Original Article

Intergenerational effects of maternal birth weight, BMI, and body composition during pregnancy on infant birth weight: Tanjungsari Cohort Study, Indonesia

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Background and Objectives: Infant birth weight might be partly contributed to by maternal nutritional status at birth and maternal nutrition during pregnancy. The objective of this study was to analyze intergenerational maternal birth weight, maternal BMI, weight change during pregnancy, and maternal body composition (FM, FFM, and TBW) changes during pregnancy. **Methods and Study Design:** We analyzed the associations between the maternal birth weight and body composition of 94 women and infant birth weight by using multiple regression adjusted for socioeconomic and reproductive history. **Results:** All associations with infant birth weight were positive. The association between infant birth weight and maternal birth weight was 0.28 (95% CI: 0.02–0.54); that for the association between infant birth weight and maternal body weight in the first, second, and third trimesters was 15.1 (95% CI: 4.92–25.3), 13.7 (95% CI: 2.78–24.6), and 16.1 (95% CI: 5.22–27.0), respectively. The association between infant birth weight and fat mass in the second and third trimesters were 18.4 (95% CI: 3.38–33.5) and 16.1 (95% CI: 5.23–27.0), respectively, and those for the association between infant birth weight and fat-free mass in the first and third trimesters were 33.6 (6.38, 60.9) and 34.8 (95% CI: 3.47–66.1), respectively. **Conclusions:** This study confirms previous findings that maternal birth weight and body composition during pregnancy are associated with infant birth weight.

Key Words: intergenerational, maternal birth weight, maternal BMI, maternal body composition, infant birth weight

INTRODUCTION

Birth weight is a critical factor influencing health during infancy and later life. Low birth weight (LBW; i.e., birth weight <2500 g) is an important risk factor for chronic diseases during adulthood, such as type 2 diabetes, hypertension, and CVD.[1,2] The global prevalence of LBW is 15.5%, or approximately 20 million babies, of which 95.6% reside in developing countries. In Indonesia, 11.1% of babies exhibited LBW in 2010, and the number slightly decreased to 10.2% in 2013.[3] Factors known to be related to LBW include maternal height, prepregnancy weight, weight gain during pregnancy, parity, maternal age at pregnancy, prenatal care, and maternal birth weight.[4-7]

Various studies have investigated the association between maternal and infant birth weights, but the results have been inconclusive.[8,9] Several factors, including genetics predisposition, epigenetic effect, and sociocultural factors, are known to influence the intergenerational effect on LBW.[10] A study investigating 558 women in Sao Paulo, Brasil, showed that maternal birth weight is associated with infant birth weight for infants weighing >3500 g but not for LBW infants.[11]

A person's body weight consists of fat mass (FM), fat-free mass (FFM), and total body water (TBW). During pregnancy, FM is associated with maternal BMI, whereas increases in FFM are an indicator of uterine, placental, and fetal growth.[12] Studies have shown that maternal pre-pregnancy BMI and weight change during pregnancy are significantly associated with infant birth weight, but results regarding the association between maternal body composition and infant birth weight have been inconsistent. In a study conducted in Jamaica, infant birth weight was found to be associated with maternal FFM, but not FM, in the first prenatal care visit (week 15 of pregnancy or earlier) and associated with an increase in FFM, but not FM, between the first prenatal care visit and week 35 of pregnancy.[13] However, another study conducted in Sweden reported a correlation between infant

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birth weight and prepregnancy FM, but not FFM, and weight at 32 weeks of pregnancy (p=0.027, p=0.013).[14]

The Tanjungsari Cohort Study is a longitudinal study that was initially a mother–newborn cohort study in 1988 and has been following its population at various points every few years. The nutritional indicators of the newborn generation of this cohort population (born between 1988 and 1990) were collected at birth until five years old up to adolescence.[15] In 2014, the newborn generation reached adult age, and some may have started their own families. Thus, this situation afforded an opportunity to compare the birth weight of the women in this generation with that of their offspring. Therefore, the present study was conducted to analyze intergenerational associations of maternal birth weight, maternal BMI, weight change during pregnancy, and maternal body composition (FM, FFM, and TBW) changes during pregnancy. The study is intended to the understanding of factors associated with infant birth weight.

