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MOTHER'S LIFETIME NUTRITION AND THE SIZE, SHAPE AND EFFICIENCY OF THE PLACENTA

Nicola R. Winder, MSC^a, Ghattu V. Krishnaveni, PhD^b, Sargoor R. Veena, MBBS^b,
Jacqueline C. Hill, PhD^a, Chitra L.S. Karat, MD^b, Kent L. Thornburg, PhD^c, Caroline H.D.
Fall, DM^a, and David J.P. Barker, FRS^{a,c}

^aMRC Lifecourse Epidemiology Unit, University of Southampton, Southampton General Hospital, Southampton, UK

^bEpidemiology Research Unit, CSI Holdsworth Memorial Hospital, Mysore 570021, India

^cHeart Research Center, Oregon Health and Science University, Portland, OR 97219, USA

Abstract

Background—Studies have shown that the shape and size of the placenta at birth predict blood pressure in later life. The influences that determine placental morphology are largely unknown. We have examined the role of mother's body size.

Methods—We studied 522 neonates who were born in a maternity hospital in Mysore, South India. The weight of the placenta and the length and breadth of its surface, were measured after delivery.

Results—Higher maternal fat mass predicted a larger placental surface ($p=0.02$), while larger maternal head circumference predicted a more oval placental surface ($p=0.03$). Higher maternal fat mass and larger maternal head circumference were associated with greater placental efficiency, indicated by lower ratios of the length ($p=0.0003$ and $p=0.0001$ respectively) and breadth ($p=0.0002$ and $p<0.0001$) of the surface to birthweight. In a sub-sample of 51 mothers whose own birthweight was available, higher maternal birthweight was related to lower ratios of the length and breadth of the surface to birthweight ($p=0.01$ and 0.002). Maternal height was unrelated to placental size or shape.

Conclusions—Higher maternal fat mass, reflecting the mother's current nutritional state, and larger maternal head circumference, reflecting the mother's fetal/infant growth, are associated with changes in the shape and size of the placental surface and greater placental efficiency. We suggest that these associations reflect effects of the mother's nutrition at different stages of her lifecourse on the development of the placenta and on materno-placento-fetal transfer of nutrients.

Keywords

Birthweight; maternal body composition; placenta; placental efficiency

Introduction

Studies have shown that the size and shape of the placental surface at birth predict blood pressure in later life (1,2), but the factors that determine placental morphology are largely unknown. The mother's body makes an important contribution to the development of her

fetus since it is the source of nutrients. Little is known, however, about the relationship between the mother's body size and placental size and shape.

The Mysore Parthenon Study is a prospective birth cohort study in the South Indian city of Mysore. It was established to examine maternal glucose tolerance and nutrition as predictors of long-term health in the children (3,4). Measurements at birth included neonatal anthropometry and measurements of the size and shape of the placental surface. We have previously reported that placental size and shape predicted blood pressure at age 9 years (5). In the present study we hypothesised that in better nourished mothers, as indicated by their body size, the placenta would be larger and more efficient, indicated by a low ratio of placental size to birthweight.

In this analysis, we use four measures of the mother's body size which reflect her nutrition at different stages of development. Her head circumference is a marker of her fetal and infant growth. 60-70% of adult head circumference is achieved by birth and 80-90% by the age of two years (6,7). In contrast, the mother's height and lean mass depend on her fetal, childhood and pubertal growth (6). The mother's fat mass reflects her current nutritional state.

Methods

Study participants

In 1997, the Mysore Parthenon study recruited pregnant women attending the antenatal clinic at the Holdsworth Memorial Hospital in Mysore, South India (3). The hospital ethical committee approved the study, and informed verbal consent was obtained from the pregnant women. All women who had a singleton pregnancy and who were not diabetic before pregnancy were eligible. Out of 1,233 eligible women 830 (67%) took part in the study.

