Relationship between maternal characteristics and neonatal birth size in Egypt

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العلاقة بين الخصائص الأمومية وبين حجم الوليد في مصر

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الخلاصة: قامت هذه الدراسة المصريّة باستقصاء تأثير عوامل أمومة معيَّنة على حجم الوليد. وجمعت البيانات بعد الولادة من 782 أماً يتمتعن ظاهرياً بالصحة، ومن ولدانهن. واستُكمِل استبيان حول الحالة الشخصية، والطبية، والاجتماعية والاقتصادية، وعادات التدخين، والتعرّض للتدخين. وقد سُجِّل وزن وطول الأمهات، ومَرَّات تناول الطعام أثناء الحمل، ومستوى الهيموغلوبين في 594، 234، 246 أمّاً على التَّوَالي. وقِيسَ وزنُ الوليد، وطوله، ومحيط رأسه. وقد لوحظ ترابُط إيجابي يُعْتَدُّ به بين المتغيِّرات الأنثروبومترية للأمهات وبين قياسات الوليد، وكان الأثر أكثر وضوحاً في الإناث من الذكور من حيث مَنْسَب كتلة الجسم ومحيط الرأس. في حين شوهدت نسبة يُعتدُّ بها إحصائياً من حالات الترابط السلبي بين مستويات الهيموغلوبين في الأمهات وبين حجم الوليد. وترابَطَ حجم الوليد ترابُطاً قوياً مع تناول الأمهات للأغذية الغنيَّة بالمغذيات الزهيدة المقدار في جميع مراحل الحمل. وقد كان للتدخين القسري تأثيرٌ يُعْتَدُّ به على وزن الوليد ومَنْسَب كتلة الجسم في الإناث والذكور.

ABSTRACT This study in Egypt investigated the influence of selected maternal factors on neonatal birth size. Data were collected after delivery from 782 apparently healthy pregnant women and their neonates. A questionnaire on personal, medical, socioeconomic status, smoking habits and exposure to smoking was completed. Maternal weight and height, food frequency intake during pregnancy and haemoglobin levels were recorded for 594, 234 and 246 of the mothers respectively. Neonatal birth weight, length and head circumferences were measured. A significant positive correlation between maternal anthropometric variables with neonatal birth dimensions was observed and the effect was more evident in girls than boys for BMI and head circumference. Statistically significant negative correlations were found between maternal haemoglobin levels and birth size. Birth size was strongly correlated with maternal consumption of micronutrient-rich food at all stages of gestation. Passive smoking significantly affected birth weight and BMI of girls more than boys.

Corrélations entre les caractéristiques maternelles et les mensurations du nouveau-né en Égypte

RÉSUMÉ La présente étude a analysé l'influence de certains facteurs maternels sur les mensurations du nouveau-né en Égypte. Les données ont été recueillies après l'accouchement auprès de 782 femmes qui étaient apparemment en bonne santé pendant leur grossesse, et auprès de leur nouveau-né. Un questionnaire a été administré afin d'évaluer leur situation personnelle et socioéconomique, leur état de santé, leurs habitudes en matière de tabagisme et l'exposition à la cigarette. Le poids et la taille des mères, la fréquence de leurs apports alimentaires pendant leur grossesse et leur taux d'hémoglobine ont été enregistrés pour 594, 234 et 246 d'entre elles, respectivement. Le poids, la taille et le périmètre crânien du nouveau-né ont été mesurés à la naissance. Une corrélation positive significative a été établie entre les variables anthropométriques maternelles et les mensurations du nouveau-né à la naissance. Celle-ci était plus élevée chez les nouveau-nés de sexe féminin pour l'indice de masse corporelle et le périmètre crânien. Les taux maternels d'hémoglobine et les mensurations du nouveau-né étaient liés par des corrélations négatives statistiquement significatives. Les mensurations du nouveau-né étaient étroitement corrélées à la consommation maternelle d'aliments riches en micronutriments à toutes les étapes de la gestation. Le tabagisme passif influait significativement sur le poids de naissance et l'indice de masse corporelle des nouveau-nés, et l'effet était plus marqué chez les filles que chez les garçons.