MATERIALS AND METHODS

Setting and population

The female second generation of the Tanjungsari Cohort Study population, coded as F2, who were still living in Tanjungsari in Sumedang, West Java, Indonesia, were surveyed in November 2013 to identify those who are planning to become pregnant in the next year; that is, the sample population included married women who were not using contraceptives. At the time of their birth approximately 25 years ago, Tanjungsari was considered a rural region. As of 2013, Tanjungsari has evolved into a periurban area with more factories than farm fields.

Data collection and measurement methods

Based on the results of the previous study involving the same cohort, we calculated the sample size for this study by using the formula (one-sided test, unpaired):[16]

$$n = \frac{(Z\alpha + Z\beta)^2\ (SD)^2}{(\bar{x}1 - \bar{x}2)^2} = 141,61 \approx 142$$

$Z\alpha$ (5%)=1.96

$Z\beta$ (20%)=0.84

SD=425 g (previous research in 2010)

($\bar{x}1$- $\bar{x}2$)=100 g

We added 20% to the total sample size to account for loss to follow-up and exclusions; thus, we planned to enroll 170 pregnant F2 women. The current study was reviewed and approved by the Ethics Committee of the Faculty of Medicine of Universitas Padjadjaran Number 128/UN6.C2.1.2/KEPK/PN/2014, West Java, Indonesia.

Community health workers, or *kader* as they are known in the local language, are responsible for field data collection at each village. Some kaders have been involved in data collection since the beginning of the Tanjungsari Cohort Study, and most of them personally know the study participants. In the present study, which was conducted between January 1, 2014 and September 30, 2015 participants were recruited from married F2 women who were not using contraceptives, and they were administered a pregnancy test. Women who were <12 weeks pregnant were included in this study, and pregnancy tests were repeated on nonpregnant women every 2 months until pregnancy or the end of the study period. The exclusion criteria were any pregnancy complication or severe health condition requiring hospitalization during pregnancy, adverse pregnancy outcomes (e.g., stillbirth or congenital malformation), or multiple births. When consent was obtained, the study participants were informed that they could withdraw from the study at any point.

At baseline, a field team of physicians and assistants recorded participants' body composition data, which consisted of body weight, height, FM, FFM, and TBW, and this team also collected socioeconomic and reproductive history by using a structured questionnaire. Maternal birth weight was obtained retroactively from the original cohort data. For each pregnant woman, maternal body composition measurements—except for body height—were repeated during the second and third trimesters. The outcome of interest, infant birth weight, was measured within 24 hours of birth by the field team based on information from the cadre in the first few hours after delivery.

Anthropometric measurements were performed using techniques explained elsewhere. The team used a tetrapolar bioelectrical impedance analysis scale (TANITA SC-240 MA, Tanita Health Equipment HK LTD, Kowloon, Hongkong) to measure body weight, FM, FFM, and TBW[17] without systematic bias,[18] and a stadiometer (SECA 204, SECA GmBH, Hamburg, Germany) was used to measure body height.[19] A baby scale (SECA 334, SECA GMBH, Hamburg, Germany) was used to measure the birth weight of infants without any clothes within 24 hours of birth.[19] All measurements were repeated, and a third measurement was taken if the difference between the two measurements was >0.1 kg. The measurement results and time of the day when the measurements were performed were recorded on an anthropometric form connected to a computer.

Statistical analyses

The association between maternal body composition and infant birth weight were analyzed using multiple regression adjusted for socioeconomic and reproductive history.

RESULTS

Subject characteristics

Between January 2014 and September 2015, 129 women were identified as pregnant, but only 94 completed the first trimester and after-delivery visits (Figure 1). Because these women are the newborn generation of a mother–child cohort, born in 1988–1990, they were all 24–26 years of age at the time of the study. Most subjects had completed 9 years of compulsory education or beyond (74.5%), were housewives (64.9%), and had a family income below the minimum wage (73.4%) (Table 1). This was the second pregnancy for 71.3% of subjects. During this pregnancy, all subjects visited a health care worker for prenatal care at least once, but only 11.7% made at least four visits as per the WHO recommendations on antenatal care.