Measurements of mothers

At 30 ± 2 weeks of gestation the mother's body size was measured, including their head circumference, height, mid-upper arm circumference and skinfold thickness at 4 sites (triceps, biceps, subscapular and supra-iliac) using standardised methods. Height was measured to the nearest 0.1 cm using a Harpenden stadiometer (CMS instruments, London, UK); mid-upper arm circumference and head circumference were measured to the nearest 0.1 cm using anthropometric tape; skinfold thicknesses were measured to the nearest 0.1 mm using Harpenden callipers (CMS Instruments, average of three readings). Arm muscle area was calculated using mid-upper arm circumference and triceps skinfold measurements according to the following formula (8),

Maternal fat mass was estimated using the four skinfolds and adjusted for the duration of pregnancy (9). At the same visit, women underwent a 100 g glucose tolerance test to diagnose gestational diabetes, using the criteria of Carpenter and Coustan (3).

Placental measurements

Placentas were measured immediately after birth. Birthweight was measured to the nearest 5 grams using digital weighing scales (Seca, Germany). The cord clamp was released to allow the blood to drain from the placenta. The amnion was stripped off and the chorion trimmed close to the placental edge. The cord was cut flush with the placenta and obvious clots removed. The placenta was weighed using an electronic balance. It was then placed on a flat surface, with the cotyledons facing upwards. The longest diameter of the surface (length) was measured using a transparent plastic ruler placed on the surface. The diameter perpendicular to the length was defined as the breadth and was measured in the same way.

Analysis sample

Of the 830 women recruited, 663 delivered at Holdsworth Memorial Hospital and had live-born babies. Glucose tolerance test data were available for 630 mothers, and we excluded 41 who had developed gestational diabetes mellitus during the pregnancy. A further 60 mothers who delivered pre-term (<37 weeks gestation) were excluded. Of the remaining 529 mothers, the 522 who had complete placental measurements were included in this analysis.

Statistical methods

Placental area was calculated assuming an elliptical surface, using $\text{length} \times \text{breadth} \times \pi/4$ (2). We calculated the difference between the length and breadth of the surface as a measure of its ovality. We derived three measures of placental efficiency using the ratios of placental weight, length and breadth to birthweight. We used 4 measurements of the mother's adult body size to reflect different stages of her development and nutrition: head circumference, reflecting fetal life and infancy; height, reflecting childhood and adolescence; and arm muscle area and fat mass, reflecting current nutritional state. Maternal birthweight was available in hospital records for a sub-sample of 51 women who were themselves born in Holdsworth Memorial Hospital. We used linear regression to examine associations between the maternal variables and birthweight and placental size, shape and efficiency. Maternal size variables (exposures) and placental measurements (outcomes) were Z-standardised in these regression models, to enable comparison of effect sizes across exposures and outcomes.

Results

Table 1 shows the characteristics of the mothers, babies and placentas. In comparison with Western populations, the mothers were young, short in stature, and had a high fat mass in relation to body weight. Fifty-one percent were primiparous. The babies had a low mean birthweight and placental weight. Birthweight was correlated with placental weight ($r=0.61$) but Figure 1 shows that there was a wide variation in placental weight for any given birthweight. For example babies weighing around 3000 g had placentas ranging from 300 to 700 g in weight. Birthweight was also correlated with the length ($r=0.40$), breadth ($r=0.41$) and area ($r=0.44$) of the placental surface. Table 2 relates the different measurements of maternal body size to birthweight and placental size, shape and efficiency. All four maternal measurements were positively related to the babies' birthweights, with the strongest effects from maternal head circumference and fat mass.

Placental size and shape

The mother's height was not related to any placental measurement. Larger maternal head circumference, arm muscle area and fat mass were all associated with heavier placental weight; again, the strongest effects were with maternal head circumference and fat mass (Table 2). The size and shape of the placental surface were only related to maternal head circumference and maternal fat mass. Larger maternal head circumference predicted a large length-breadth difference, that is a more oval placental surface, while higher maternal fat mass predicted a larger placental surface. We examined the combined effects of maternal fat mass and head circumference on the size of the surface. In a simultaneous regression, increase in fat mass was associated with increasing length ($p=0.02$), breadth ($p=0.009$) and area ($p=0.007$). In contrast, increasing head circumference was associated with reduced breadth ($p=0.009$), and area ($p=0.06$) but not length ($p=0.45$). Maternal age was not associated with birthweight or with any of the placental measurements.