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Introduction

Intrauterine growth is now considered an important determinant of both short and long-term outcomes for an individual [1]. Remarkable diversity of size and health of offspring are observed after normal pregnancies. When pregnancies are complicated by extrinsic variables such as parental factors [2], inappropriate maternal nutrition [3], maternal anaemia [4] or smoking [5], the birth weight and health of the neonate are substantially affected.

Maternal anthropometry is a potentially valuable tool in the evaluation of pregnancy status and prediction of birth weight [6]. In recent years infant birth weight has been increasing in many countries, representing an obstetric hazard and a potential public health problem since high birth weight involves a risk of obesity later in life [7]. In contrast, a low pre-pregnancy body mass index (BMI) is one of strongest predictors of adverse pregnancy outcomes such as preterm birth and fetal growth retardation. A low BMI interacts with other risk factors such as smoking and stress to increase risk of these outcomes, whereas zinc supplementation and low-dose aspirin increase birth weight in thin but not normal size women. The association between maternal thinness and adverse pregnancy outcomes may be mediated more by a low plasma volume than by decreased protein or energy status. Maternal micronutrient status may partially mediate plasma volume expansion in pregnancy, therefore improving maternal micronutrient status may reduce adverse outcomes through this mechanism [8].

Policy-makers and health care providers need evidence about the state of maternal and child health, especially of neonates, in order to plan counselling and behavioural interventions for pregnant women. The aim of the current study in Egypt was to investigate the influence of selected maternal factors—nutritional status, haemoglobin levels, socioeconomic class and exposure to passive smoking during pregnancy—on birth size.

Methods

Sample

This was a cross-sectional study of normal newborn babies delivered at El-Galaa hospital for gynaecology and obstetrics in Cairo and their mothers. Permission to perform the study was granted by the Ministry of Health and Population and local ethical approval was received from El Galaa hospital. The mothers were informed about the purpose of the study and their verbal informal consent was obtained. This hospital is the largest referral hospital for gynaecology and obstetric cases in Egypt and receives women of different socioeconomic status from all governorates of Egypt.

All neonates delivered on 3 days per week during the study period (from January to June 2008) were selected. The total sample was 782 newborn babies of both sexes (404 boys and 378 girls) and their mothers. The selected babies were singletons, full term, of gestational age range between 37 and 41 weeks (expressed as completed weeks since the first day of the last menstrual period), documented by ultrasound. None had detectable congenital anomalies, genetic malformations or evident intrauterine infections. The mothers, aged between 20 and 35 years, were free from any apparent pathological conditions or risk factors which might impair fetal intrauterine growth, such as diabetes, hypertension or renal disease. The mean age of the mothers was 26.3 years, and 34.5% were primiparous. All had had a normal vaginal delivery.

Maternal data collection

A simple questionnaire was distributed to the mothers to collect information on: demographic data; obstetric history of the present pregnancy and previous pregnancies; self-reported smoking habit and exposure to passive smoking; and nutritional history during the present pregnancy. Trained researchers helped the mothers to complete the questionnaire.

Smoking exposure

Mothers were asked to provide data about active and passive smoking before and during the pregnancy: her own smoking habit (how many cigarettes smoked per day); smoking habit of the baby's father (how many cigarettes smoked per day); and her exposure to environmental tobacco smoke at home or at work (how many smokers who smoked more than a packet a day were present at her usual place of work/home). On the basis of the questionnaire, the mothers were divided into 2 groups: controls (non-smokers and non-exposed); and smoke-exposed (smokers and passive smokers). In fact none of the women were smokers so the smoke-exposed comprised only mothers with exposure to environmental tobacco smoke at work or at home. The controls included 241 women and their infants (118 males and 123 females) and the passive smoke-exposed group included 541 women and their infants (286 males and 255 females).

