22.2	24.0	0.613
Birth weight (g)	2923 ± 387	(1980, 3940)	2834 ± 480	2928 ± 382	3012 ± 423	0.256
Placenta weight (g)	577 ± 120	(300, 900)	563 ± 121	580 ± 130	588 ± 108	0.750
Gestational age (weeks)	37.9 ± 1.6	(32, 41)	38.5 ± 1.5	37.5 ± 1.9	37.8 ± 1.2	0.046

[a]Values are mean ± SD (continuous variables) or % (categorical). P-values from one-way ANOVA (continuous) or chi-square (categorical).
[b]n = 69.
[c]Body mass index.
[d]n = 76.
[e]n = 71.
[f]n = 79.

predicting BW. To allow direct comparisons of effect sizes across outcomes and predictors, we calculated standardized regression coefficients in which both predictors and outcome were first converted to standard deviation (SD) scores, allowing assessment of the change in BW or placental weight (in SD units) predicted by a 1-SD change in each predictor. Heteroscedasticity was evaluated using visual inspection of residuals plotted against each predictor and the hettest command in Stata. Multicollinearity was evaluated by calculating a variance inflation factor (VIF) for each predictor included in multivariate models.

RESULTS

Characteristics of the mothers and infants included in this study, in aggregate and also stratified on tertiles of maternal LL, are reported in Table 1. More than half of the women were either not married or currently cohabiting. Mean stature was relatively low as compared to US young adult females (50th centile for women 20–39 years 163.0 cm; McDowell et al., 2008), but similar to heights reported for other Filipino young adult women from rural areas of metropolitan Cebu City further south in the Philippines (mean 151.5 ± 5.2 cm; unpublished data from the Cebu Longitudinal Health and Nutrition Survey; for study details see Adair et al., 2011). Most mothers had attained a high school level of education, and there were no differences in educational attainment across LL tertiles. On average, boys were 125 g heavier than girls, and the mean BW of the sample was 2923 g, with a visible but nonsignificant BW gradient across maternal LL tertiles. Maternal height, infant BW, and placental weight all steadily increased across the tertiles of maternal LL, although only the trend in height was significant.

We next evaluated the relationship between maternal LL and TL and offspring BW using a series of regression models. Beginning with a univariate regression between maternal LL and BW, we progressively added variables to evaluate potential sources of confounding (Table 2). Model 1 shows the crude relationship between maternal LL and BW with every centimeter increase in mother's LL predicting roughly a 24 g increase in offspring BW ($P \leq 0.05$). Trunk length was not a significant predictor of offspring BW, either before or after simultaneous control of LL (Model 2). Adding TL did not modify the coefficients linking maternal LL to infant BW (Model 3). Since gestational age at delivery was latest among the short LL group, we adjusted models for gestational age. Offspring sex was also added to the model to account for any BW differences between male and female offspring (Model 4). These further adjustments increased the coefficient relating LL and BW modestly.

Adjusting for the mother's current nutritional status, as reflected in her BMI (Model 5), further strengthened the coefficient and significance of the association between LL and BW. Figure 1 shows the relationships between BW and LL and TL from Model 5, while Figure 2 shows mean BW stratified on tertiles of LL and adjusted for key covariates. Adjustment for the mother's smoking status in the sub-sample with information on smoking ($n = 76$) revealed a nonsignificant decline in BW in relation to smoking ($P < 0.3$); this adjustment left the coefficients linking LL and TL unchanged (results not shown). Maternal educational attainment (high school and college modeled as dummy variables with elementary school as reference), hemoglobin levels and primiparity status were not significant predictors of BW or placental weight (all $P > 0.2$) and were thus not included in models.

We next added placental weight to the full model to evaluate its potential role as a pathway influencing offspring BW (Table 3, Model 6). Adjusting for placental weight attenuated the regression coefficient for LL, although LL remained a significant predictor. Adjusting for placental

TABLE 2. Regression models relating infant birth weight (g) to maternal leg and trunk lengths[a]