The average of infant birth weight was 3013 g, higher than average of maternal birth weight was 2777 g (Figure

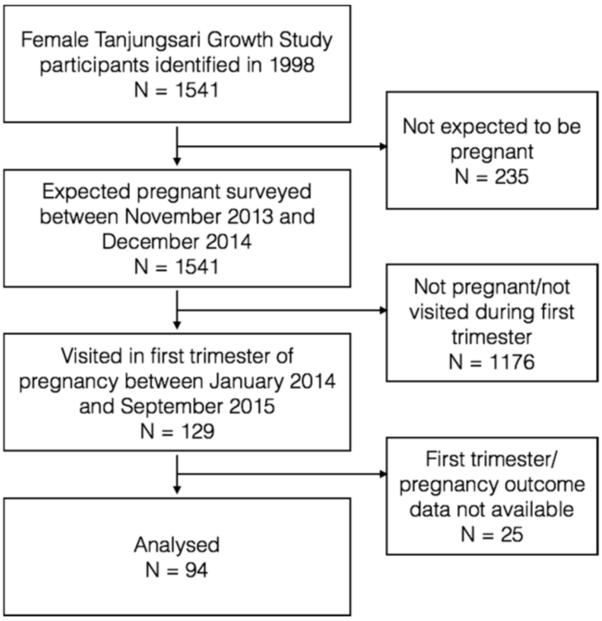

Figure 1. Flowchart for the enrollment of study participants.

2). The LBW proportion of maternal birth weight was 18.1% and infant birth weight was 19.1% (Figure 3), and in the entire F2 population, the LBW prevalence was 14.7% in 1988.

Trimester and delivery visits

Of the 94 women with complete records for the first-trimester measurements, second- and third-trimester measurements were recorded for only 90 and 78 women, respectively. The average height of the participants was 150 cm, with 17% categorized as short (<145 cm) (Table 2). Approximately half of them had normal BMI (18.5–24.9 kg/m^2) in the first trimester (54.3%), and 22.9% were overweight (BMI, 25–29.9 kg/m^2). Their weight, FFM, and TBW significantly increased in each trimester, whereas FM increased significantly only between the second and third trimesters. Thus, maternal weight, FM, FFM, and TBW peaked in the third trimester.

Birth weight as the outcome of interest was recorded for all 94 women whose first-trimester data were available. The average birth weight of the offspring was higher than that of the mothers (mean±SD, 3013±514 g), but a higher proportion of the infants exhibited LBW (17.8%).

Association between maternal body composition and pregnancy outcome

In this study, we found a significantly positive correlation between maternal and infant birth weights (p=0.03, r=0.23).

Regression analyses were performed to estimate the association of maternal birth weight and maternal body composition with infant birth weight as a pregnancy outcome, and these analyses were adjusted for maternal age, parity, and frequency of prenatal care visits (Table 3).

Maternal birth weight in each trimester and the first-trimester BMI were positively associated with infant birth weight. A positive association was also observed between FM and infant birth weight but only in the second and third trimesters. After adjustment, the association be-

Table 1. Participant characteristics

Variables	n(%)
Age in years, mean±SD	25.2±1.08
Years of education, n (%)	
0–6	24 (25.5)
9–12	64 (68.1)
>12	6 (6.4)
Income below minimum wage, n (%)	69 (73.4)
Housewives, n (%)	61 (64.9)
Antenatal care with a health worker, n (%)	
Once	19 (20.2)
Twice	34 (36.2)
Three Times	30 (31.9)
Four Times	11 (11.7)
Maternal birth weight, mean±SD	2777±433
Low birth weight, n (%)	17 (18.1)
Normal birth weight, n (%)	77 (81.9)
Number of previous pregnancies, n (%)	
0	23 (24.5)
1	67 (71.3)
2	3 (3.2)
3 or more	1 (1.1)