Socioeconomic status

Mother's SES was classified using a composite score based on parental education, paternal occupation crowding score, water supply, housing, light supply and sewage disposal. A score of 16 was used as the cut-off point between high and low SES (8–15 = low SES and 16–22 = high SES). All the mothers were housewives.

Dietary intake

Maternal dietary intake was assessed retrospectively using a food frequency questionnaire (FFQ) to obtain the frequency of consumption of 12 food categories (beverages, rice/macaroni, legumes, vegetables, green leafy vegetables, fruits, meat/fish/liver/chicken, eggs, milk/milk products, bakery products, sweets/molasses/*halawa* etc.) on a 3-point scale (once a week or less, twice a week and alternate days/ every day). This dietary questionnaire was completed by 234 mothers who agreed to participate in this part of the study (of whom 116 delivered boys and 118 delivered girls). The food frequency questionnaire was filled in after the birth: mothers were asked to remember what they ate during the 1st, 2nd and 3rd trimesters of pregnancy.

Anthropometric measurements

The following measurements were taken for 594 mothers who agreed to participate in the assessment of maternal anthropometric status and health status (of whom 310 delivered boys and 284 delivered girls): body weight to the nearest 0.1 kg with minimal clothes using a standardized Seca beam balance; and body height to the nearest 0.1 cm using a Holtain portable anthropometer.

Maternal haemoglobin

Maternal blood haemoglobin level was evaluated for 246 of the mothers who agreed to the laboratory tests for haemoglobin (of whom 156 delivered boys and 108 delivered girls). Maternal venous blood was taken during the first stage of labour before the administration of any venous fluids during labour; a 5 mL sample was drawn into EDTA for complete blood count [haemoglobin (Hb) level, red cell count, haematocrit value and blood indices]. Maternal blood Hb value was determined by the standard cyanmethaemoglobin technique.

Neonatal data collection

The neonates were matched to the predetermined inclusion criteria using information from a simple questionnaire to mothers about her obstetric history of previous pregnancies and the present pregnancy.

Anthropometric measurements

Each neonate was examined clinically to exclude those having any anomaly that might affect their growth. Anthropometric measures were obtained for all 782 selected neonates and 594 mothers [9]. The infants were measured after 6 hours to allow for birth oedema to subside and not more than 24 hours after delivery. All measurements were made by the same 2 researchers. The neonates wore no/or minimal clothes (for which no correction was made). The following measurements were made: body weight to the nearest 10 g using a Zalamp scale; recumbent length (crown–heel length) to the nearest 0.1 cm using a Harpenden infantometer; and head circumference (at the level of the occiput, parietal prominence and supra-orbital ridge) to the nearest 0.1 cm using a flexible non-stretchable plastic tape. Each measure was recorded as the mean of 3 consecutive readings.

Statistical analysis

Body mass index (BMI) in kg/m^2 was calculated for each mother and neonate. Mean and standard deviation of the anthropometric measurements were calculated separately for boys, girls and the sexes combined, and for mothers. Pearson correlation test was used for the anthropometric measurements of the neonates' weight, length, head circumference and BMI and their mother's weight, height, BMI and Hb level. The correlations were repeated with boys, girls and the combined sample.

Maternal dietary intake was classified into macronutrients (proteins, carbohydrates, and fat) and micronutrient-rich foods (milk and milk products, fruits and green leafy vegetables). Intake of specific foods based on the FFQ and socioeconomic scores were analysed as grouped variables. These groupings reflected as closely as possible the frequency of consumption per week. All analyses were adjusted for the neonate's sex and maternal parity. Analysis of variance test was done to examine the relationship between frequency of intake of different food categories and the neonatal anthropometric measurements.

Mean and standard deviation (SD) of the studied anthropometric parameters were calculated separately for the controls and the study group, and compared using the Student *t*-test.

Data were analysed using *SPSS*, version 9.05.

Results

Anthropometric characteristics

Anthropometric measurements were recorded for 594 mothers and their neonates (310 boys and 284 girls). For various reasons, 1 or more measurements were missing for some of the babies and mothers.

