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Maternal body composition in relation to infant birth weight and subcutaneous adipose tissue

Elisabet Forsum[1]*, Marie Löf[1], Hanna Olausson[1] and Elisabeth Olhager[2]

[1]*Department of Biomedicine and Surgery, Division of Nutrition, University of Linköping, SE-581 85 Linköping, Sweden*
[2]*Department of Molecular and Clinical Medicine, Division of Paediatrics, University of Linköping, University Hospital, SE-581 85 Linköping, Sweden*

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Infant birth weight has increased recently, representing an obstetric and potentially a public health problem since high birth weight involves a risk of obesity later in life. Maternal nutritional status is important for fetal growth and therefore relationships between maternal body weight and composition *v.* birth weight and infant subcutaneous adipose tissue were investigated in twenty-three healthy women and their newborn infants using multiple and simple linear regression analysis. Furthermore, using previously published data for nineteen infants, it was demonstrated that an anthropometric method could provide useful estimates of the amount of subcutaneous adipose tissue. Birth weight was correlated with the maternal content of total body fat (TBF) both before pregnancy and in gestational week 32 and, together with gestational age at birth, TBF (%) before pregnancy explained 45 % of the variation in birth weight. This figure was not increased when gestational gains in weight or TBF were added to the model. Furthermore, in infants, birth weight correlated with the amount of their subcutaneous adipose tissue. Together maternal TBF (%) and amount of subcutaneous adipose tissue in infants explained 61–63 % of the variation in birth weight while the amount of infant subcutaneous adipose tissue alone explained only 55 %. The maternal TBF content is likely to be important for the recent increase in birth weight. This factor probably causes a general augmentation in fetal growth rather than a specific stimulation of adipose tissue growth.

Birth weight: Maternal nutritional status: Subcutaneous adipose tissue: Total body fat

The relationship between the nutritional status of women and reproductive outcome, for example infant birth weight, is well recognized (Coad, 2003). However, our knowledge about the factors important for fetal growth is unfortunately incomplete, although it is known that genetics and nutrition are involved. During recent years the average birth weight has increased in many countries (Meeuwisse & Otterblad Olausson, 1998; Kramer *et al.* 2002; Odlind *et al.* 2003), representing increased health risks for infants and for mothers at delivery (Surkan *et al.* 2004). Furthermore, a high birth weight is associated with an increased risk of obesity later in life (Stettler *et al.* 2002; Dietz, 2004), which is potentially a very serious problem since diseases related to obesity are major causes of morbidity and death in many populations. Reports (Kramer *et al.* 2002; Surkan *et al.* 2004) linking a concurrent increase in maternal BMI to the observed increase in birth weight motivate further studies of how the maternal nutritional situation influences fetal growth and development. Maternal preconceptional body weight and composition, as well as gestational weight gain, are known to be important (Villar *et al.* 1992; Butte *et al.* 2003; Thame *et al.* 2004) in this context, and the gestational weight gain recommended by the Institute of Medicine (1990) differs for women with different BMI. Prepregnant BMI is generally considered to reflect the maternal nutritional status since BMI is related to the total body fat (TBF) content although the relationship between TBF and BMI is not perfect (Gallagher *et al.* 2000). Furthermore, for a long time the specific components of gestational weight gain that are critical for fetal growth were not clearly delineated, mainly due to difficulties involved in the measurement of body composition during pregnancy. Using appropriate techniques, Butte *et al.* (2003) recently found that birth weight was correlated with gestational gain in weight but not with gestational gain in TBF. However, their estimate of gestational weight gain explained only a small proportion of the variation in birth weight and by including pre-pregnancy weight and gestational age a larger proportion of this variation could be explained (Butte *et al.* 2003). It seems likely that this observation, at least partly, was a consequence of the pre-pregnant maternal TBF content, since a significant correlation between this content (in kg) and infant birth weight was also reported (Butte *et al.* 2003).