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Leg length (cm)	24.4 ± 8.6[c]		24.3 ± 8.6[c]	28.8 ± 8.0[c]	32.0 ± 7.9[d]	22.7 ± 6.9[c]
Trunk length (cm)		12.0 ± 13.9	11.3 + 13.3	10.8 ± 12.2	11.8 ± 11.9	13.6 ± 10.1
Gestational age (weeks)				92.8 ± 24.8[d]	93.9 ± 24.2[d]	56.0 ± 21.6[b]
Male offspring				50.9 ± 79.6	29.4 ± 78.4	39.9 ± 66.3
BMI (kg/m^2)					25.4 ± 11.8[b]	13.0 ± 10.2
Placenta weight (g)						1.6 ± 0.3[d]
Constant ± SE	1118.8 ± 634.2	1981.4 ± 1093.8	238.3 ± 1215.3	−3605.5 ± 1503.3	−4513.7 ± 1526.4	−3183.7 ± 1313.6
Model adjusted R^2	0.083	−0.003	0.080	0.224	0.261	0.471

[a]β ± SE
[b]$P \leq 0.05$
[c]$P \leq 0.01$
[d]$P \leq 0.001$.

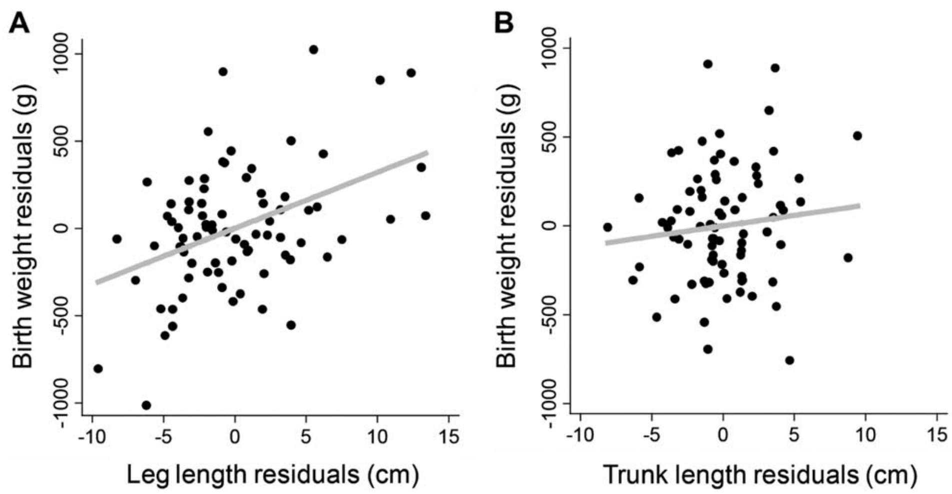

Fig. 1. Scatterplots and regressions of infant birth weight on (A) maternal leg length and (B) maternal trunk length. Models adjusted for gestational age, offspring gender, maternal BMI, and either (A) maternal trunk length or (B) leg length.

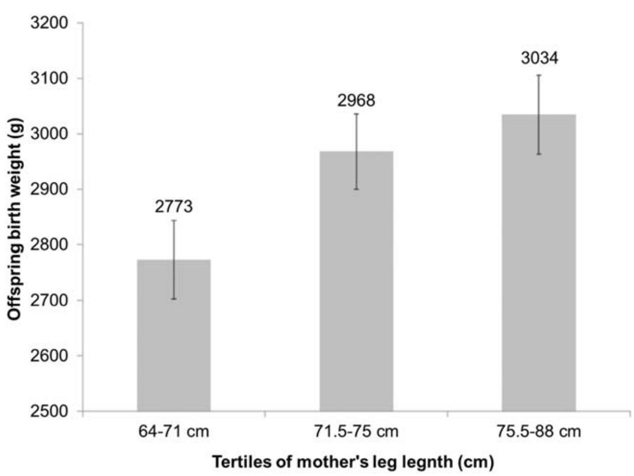

Fig. 2. Infant mean (±SE) birth weight by tertiles of maternal leg length adjusted for gestational age at birth, offspring gender, mother's postpartum BMI, and trunk length. Middle tertile versus shortest tertile ($P < 0.054$); Longest tertile versus shortest tertile ($P < 0.012$); joint-F ($P < 0.032$).

weight also attenuated the coefficients linking gestational age and maternal BMI to offspring BW, suggesting that differences in placental growth help explain these relationships as well. The (nonsignificant) coefficient linking TL to offspring BW, in contrast, was not changed substantively after adjustment for placental weight.

For comparison with models including LL and TL, comparable models were run relating maternal height to offspring BW (Table 3). Before adjusting for placenta weight, a 1 cm increase in height predicted a 25.7 g increase in offspring BW, which was slightly less than the 32.0 g change in BW predicted by a 1 cm change in LL (Table 2).