The anthropometric measurements of the mothers and their neonates are presented in Table 1. The boys had slightly higher mean values for birth weight, length and head circumference than the girls, but the differences were not significant. There were also non-significant differences regarding the anthropometric measurements of the mothers who delivered boys and those who delivered girls.

Correlation between maternal and neonatal anthropometric measurements

Correlation tests between maternal and neonatal anthropometric measurements revealed that for both sexes combined, maternal weight as well as height had a significant positive correlation with neonatal birth weight, length, BMI and head circumference, while maternal BMI showed a significant positive correlation only with birth weight, length and BMI. Similar results were found when analysing the data for girls separately. For boys, all maternal anthropometric measurements showed significant positive correlations only with birth weight and length (Table 2).

To control for the influence of maternal height, the results of partial correlation tests between maternal weight and neonatal birth weight were: for boys

Table 1 Anthropometric parameters for neonates and their mothers

Variable	Neonatal parameters		Maternal parameters	
	No. of neonates	Mean (SD)	No. of mothers	Mean (SD)
Boys				
Weight (kg)	308	3.38 (0.5)	310	71.4 (12.1)
Length (cm)	309	49.8 (2.2)	285	157.5 6.2)
BMI (kg/m^2)	307	13.6 (1.5)	285	28.8 (4.6)
HC (cm)	310	34.8 (1.4)	n/a	n/a
Girls				
Weight (kg)	284	3.32 (0.52)	284	71.6 (13.3)
Length (cm)	284	48.9 (2.3)	255	157.7 5.8)
BMI (kg/m^2)	284	13.8 (1.6)	255	28.8 (5.1)
HC (cm)	284	34.2 (1.4)	n/a	n/a
Both sexes				
Weight (kg)	592	3.35 (0.49)	594	71.5 12.7)
Length (cm)	593	49.4 (2.3)	540	157.6 (6.0)
BMI (kg/m^2)	591	13.7 (1.6)	540	28.8 (4.8)
HC (cm)	594	34.5 (1.4)	n/a	n/a

BMI = body mass index; HC = head circumference; SD = standard deviation; n/a = not applicable.

$r = 0.138$, $P = 0.020$, for girls $r = 0.178$, $P < 0.001$ and for the sexes combined $r = 0.160$, $P < 0.001$. The results of the correlation tests before and after controlling for maternal height were not significantly different.

Correlation between maternal Hb & neonatal anthropometric measurements

The correlation tests showed that overall maternal Hb level had a negative correlation with all neonatal anthropometric measurements, which was significant for neonatal weight, length and head circumference (Table 2). The same findings were recorded for each sex separately (data not shown).

Maternal nutrient intake and social class

This dietary questionnaire was completed by 234 mothers (of whom 116 delivered boys and 118 delivered girls).

Over the 3 trimesters there were no significant differences between mothers of high and low SES classes as regards the frequency of maternal intake of the micronutrients studied (milk and milk products, fruits or green leafy vegetables) for both sexes, and of the macronutrients (proteins, carbohydrates and fat) for the female neonates (data not shown). However, for male neonates, there was a significant difference between mothers' SES as regards the frequency of maternal intake of protein and carbohydrate in the 1st trimester and of protein in the 2nd ($P < 0.001$).

Table 2 Correlation between maternal and neonatal anthropometric measurements for boys and girls and correlation between neonatal anthropometric measurements and maternal haemoglobin (Hb) level in both sexes combined