Placental efficiency

No measure of maternal size was related to the ratio of placental weight to birthweight. Ratios of placental surface size to birthweight fell with increasing maternal head circumference, fat mass and arm muscle area. In a simultaneous regression increasing head circumference and fat mass were both associated with a reduced length to birthweight ratio ($p=0.007$ and $p=0.02$) and with a reduced breadth to birthweight ratio ($p<0.001$ and $p=0.05$). Increased arm muscle area was associated with a reduced breadth to birthweight ratio (Table 2).

Mother's birthweight

Table 3 shows that, in the sub-sample for whom the mother's birthweight was available, higher maternal birthweight was related to higher birthweight in the baby. Maternal birthweight was not related to the size of the placental surface but higher birthweight was associated lower ratios of the length and breadth of the surface to birthweight.

Sex, parity and maternal age

There were no significant differences between the sexes in any of the associations described. Higher maternal parity was associated with increased birthweight ($p=0.02$), placental weight ($p=0.01$), breadth ($p=0.01$) and area ($p=0.05$) but not length. Maternal parity was not related to any of the measures of placental efficiency. None of the findings in Table 2 were changed by adjusting the regression analyses for maternal parity. Maternal age was not related to placental size, shape or efficiency.

Discussion

As expected, increases in all four measures of maternal body size were associated with increased birthweight. The associations with placental size and shape were more specific. Different measures of maternal body size, reflecting nutrition at different stages of life, had different associations. Higher mother's fat mass, a marker of her current nutrition, was associated with a larger placental surface. Larger maternal head circumference, a marker of fetal and infant development, together with higher maternal fat mass and, weakly, larger arm muscle area were associated with a more efficient placenta. In our study we measured placental efficiency using the ratios of the length and breadth of the surface to birthweight in addition to the customary ratio of placental weight to birthweight. Maternal height, reflecting her nutrition through childhood, was not related to any measures of placental size or efficiency.

Placental efficiency

Consistent with other studies, we found a wide variation in placental weight for any given birthweight (Figure 1) suggesting that there are large differences in placental efficiency. The ratio of placental weight to birthweight is a widely used marker of placental efficiency (10,11). Because in our study the length and breadth of the placental surface was measured we were able to use the ratios of placental length and breadth to birthweight as additional indices of efficiency. While none of our four measures of maternal body size was related to the ratio of placental weight to birthweight, increased maternal head circumference, fat mass and arm muscle area were all associated with a reduced ratio of placental surface length or breadth to birthweight. This suggests that these markers of increased efficiency reflect a different aspect of the control of the placental exchange surface than is reflected in the ratio of placental weight to birthweight. We are unable to define the mechanisms for this from our data. Maternal anaemia and smoking, and living at high altitude, are associated with

increased placental weight to birthweight ratio (12-15), which suggests that oxygen availability may be one of the controlling influences on this ratio.

The mother's current nutritional state

High maternal body mass index is known to be associated with increased placental weight (16-17). Our finding that greater maternal fat mass and arm muscle area predict higher placental weight is consistent with this. We also found that greater maternal fat mass, but not arm muscle area, was associated with increased size of the placental surface. Higher fat mass was also associated with increased placental efficiency, so that there was a higher birthweight for a given surface size. Higher maternal fat mass is associated with higher circulating concentrations of lipids and glucose (18), which may result in greater growth of the surface and greater transfer of these nutrients per unit of placental surface area (19). Higher maternal fat mass is also likely to be associated with increased levels of maternal metabolic hormones, such as insulin, IGF-I and leptin, which are well-established to stimulate nutrient transport capacity in the placenta (20). Furthermore, nutrients are required for vascularisation of the placental villi and an increased nutrient supply might allow richer vascularisation. However little is known about specific nutrient requirements for placental development.