We next evaluated the predictors of placental weight (Table 4), which was strongly positively correlated with BW (Fig. 3). Similar to findings with offspring BW, we found that LL was the strongest maternal anthropometric predictor of placental weight, and that this relationship was strengthened after adjustment for gestational age, offspring gender, and maternal BMI. In contrast, TL was unrelated to placental weight ($P < 0.8$). Figure 4 shows the relationships between placental weight and LL and TL from Model 4. Figure 5 reports standardized regression coefficients (with predictors and outcomes both converted to SD-scores) linking each predictor in the full models to offspring BW and placental weight, visually

TABLE 3. Regression models relating infant birth weight (g) to maternal stature

	Model 1	Model 2	Model 3	Model 4
Standing height (cm)	20.4 ± 7.1[b]	23.3 ± 6.6[c]	25.7 ± 6.6[c]	19.8 ± 5.6[c]
Gestational age (weeks)		89.6 ± 24.7[c]	90.2 ± 24.2[c]	53.5 ± 21.3[a]
Male offspring		56.8 ± 79.8	37.0 ± 78.7	43.5 ± 66.0
BMI (kg/m^2)			24.2 ± 11.8[a]	12.2 ± 10.1
Placenta weight (g)				1.6 ± 0.3[c]
Constant ± SE	−192.8 ± 1090.1	−4068.7 ± 1459.1	−4989.7 ± 1498.0	−3137.0 ± 1276.0
Model adjusted R^2	0.083	0.219	0.251	0.474

β ± SE.
[a]$P \leq 0.05$
[b]$P \leq 0.01$
[c]$P \leq 0.001$

TABLE 4. Regression models relating placenta weight to maternal characteristics (g)

	Model 1	Model 2	Model 3	Model 4	Model 5
Leg length (cm)	3.6 ± 2.7	3.6 ± 2.8	4.8 ± 2.7~	5.8 ± 2.7[a]	
Trunk length (cm)		−1.3 ± 4.3	−1.4 ± 4.1	−1.2 ± 4.1	
Standing height (cm)					3.7 ± 2.2
Gestational age (weeks)			23.4 ± 8.1[b]	23.7 ± 8.2[b]	22.4 ± 8.2[b]
Male offspring			0.02 ± 26.9	−6.6 ± 26.6	−4.0 ± 26.7
BMI (kg/m^2)				7.8 ± 4.0~	7.4 ± 4.0~
Constant ± SE	308.0 ± 203.4	406.9 ± 391.3	−553.6 ± 507.2	−832.0 ± 517.8	−995.5 ± 508.3
Model adjusted R^2	0.009	−0.002	0.073	0.107	0.094

β ± SE.
~$P \leq 0.1$
[a]$P \leq 0.05$
[b]$P \leq 0.01$

illustrating the stronger effect of LL, as compared to TL, on both BW and placental weight.

DISCUSSION

We found that maternal LL was a stronger predictor of offspring BW than was maternal TL, which was not a significant predictor of BW. This relationship largely accounted for the positive relationship between maternal height and offspring BW, and was strengthened after adjusting for gestational age, offspring gender, and maternal BMI. There was also evidence for involvement of placental growth as a mediator or pathway linking maternal LL with offspring BW. Collectively, these findings support the hypothesis that a woman's own early nutrition and growth conditions influence not only her adult height and body proportions, but also the fetal nutrition and birth outcomes of her future offspring (Kuzawa, 2005).

These findings are consistent with previous studies linking adult LL of women to BW of their offspring (Lawlor et al., 2003; Martin et al., 2004). The two published studies that we are aware of that have investigated this relationship sampled 23 towns in England, Scotland, and Wales (Lawlor et al., 2003) and 16 urban and rural districts in Britain (Martin et al., 2004). The women in our sample, in contrast, were mostly from underprivileged families with very low socioeconomic status (SES) and relatively low stature. This was reflected in the fact that newborns from our sample weighed 0.4 kg less, on average, than those from the British samples. Despite these population differences, our results were similar to findings in these two prior studies, as we too found that LL was considerably stronger than TL as a predictor of offspring BW. Although