Neonatal parameter	Maternal parameter							
	Weight		Height		BMI		Hb level	
	r	*P*-value	*r*	*P*-value	*r*	*P*-value	*r*	*P*-value
Boys								
Weight	0.19	< 0.001	0.12	0.037	0.13	0.026	–	–
Length	0.20	< 0.001	0.15	0.011	0.14	0.022	–	–
BMI	0.07	0.194	0.05	0.371	0.05	0.430	–	–
HC	0.07	0.196	0.10	0.095	0.03	0.630	–	–
Girls								
Weight	0.24	< 0.001	0.18	0.003	0.37	0.006	–	–
Length	0.18	0.003	0.15	0.018	0.13	0.045	–	–
BMI	0.18	0.003	0.13	0.032	0.13	0.046	–	–
HC	0.15	0.012	0.15	0.020	0.10	0.102	–	–
Both sexes								
Weight	0.22	< 0.001	0.15	< 0.001	0.15	< 0.001	−0.11	0.03
Length	0.18	< 0.001	0.14	< 0.001	0.13	0.003	−0.13	0.03
BMI	0.13	0.002	0.09	0.029	0.09	0.041	−0.00	0.45
HC	0.11	0.009	0.11	0.008	0.07	0.133	−0.14	0.02

BMI = body mass index; HC = head circumference.

Effect of maternal nutrient intake on neonatal anthropometric measurements

The effect of the frequency of maternal intake of nutrients (once a week, twice a week or on alternate days) during the 3 trimesters of pregnancy, on the physical growth of neonates was studied.

For boys, the frequency of maternal intake of macronutrients (carbohydrates, fat and protein) had a non-significant influence on neonatal anthropometric measurements during the 3 trimesters (data not shown). For girls, frequent intake of carbohydrates by mothers showed a non-significant effect on neonatal anthropometric measurements during the 3 trimesters. The frequency of maternal intake of fats had a significant effect on weight and BMI during the 3rd trimester. The frequency of maternal intake of protein during the 2nd trimester had a significant effect on length and head circumference and during the 3rd trimester on weight ($P < 0.05$).

A significant relationship with birth size was found for frequency of maternal consumption of micronutrient-rich foods (milk and milk products, fruits and green leafy vegetables) especially during the 2nd trimester (Tables 3–5).

For boys, maternal intake of milk and milk products during the 2nd trimester had a significant relationship with birth weight and BMI (Table 3). Consumption of these during the 3rd trimester had a significant influence on boys' birth weight (Table 5). Frequent intake of fruits and green leafy vegetables from the 2nd trimester had a significant effect on boys' birth weight, length, head circumference and BMI at birth. Frequency of intake of fruits and green leafy vegetables during the 3rd trimester showed a significant effect on boys' birth weight.

For girls, the frequency of maternal consumption of milk and milk products during the 2nd trimester had a significant relationship with birth weight and BMI but not length (Table 4). Frequent intake of fruits during the 2nd trimester had a significant effect on girls' weight, length and BMI. Frequent intake of fruits during the 3rd trimester had a significant effect on girls' birth weight and BMI (Table 5). Maternal intake of green leafy vegetables during the 2nd trimester had a significant effect on girls' birth weight and BMI and during the 3rd trimester had a significant effect on BMI. Data for head circumference for girls showed no significant influences on neonatal anthropometric measurements (data not shown).

Effect of passive smoking on neonatal anthropometric measurements

Comparison of the neonatal anthropometric parameters of the control group, whose mothers were not exposed, and the group whose mothers were exposed to environmental tobacco smoke are presented in Table 6. For both sexes

Table 3 Relationship between maternal intake of food rich in micronutrients during the second trimester and newborn anthropometric measurements for boys

Food group/maternal frequency of intake	No. of neonates	Neonatal parameters: boys			
		Weight (kg) Mean (SD)	Length (cm) Mean (SD)	HC (cm) Mean (SD)	BMI (kg/m²) Mean (SD)
Milk & milk products					
Once a week	6	3.23 (0.43)	49.8 (1.8)	34.3 (1.0)	13.0 (0.8)
Twice a week	48	3.11 (0.45)	49.2 (2.6)	34.0 (1.6)	12.8 (1.5)
Alternate/every day	62	3.45 (0.43)	50.4 (2.0)	34.6 (1.3)	13.6 (1.3)
F-value		6.79	2.68	1.75	4.34
P-value		0.002	0.073	0.179	0.015
Fruits					
Once a week	14	2.83 (0.34)	48.4 (2.6)	33.1 (0.9)	12.1 (1.2)
Twice a week	34	3.17 (0.49)	49.1 (2.4)	33.9 (1.5)	13.1 (1.5)
Alternate/every day	68	3.45 (0.43)	50.4 (2.0)	34.6 (1.3)	13.5 (1.3)
F-value		13.37	7.49	8.32	6.74
P-value		< 0.001	< 0.001	< 0.001	0.002
Green leafy vegetables					
Once a week	2	3.33 (0.11)	50.5 (0.7)	33.7 (0.5)	13.0 (0.1)
Twice a week	33	3.02 (0.43)	48.9 (2.5)	33.7 (1.3)	12.6 (1.2)
Alternate/every day	81	3.40 (0.47)	50.2 (2.2)	34.5 (1.4)	13.5 (1.4)
F-value		8.11	3.85	3.53	4.87
P-value		< 0.001	0.024	0.033	0.009