The mother's fetal and infant growth

We used the mother's head circumference as a marker of her fetal and infant growth. In contrast, height depends on childhood and pubertal growth. The association between increased maternal head circumference and increased placental efficiency, and the lack of such an association with maternal height, points to the importance of the fetal/infant phase of a girl's growth, rather than the adolescent phase, in determining placental efficiency. This conclusion is supported in the sub-sample of babies for whom maternal birthweight was recorded. Increased maternal birthweight was associated with increased placental efficiency reflected in lower ratios of both length and breadth to birthweight. We speculate that this increased efficiency reflects the development of a denser spiral artery supply to the maternal decidua during her intra-uterine life, associated with better fetal nutrition (21). This enables adequate numbers of spiral arteries to be recruited over a smaller area. We found that increased maternal head circumference was associated with a reduced breadth of the placental surface so that it had a more oval shape. We suggest that other variations in uterine characteristics eg size, shape or endometrial function could also potentially influence efficiency. An alternative explanation could be more effective cardiovascular and/or metabolic adaptations to pregnancy in mothers who were better nourished in utero.

Our findings differed from those in a recent study in Perth, Australia, in which higher maternal birthweight was associated with increased placental surface size (22). In the Australian study the mean placental surface area was 323 cm² compared with 263 cm² in our study. The small size of the Indian placental surface could explain why maternal head circumference is associated with the efficiency of the surface but not with its size.

Strengths and limitations of the study

A strength of the Parthenon study is that, maternal, newborn and placental size, were measured by trained research staff according to standard protocols. Most of the pregnancies were healthy. None of the mothers smoked and only six had pregnancy-induced hypertension. A limitation of the study is that it was based on births in one hospital in Mysore, and the participants may therefore be unrepresentative of the whole Mysore population. However at the time of the study the Holdsworth Memorial Hospital was one of three large maternity units in Mysore and was not a specialist referral centre, and therefore did not treat a high proportion of complicated pregnancies. It is situated in a relatively poor

area of the city, and most of the patients come from 'lower middle-class and middle class' families; most women choose to deliver there simply because of its proximity to home. We therefore consider our study sample representative of middle-class women (not poor, not rich) in Mysore. Another limitation is that we have no data on maternal diet and nutrient status either during the pregnancy or in early life and no data on placental microstructure or nutrient transport function.

Conclusion

Among neonates in South India high maternal fat mass was associated with a large placental surface at birth and greater placental efficiency, indicated by low ratios of the length and breadth of the surface to birthweight. Greater placental efficiency was also associated with a larger maternal head circumference. Our study was observational and therefore cannot attribute causality. However we speculate that these associations reflect effects of the mothers' nutrition at different stages of her lifecourse on placental development and on the materno-placento-fetal transfer of nutrients.

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Figure 1.

Table 1

Characteristics of the mothers, newborns and placentas

	N	Mean / [%]	(SD)
Mother			
Age (years) *	52 2	23	(20, 26)
Parity			
0	26 6	[51]	
1 or more	25 6	[49]	
Birthweight (kg)	51	2.797	(0.471)
Height (cm)	52 2	154.6	(5.4)
Weight (kg)	52 2	56.0	(8.8)
Body mass index (kg/m ²)	52 2	23.4	(3.4)
Head circumference (cm)	49 7	53.4	(1.5)
Arm muscle area (cm ²)	52 2	21.7	(4.8)
Fat mass (kg)	52 2	19.4	(5.9)
Percentage body fat (%)	52 2	34.0	(5.6)
Newborn			
Gestational age (weeks)	52 2	39.5	(1.1)
Birthweight (kg)	52 2	2.890	(0.412)
Placental size and shape			
Weight (g)	52 2	412.1	(83.8)
Length (cm)	52 2	19.5	(2.0)
Breadth (cm)	52 2	17.0	(1.9)
Area (cm ²)	52 2	262.8	(49.9)
Length-breadth difference (cm)	52 2	2.5	(1.7)
Number of cotyledons	52 2	6.6	(2.5)
Placental efficiency			
Weight : birthweight (g:kg)	52 2	143.0	(23.2)
Length : birthweight (cm:kg)	52 2	6.9	(1.0)
Breadth : birthweight (cm:kg)	52 2	6.0	(0.9)