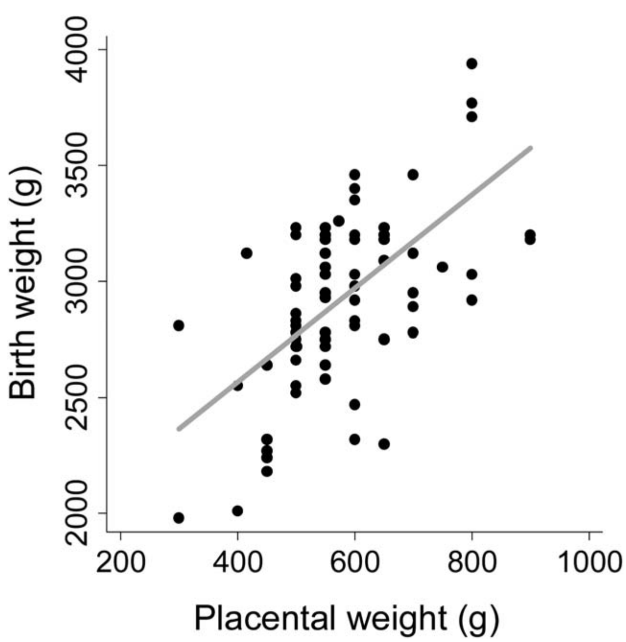

Fig. 3. Scatterplot and bivariate regression of birth weight on placental weight. BW (g) = 2.02 (PW) +1760.3; R^2 = 0.387.

comparisons are difficult across studies owing to the differences in control variables, it is notable that the change in BW predicted by LL in the present sample (156.3 g/SD-score of LL) was considerably stronger than that documented in the Boyd Orr Cohort (89.8 g/SD-score of LL)

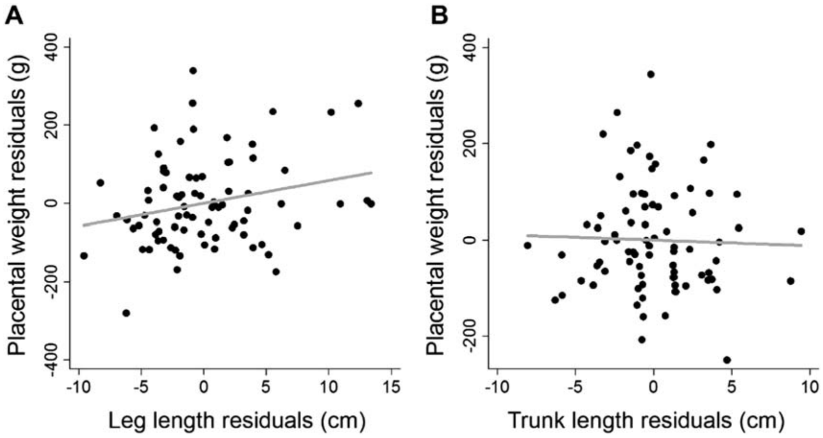

Fig. 4. Scatterplots and regressions of placental weight on (A) maternal leg length and (B) maternal trunk length. Models adjusted for gestational age, offspring gender, maternal BMI, and (A) either maternal trunk length or (B) leg length.

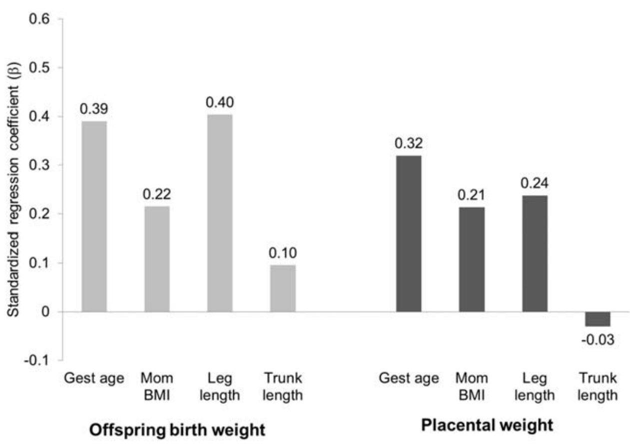

Fig. 5. Standardized regression coefficients (β) from multivariate models predicting offspring birth weight (Table 2, model 5) and placental weight (Table 4, model 4). Values indicate the change in each outcome (in SD units) predicted by a 1-SD change in the predictors. Gest age: gestational age at delivery; BMI: body mass index. Models also adjusted for offspring gender.

perhaps indicating that early nutrition has stronger effects on the next generation when nutritional stress and nutritional stunting are common.