BMI = body mass index; HC = head circumference; SD = standard deviation.

Table 4 Relationship between maternal intake of food rich in micronutrients during the second trimester and newborn anthropometric measurements for girls

Food group/ maternal frequency of intake	No. of neonates	Neonatal parameters: girls		
		Weight (kg)	Length (cm)	BMI (kg/m²)
		Mean (SD)	Mean (SD)	Mean (SD)
Milk & milk products				
Once a week	13	2.92 (0.71)	48.3 (3.2)	12.4 (2.1)
Twice a week	45	3.12 (0.41)	48.6 (2.4)	13.2 (1.1)
Alternate/every day	61	3.27 (0.38)	49.2 (1.9)	13.5 (1.4)
F-value		4.21	1.53	3.80
P-value		0.017	0.221	0.025
Fruit				
Once a week	25	2.82 (0.39)	47.8 (2.2)	12.3 (1.3)
Twice a week	38	3.18 (0.45)	48.9 (2.3)	13.3 (1.3)
Alternate/every day	56	3.33 (0.37)	49.3 (2.1)	13.8 (1.4)
F-value		14.07	3.73	10.37
P-value		< 0.001	0.027	< 0.001
Green leafy vegetables				
Once a week	4	2.74 (0.91)	48.8 (3.0)	11.3 (3.2)
Twice a week	34	3.08 (0.39)	48.5 (1.8)	13.1 (1.2)
Alternate/every day	81	3.24 (0.43)	49.0 (2.4)	13.5 (1.4)
F-value		3.63	0.59	5.09
P-value		0.029	0.555	0.008

BMI = body mass index; SD = standard deviation.

Table 5 Relationship between maternal intake of food rich in micronutrients during the third trimester and birth weight and BMI for both sexes

Food group/ maternal frequency of intake	No. of neonates	Neonatal parameters		
		Boys	Girls	Both
		Weight (kg)	Weight (kg)	BMI (kg/m²)
		Mean (SD)	Mean (SD)	Mean (SD)
Milk & milk products				
Once a week	42	2.97 (0.37)	3.03 (0.30)	13.0 (1.1)
Twice a week	48	3.47 (0.47)	3.31 (0.52)	13.6 (1.7)
Alternate/every day	26	3.47 (0.41)	3.33 (0.54)	13.4 (1.7)
F-value		3.38	1.43	0.75
P-value		< 0.001	0.099	0.822
Fruits				
Once a week	38	3.12 (0.34)	3.02 (0.26)	12.9 (1.2)
Twice a week	26	3.29 (0.52)	3.15 (0.53)	13.1 (1.5)
Alternate/every day	51	3.46 (0.50)	3.64 (0.42)	14.5 (1.4)
F-value		1.72	3.66	3.00
P-value		0.026	< 0.001	0.004
Green leafy vegetables				
Once a week	20	3.05 (0.39)	3.13 (0.52)	13.2 (1.7)
Twice a week	48	3.24 (0.48)	3.19 (0.38)	13.3 (1.3)
Alternate/every day	48	3.44 (0.48)	3.21 (0.49)	13.3 (1.3)
F-value		2.55	1.06	1.98
P-value		< 0.001	0.409	0.045

BMI = body mass index; SD = standard deviation.

combined and for girls separately, the control group had higher values than the smoke-exposed group but the differences were significant only for weight and BMI. For boys, no significant differences were observed for any anthropometric parameters.