Low birth weight: <2500 gram

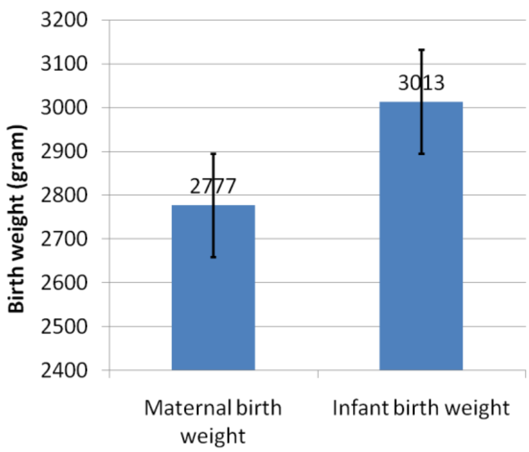

Figure 2. The average of maternal and infant birth weight.

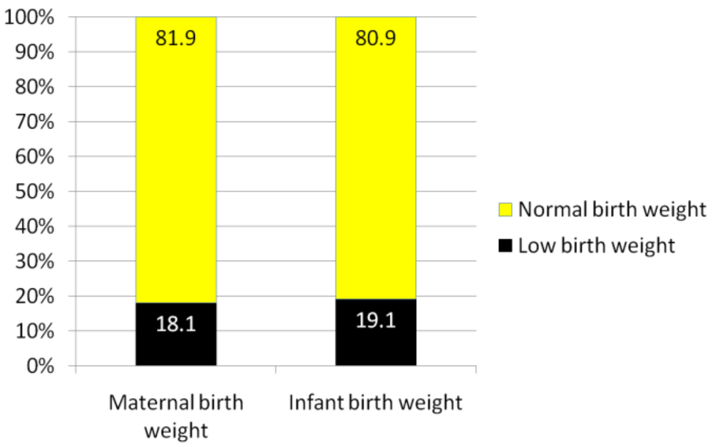

Figure 3. The proportion of low birth weight and normal birth weight on second generation (mother) and third generation (infant). Low birth weight: <2500 gram.

tween FFM and infant birth weight was positive in the first and third trimesters. A positive association was also observed between TBW and infant birth weight in the first trimester.

DISCUSSION

The average of infant birth weight higher than maternal birth weight in this study, nevertheless the proportion of LBW of infant not too different from mother (Figure 2 and Figure 3). The result of this study differ from other studies. In the Philippines, the average of maternal birth weight was 3000 g and the average infant birth weight was 2999 g.[20]

LBW is intergenerationally persistent. The mechanism may be same for obesity, metabolic alteration in the pregnant mother and early exposure through breastmilk affect metabolism of an individual. In the case of high carbohydrate diet exposure, the ensuing gestational diabetes in the mother, affects the metabolism of the fetus in the form of insulin resistance. Female progeny will develop similar insulin resistance during their life, and transmit this phenotype to their future progeny. This effect is mediated by changes in the gene expression, referred to as epigenetics. This phenotypic change proved to be persistent and resistant to reversal or changes in diet. Supplementation of methyl supplement responsible for epigenetic process, are partially able to prevent the amplification of this phenotype in the next generation.[21-24] After adjusting for maternal age, parity, and frequency of prenatal care visits, we observed an independent association between maternal body composition and infant birth weight. Moreover, statistically significant associations were observed between infant birth weight and maternal birth weight; first-trimester maternal body weight, BMI, FFM, and TBW; second-trimester maternal body weight and FM; and third-trimester maternal body weight, FM, and FFM.

The association between maternal and infant birth weights found in the present study is consistent with the findings of other studies. In South India, every 1 kg increase in maternal birth weight was shown to be associated with a 255-g increase in infant birth weight.[8] Another study in Sweden reported the same increase to be associated with a 165-g increase in infant birth weight and that maternal birth weight explained 6% of its variance.[9] This finding supports the concept of maternal constraint; that is, maternal genetic and environmental factors limit fetal development from achieving the optimal genetic potential.[8,9]

The independent association between first-trimester maternal BMI and infant birth weight found in this study is like the finding of a previous study in Bangladesh.[25] First-trimester maternal BMI is a proxy of prepregnancy weight, which was not measured in the present study. Based on the Institute of Medicine recommendation for weight gain during pregnancy, first-trimester weight gain should be between 0.5 and 2 kg; thus, first-trimester BMI can be used to approximate prepregnancy BMI, which has