*
median and inter-quartile range

Table 2
Standardised birthweight and placental measurements according to maternal body size

Z-Standardised	Maternal head circumference n=497			Maternal height n=522			Maternal arm muscle area n=522			Maternal fat mass n=522		
	Beta	(95% CI)	p-value	Beta	(95% CI)	p-value	Beta	(95% CI)	p-value	Beta	(95% CI)	p-value
Newborn												
Birthweight	0.18	(0.10, 0.27)	<0.0001	0.09	(0.01, 0.18)	0.03	0.11	(0.02, 0.19)	0.01	0.24	(0.15, 0.32)	<0.0001
Placental size and shape												
Weight	0.16	(0.08, 0.25)	0.0002	0.06	(-0.02, 0.15)	0.14	0.09	(0.01, 0.18)	0.04	0.17	(0.09, 0.25)	<0.0001
Length	0.01	(-0.08, 0.10)	0.84	0.05	(-0.04, 0.13)	0.26	0.04	(-0.04, 0.13)	0.32	0.10	(0.01, 0.18)	0.02
Breadth	-0.08	(-0.17, 0.01)	0.08	0.07	(-0.02, 0.15)	0.12	-0.02	(-0.11, 0.07)	0.66	0.08	(-0.00, 0.17)	0.06
Area	-0.04	(-0.13, 0.05)	0.38	0.06	(-0.02, 0.15)	0.16	0.02	(-0.07, 0.10)	0.72	0.10	(0.01, 0.18)	0.02
Length-breadth difference	0.10	(0.01, 0.18)	0.03	-0.02	(-0.10, 0.07)	0.72	0.07	(-0.01, 0.16)	0.10	0.03	(-0.06, 0.11)	0.53
Placental efficiency												
Weight : birthweight	0.05	(-0.04, 0.13)	0.30	0.01	(-0.07, 0.10)	0.79	0.01	(-0.07, 0.10)	0.75	0.00	(-0.08, 0.09)	0.98
Length : birthweight	-0.17	(-0.26, -0.09)	0.0001	0.04	(-0.13, 0.04)	0.30	-0.07	(-0.15, 0.02)	0.12	-0.15	(-0.24, -0.07)	0.0003
Breadth : birthweight	-0.24	(-0.32, -0.15)	<0.0001	-	(-0.11, 0.06)	0.52	-0.11	(-0.20, -0.03)	0.01	-0.16	(-0.24, -0.08)	0.0002

Analyses were performed using linear regression, adjusting for gestational age at birth. Maternal size measurements and newborn and placental measurements were Z-standardised to enable comparison of effect sizes.

Table 3

Birthweight and placental measurements according to the mother's birthweight

Z-Standardised	Mother's birthweight			
	n	Beta	(95% CI)	p-value
Newborn				
Birthweight	51	0.49	(0.27, 0.70)	<0.0001
Placental size and shape				
Weight	51	0.15	(-0.10, 0.40)	0.24
Length	51	0.25	(-0.03, 0.53)	0.08
Breadth	51	0.15	(-0.10, 0.39)	0.24
Area	51	0.22	(-0.03, 0.48)	0.08
Length-breadth difference	51	0.13	(-0.19, 0.46)	0.40
Placental efficiency				
Weight : birthweight	51	-0.26	(-0.53, 0.02)	0.06
Length : birthweight	51	-0.33	(-0.59, -0.08)	0.01
Breadth : birthweight	51	-0.39	(-0.64, -0.15)	0.002

Analyses were performed using linear regression, adjusting for gestational age at birth. Maternal birthweight measurements and newborn and placental measurements were Z-standardised to enable comparison of effect sizes.