Discussion

There is a considerable amount of evidence from humans and other animals, including the results of embryo transfer studies, that size at birth is primarily determined by the mother, whose influence acts more through the intrauterine environment than through the genes transmitted to her baby [10,11].

Transplacental exchange provides all the metabolic demands of fetal growth and uterine and umbilical blood flow rates are in turn dependent to a large degree on the vascularization of the placenta. Therefore, factors that influence placental vascular development are likely to impact on fetal growth and development, and thus on neonatal morbidity and mortality [12]. In a study on nutrient intake in rats during pregnancy on placental growth and vascular development, both nutrient restrictions and over-nourishment during pregnancy suppressed placental cell proliferation and vascularity [12]. Further studies in this area will lead to improved methods of managing nutritionally-compromised pregnancies.

Maternal passive smoking has also been shown to affect the fetal environment, causing fetal growth disturbance [13] and abnormal morphological changes in the internal tissue of newborns [14]. Non-smoking pregnant women exposed to environmental smoke have been found to have detectable elevated levels of nicotine and cotinine in their serum, urine and umbilical cord blood [15–17] and hair [18]. Although these levels were not as high as those of active smokers, there is evidence that exposure to passive smoking

Table 6 Comparison of neonatal anthropometric measurements by maternal passive smoking exposure

Neonatal parameter	Controls (boys n = 118; girls n = 123) Mean (SD)	Passive smoke-exposed (boys n = 286; girls n= 255) Mean (SD)	P-value
Boys			
Weight (kg)	3.39 (0.42)	3.38 (0.37)	NS
Length (cm)	49.9 (2.1)	49.8 (2.0)	NS
BMI (kg/m²)	13.6 (1.4)	13.6 (1.4)	NS
HC (cm)	34.7 (1.3)	34.8 (1.4)	NS
Girls			
Weight (kg)	3.41 (0.53)	3.30 (0.49)	< 0.01
Length (cm)	49.1 (1.9)	48.9 (2.0)	NS
BMI (kg/m²)	14.1 (1.8)	13.7 (1.5)	< 0.01
HC (cm)	34.4 (1.5)	34.1 (1.3)	NS
Both sexes			
Weight (kg)	3.40 (0.48)	3.34 (0.43)	< 0.05
Length (cm)	49.5 (2.0)	49.4 (2.1)	NS
BMI (kg/m²)	13.9 (1.6)	13.6 (1.5)	< 0.05
HC (cm)	34.5 (1.4)	34.5 (1.4)	NS

SD = standard deviation; BMI = body mass index; HC = head circumference; NS = not significant.

can produce nicotine uptake sufficient to affect birth outcome through mechanisms similar to those affecting smokers. Passive smoking causes placental vasoconstriction, resulting in diminished utero–placental blood flow which contributes to the lower birth weight associated with passive smoking. Also, fetal growth is known to be retarded by the direct toxic effects of nicotine, carbon monoxide and other substances generated by burning cigarettes [19–21].

Our findings highlighted the interrelations between the body physique of the mother, her nutritional status, haemoglobin levels, socioeconomic class and her exposure to passive smoking during pregnancy versus intrauterine growth and birth size of her neonate. Significant positive correlations between maternal anthropometric parameters and neonatal birth dimensions were observed. These effects were more evident in girls than boys as regards BMI and head circumference. Our results are in agreement with many other studies which indicated that neonatal growth, as reflected by birth weight, length and head circumference, are mostly influenced by maternal size [22,23]. A study in Bangladesh found that the best predictor of birth weight as a continuous variable was maternal weight at registration and that a combination of initial weight and height of the mother was not as good a predictor of low birth weight as weight alone [24]. A study in Canada concluded that slower fetal growth due to maternal short stature or low prepregnancy BMI was physiological and not associated with a risk of perinatal death [25]. In Croatia, maternal pregestational weight, weight at delivery, gestational weight gain and body height correlated significantly with neonatal birth weight and birth length [26]. However, Gonzalez-Cossio et al. [27] and Haschke and Van't Hof [28] found that maternal predictors for neonatal birth weight were different from those for neonatal birth length.