Table 2. Maternal anthropometry, body composition, and infant birth weight

	1st trimester (n= 94)	2nd trimester (n=90)	3rd trimester (n=78)	After delivery (n=94)
Height, cm	150±6.13			
BMI, kg/m^2	24.2±4.53			
Weight, kg	54.8±10.8	57.1±10.4*	62.1±10.5**	
FM, kg	20.5±13.5	20.3±7.36	23.8±7.57**	
FFM, kg	36.3±4.23	36.8±4.23*	38.3±3.91**	
TBW, L	26.1±3.52	27.0±3.45*	28.2±3.39**	
Infant birth weight, g				3013±514

BMI: body mass index; FM: fat mass; FFM: fat free mass; TBW: total body water.
$^*p<0.05$ for *t* test pairs between the first and second trimesters.
$^{**}p<0.05$ for *t* test pairs between the second and third trimesters.

Table 3. Association between infant birth weight and maternal birth weight, anthropometry, and body composition across gestation

Maternal measurements	Birth weight, g (not adjusted)		Birth weight, g (adjusted)†	
	β (95% CI)	*p* value	β (95% CI)	*p* value
Maternal birth weight, g	0.29 (0.03, 0.55)	0.03*	0.28 (0.02, 0.54)	0.03*
Maternal body weight, kg				
1st trimester	15.3 (5.95, 24.7)	<0.001*	15.1 (4.92, 25.3)	<0.001*
2nd trimester	14.8 (4.81, 24.7)	<0.001*	13.7 (2.78, 24.6)	0.02*
3rd trimester	17.5 (7.57, 27.5)	<0.001*	16.1 (5.22, 27.0)	<0.001*
BMI, kg/m^2				
1st trimester	31.9 (9.29, 54.4)	0.01*	31.1 (7.26, 55.1)	0.01*
FM, kg				
1st trimester	4.37 (-3.82, 12.6)	0.23	4.37 (-3.82, 12.6)	0.29
2nd trimester	20.7 (6.13, 34.4)	0.01*	18.4 (3.38, 33.5)	0.02*
3rd trimester	24.2 (10.3, 38.1)	<0.001*	16.1 (5.23, 27.0)	<0.001*
FFM, kg				
1st trimester	32.0 (7.62, 56.5)	0.01*	33.6 (6.38, 60.9)	0.02*
2nd trimester	25.5 (4.58, 54.5)	0.02*	26.4 (-1.29, 54.2)	0.06
3rd trimester	35.5 (11.0, 66.1)	0.01*	34.8 (3.47, 66.1)	0.03*
TBW, L				
1st trimester	37.5 (7.92, 67.0)	0.01*	41.2 (8.54, 74.0)	0.01*
2nd trimester	30.7 (-0.94, 62.4)	0.06	30.8 (-3.63, 65.3)	0.08
3rd trimester	25.6 (-7.42, 58.7)	0.13	22.4 (-15.4, 60.2)	0.24

BMI: body mass index; FM: fat mass; FFM: fat free mass; TBW: total body water.
†Adjusted by maternal age, parity, and frequency of prenatal care visits.
*$p<0.05$ for linear regression.

been shown to be independently associated with infant birth weight.[26,27] Therefore, although the direct pathway is unclear, the association between prepregnancy BMI and infant birth weight is biologically plausible.[28]

In line with previous studies, we observed a significant increase in maternal body weight in each trimester,[25,29] and maternal body compositions (e.g., FM and FFM) and fetal tissues (e.g., the fetus itself , placenta, and amniotic fluid) contributed to the weight increase.[30] This finding supports the results of a smaller study involving 10 women in Taiwan, in which significant associations were observed between maternal weight in each trimester and infant birth weight.[27]