Using US NHANES III data, Bogin and Varela Silva (2008) found that increased buttocks fat deposition can artificially inflate calculated sitting height, thus leading to a systematic underestimation of leg length in overweight individuals. While this could lead to spurious findings of more adverse adult health outcomes among shorter-legged individuals, for the purposes of our analysis a spurious association between BMI (a marker of nutritional status that is positively associated with offspring BW) and shorter legs would work counter to our general finding of higher BW among longer-legged women. Consistent with this interpretation, adjusting for the BMI strengthened the coefficients linking leg length to both BW and placental weight.

To our knowledge, our study is the first to investigate the potential role of the placenta in mediating the relationship between maternal early life nutrition, as indicated by LL, and her offspring's BW. Placental weight was not only a strong predictor of offspring BW, but LL was a strong and significant predictor of placental size in final models, whereas TL was effectively unrelated to placental weight. Adjusting for placental weight in models predicting BW greatly attenuated the relationship between maternal LL and offspring BW. Combined, these findings suggest that the relationship between maternal LL and offspring BW is mediated, in part, by tightly correlated changes in placental size. The specific placental mechanism potentially linking maternal early life nutrition with placental weight and fetal growth rate remain uncertain. A mother's exposure to nutritional, metabolic, inflammatory, or psychosocial stressors can alter hormone regulation (Fowden and Frohead, 2009; Gheorghe et al., 2010) and the density of nutrient transporters (Lesage et al., 2002; Zamudio et al., 2006), which underlie placental nutrient transport and drive fetal growth (Rutherford, 2013). Future research should focus on describing the specific morphological or epigenetic changes in the placenta that result from a woman's early life nutritional experiences, and that drive variation in fetal nutrition and offspring birth outcomes (Rutherford, 2012).

These findings have bearing on strategies to improve fetal nutrition and birth outcomes, especially in developing economies like the Philippines. Studies have shown that the prevalence of cardiometabolic diseases is increasing in the context of nutritional, economic, and lifestyle transitions (Prentice and Moore, 2005). The results from the current study, combined with evidence that nutritional supplementation during pregnancy generally only has modest effects on BW, add to growing evidence that improving the early life growth conditions of young girls could be an effective strategy to reduce the burden of cardiovascular and related diseases in future generations, while also improving human capital (Victora et al., 2008).

Although the present sample was relatively small, the relationships between anthropometric indices and offspring BW in this sample were sufficiently robust to allow identification of strong statistically significant relationships, and to differentiate between the relative importance of different anthropometric predictors. Nonetheless, several limitations of this study warrant mention.

Because the sample was a convenience sample of women who used the local birthing center, relationships may not be generalized outside of this rural and relatively low income population. Because we only obtained information on the women who gave birth at the clinic, we were not able to evaluate how the women in our sample might have varied as compared to women from the surrounding community who did not use the clinic. One characteristic specific to this sample is that the women may have delivered early due to factors such as poor dental care and a relatively high prevalence of untreated periodontal diseases. Since the clinic was not equipped with modern ultrasound technology at the time of the study, estimated delivery dates and gestational ages for these women were based on the woman's self-reported last menstrual period (LPM) following Naegele's Rule. Prior work has shown that the LMP method has relatively low reliability—thus potentially reducing the statistical power of our analyses—but does not introduce bias (Nakling et al., 1995). We also could not control for the time at which individual heights were measured as the participants visited the clinic during different times of day. This might have contributed to measurement error as studies have shown height changes throughout the day (Strickland and Shearin, 1972; Whitehouse et al., 1974). Lastly, our measurement of placental phenotype was limited to placental weight, while studies have identified more fine-grained anatomical measures that predict birth outcomes (Rutherford, 2013). We hope that the present findings will help stimulate interest in future work aimed at elucidating the specific placental pathways linking a woman's early life nutrition with the intrauterine milieu, growth rate, and long-term health of her future offspring.

In sum, we found that maternal LL, but not TL, was a significant predictor of offspring BW. Since maternal LL is the component of stature most sensitive to the mother's own infancy and early childhood nutrition, these results suggest that the mother's nutritional status and growth during early life are potentially important determinants of fetal nutrition and BW—and by extension, adult health—in the next generation. These findings have important public health implications in low resource countries, and suggest that efforts to improve nutrition and growth conditions during infancy and childhood, particular among young girls, could have health benefits that transcend the present generation.

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