A study in the Netherlands showed that there were ethnic differences in fetal growth, which to a large extent could be attributed to differences in maternal weight, height, age and parity. For some ethnic groups, however, additional factors are involved, as differences remain significant after correction for fetal and maternal characteristics [29].

Statistically significant negative correlations were found between maternal haemoglobin levels and birth size. These findings agree with results reported on neonates from different ethnic communities of African, European and American neonates [30–32]. The increase in plasma volume appears necessary for normal fetal growth and development. It has been reported that this physiological change results in low haematocrit values during pregnancy [33]. It is likely that poor outcomes associated with a high haematocrit are related to a failure of expansion of plasma volume which is necessary for promotion of the uteroplacental circulation which in turn promotes the nourishment and growth of the fetus. In ours study among the macronutrients, only fat and protein intake showed an association with girls' birth size during the 3rd trimester. The frequency of maternal intake of macronutrients was unrelated to any of the studied anthropometric indices for boys. Agarwal et al. indicated that increased caloric intake during pregnancy was significantly associated with increased birth weight [34]. On the other hand, in a study in Spain, caloric intake did not show a direct effect on intrauterine growth retardation [35]. However, other studies found that balanced protein–energy supplements during pregnancy can reduce the incidence of small-for-gestational-age infants by almost one-third [36,37]].

Birth size was strongly correlated with maternal micronutrient-rich food intake at all stages of gestation. The present data suggest that improved maternal intake of milk and green leafy vegetables at all stages of gestation and fruits from the second trimester until late gestation could lead to improved fetal growth. In a Danish study, milk intake in pregnancy was associated with higher birth weight for gestational age, lower risk of small-for-gestational-age babies, and higher risk of large-for-gestational-age babies. Birth weight was related to intake of protein, but not of fat derived from milk [38]. Rao et al. in India found that birth size was affected by milk and its products at week 18 of gestation and by high intake of fruits and green leafy vegetables at week 28 [39]. Godfrey et al. concluded that low maternal intakes of dairy and meat protein in late pregnancy were associated with lower placental growth and birth weight [40]. Maternal energy requirements are not a great influence on small-for-gestation-age babies but maternal consumption of micronutrients is believed to have an effect [41]. In south-east Nepal multiple micronutrients increased birth weight and head and chest circumferences but not body length [42].

Passive smoking of mothers in our study significantly affected the birth weight and BMI of girls more than boys. No explanation could be found in the literature for this sex difference. Jadsri and Jadsri in Thailand observed no association between maternal passive smoking, low birth weight and sex of newborn infants [43]. In Nagoya, Japan, a prospective study on maternal active and passive smoking and fetal growth reported an adverse effect of maternal active smoking on fetal growth in the Japanese pregnant population, but with a small influence of maternal passive smoking [44]. In the Czech Republic, passive smoking exposure increased the risk of low birth weight [45]. Nafstad et al. also concluded that women exposed to passive smoking were more likely to deliver small-for-gestational-age infants [18]. On the other hand, Chen, Pederson and Lefcoe found a non-significant birth weight difference between newborn infants of mothers exposed and not exposed to passive smoking [46]. Read and Stanley stated that paternal smoking was an independent risk factor for recurrent small-for-gestational-age term births among non-smoking mothers [47]. Luciano et al. noted that exposure of the fetus to passive smoking involved a reduction of most anthropometric measurements and body fat, not only birth weight [48]. This agrees to a certain extent with the current results in female neonates.

Conclusions

Maternal anthropometric parameters, haemoglobin level, exposure to passive smoking, nutritional intake and socioeconomic status affected the birth dimensions of neonates in Egypt.

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