In the present study, the increase in maternal FM was found to be highest in the third trimester, and maternal FM in the third trimester differed significantly from that in the previous trimester. This result is consistent with the findings of other studies that have used different methods of fat measurement. One study that used a fat measurement method similar to the one used in the present study showed that FM (%) was higher in the late third trimester than in early pregnancy (<20 weeks), whereas another study, which was conducted in Sweden, measured the subcutaneous adipose tissue volume and showed that maternal FM peaked in the week 32 of pregnancy.[14,17] In previous studies that have adopted the classic method of measuring skinfold thickness and total body potassium, the increase in FM has been shown to be at its highest between weeks 26 and 28 before decreasing in the third trimester.[17,28] Measuring FM with a bioelectrical impedance analysis scale yields a lower estimate than using densitometry, anthropometry, or isotope dilution.[17] However, the various methods consistently suggest that FM increases throughout pregnancy to provide energy reserves for delivery.

Although maternal FM increases throughout pregnancy, it does not necessarily imply that FM is significantly associated with infant birth weight. In this study, first-trimester FM showed no association with infant birth weight, which is consistent with the findings of a study conducted in Bangladesh, in which FM was measured at 10 weeks of pregnancy.[25] However, our finding of associations of second- and third-trimester FM with infant birth weight is not corroborated by other studies. The study conducted in Bangladesh even reported a negative association between infant birth weight and FM at weeks 20–32.[25] This inconsistent finding may be attributable to the difference in the maternal nutritional status of the subjects of both studies. The average first-trimester BMI was lower in the Bangladesh study than in the present study (19.5±2.5 vs 24.2±4.5 kg/m^2).[25] However, another study conducted in Sweden reported an association between third-trimester FM and infant birth weight, and the prepregnancy BMI in that population was similar that in our population (24.2±4.9 kg/m^2).[14] A lower maternal nutritional status may shift the body's priority from fetal development to establishing a maternal energy reserve.

In the present study, maternal FFM increased in each trimester, peaking in the third trimester. The FFM increase reflects an increase in body protein mass, which consists of the fetus (42%), uterus (17%), blood (14%), placenta (10%), and breasts (8%). A study conducted in the United Kingdom reported that maternal FFM increased by 0.9 kg between the first and third trimesters; however, in the present study, FFM increased by an average of 2 kg for the same period (Table 1).[29,30] This difference might be attributable to the different methods of FFM measurement; the United Kingdom study[28] measured FFM according to total body potassium, whereas a bioelectrical impedance analysis scale was employed in the present study used. The association we observed between FFM and infant birth weight in the first and third trimesters corroborates the findings of a previous study conducted in Bangladesh. First-trimester maternal FFM plays a crucial role in infant birth weight, and fetal FFM contributes to 42% of third-trimester FFM.[30]

In this study, TBW increased in each trimester, peaking in the third trimester, which agrees with the results of other similar studies.[29,31] The association between TBW and infant birth weight was observed only in the first trimester, like the study conducted in Bangladesh. Maternal plasma volume, intracellular and extracellular water, amniotic fluid, and water in the conceptus contribute to the TBW increase during pregnancy; therefore, TBW might be too general to have an association with infant birth weight.[25]

The limitation of this study is that measurements were not performed throughout the pregnancies. This study lacked prepregnancy and postdelivery measurements of maternal indicators, although a previous study reported no difference between first-trimester and prepregnancy measurements of maternal body weight, BMI, FM, and FFM.[28] The decrease in the peak maternal body composition from the third trimester to postdelivery might depict the development of maternal body composition and the conception product.[14,25,29,31] A more comprehensive analysis of the factors influencing fetal growth and maternal nutritional intake during pregnancy might improve our understanding of their association with infant birth weight. The strength of this study is the use of a longitudinal analysis of maternal body composition combined with a history of maternal body weight, which is rarely found in studies in developing countries; this history could be obtained because the study was a continuation of a cohort study commenced in 1988.

The findings of the present study elucidate the factors associated with LBW and are may augment efforts to reduce its prevalence. Maternal birth history, maternal BMI, and maternal pregnancy weight influence placental growth. Placental growth is also influenced by FFM and TBW in the first trimester, whereas the influence of FM is stronger in the subsequent trimesters. Paternal birth weight and maternal nutritional intake, physical activity during pregnancy, and smoking may also influence infant birth weight. These factors should be investigated in future studies.

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AUTHOR DISCLOSURES

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