When studying the intrauterine origins of obesity the body composition of newborns becomes of interest. In this context information regarding the amount of adipose tissue in the infant body as well as its fat content is relevant. Such information is often obtained using a so-called skin fold caliper. Obviously this device provides an estimate of the thickness

Abbreviations: ATV, adipose tissue volume; MRI, magnetic resonance imaging; s.c., subcutaneous; TBF, total body fat.

* **Corresponding author:** Dr Elisabet Forsum, fax +46 13 223570, email EliFo@ibk.liu.se

of subcutaneous (s.c.) adipose tissue while a recent report demonstrates that such estimates do not represent useful estimates of TBF in infants (Olhager & Forsum, 2006). We have previously described a method by which the subcutaneous adipose tissue volume (s.c. ATV) in the infant body can be identified and assessed *in vivo* (Olhager *et al.* 1998) using magnetic resonance imaging (MRI) and such estimates (s.c. ATV-MRI) have been reported for healthy infants under 4 months of age (Olhager & Forsum, 2003; Olhager *et al.* 2003). Furthermore, Kabir & Forsum (1993) have described an anthropometric method by which the s.c. ATV can be assessed on the basis of measurements obtained using a tape measure and a skin fold caliper and in this paper estimates of s.c. ATV obtained using this method (s.c. ATV-Kabir) are compared with s.c. ATV-MRI. In addition, we have previously presented a mother–infant study describing the body composition of healthy women before, during and shortly after pregnancy, as well as the birth weight of their infants (Löf & Forsum, 2004; Löf *et al.* 2005). The results were obtained using methodology appropriate for estimating body composition of women during reproduction. The newborn infants were investigated with regard to their s.c. ATV-Kabir. Consequently, the data could be used to study relationships between maternal weight and body composition variables, on the one hand, and infant weight and amount of s.c. adipose tissue on the other, and these data are reported later. In particular, the present paper addresses the hypothesis that the maternal body fat content stimulates growth of the fetus and its adipose tissue.

Materials and methods

Study of the validity of the Kabir subcutaneous adipose tissue volume assessment method

Nineteen infants (eleven full term and eight preterm), 4–75 d old, were investigated with regard to their body weight, TBF, s.c. ATV-MRI, s.c. ATV-Kabir and the average of ten skin folds. For each infant, all these estimates were assessed in 1 d. These infants were part of a larger study (Olhager & Forsum, 2003; Olhager *et al.* 2003) where the ATV of infants was investigated. The nineteen infants were included in the present study since their s.c. ATV-Kabir results were comparable with those found for the infants in the mother–infant study.

Mother–infant study

Twenty-three healthy women, with parity of zero to two and planning pregnancy, participated in the present study (Löf & Forsum, 2004, 2006; Löf *et al.* 2005). When a woman had conceived, gestational age was estimated on the basis of an ultrasound measurement, generally in gestational week 12 (Jörgensen, 1997). Each woman delivered one healthy baby. Body weight, TBF and fat-free weight of the women were assessed before pregnancy, in gestational week 32 and 2 weeks postpartum. Their body weight was also measured in the delivery room prior to childbirth. Fetal weight was assessed by means of ultrasound in gestational week 31 (Jörgensen, 1997). In the infants, birth weight was recorded shortly after delivery, while ten skin folds, s.c. ATV-Kabir and body weight were assessed at the age of 3 ± 2 d.

Methods

For assessing TBF of the women, a two-component model based on total body water was used as previously described (Löf & Forsum, 2004). Fat-free weight was calculated from total body water using the hydration factors 0·718, 0·747 and 0·734 before pregnancy, in gestational week 32 and postpartum, respectively (Löf & Forsum, 2004). TBF was body weight minus fat-free weight. Weight of the babies was assessed using an electronic baby scale (Tanita Corporation, Tokyo, Japan). The procedures used to assess s.c. ATV-MRI (Olhager *et al.* 1998, 2003; Olhager & Forsum, 2003) and TBF (‘TBF-BWD’ by isotope dilution) (Olhager & Forsum, 2006) of the infants in the study of validity of the Kabir s.c. ATV assessment method have been described previously. In the isotope dilution method ^{2}H and ^{18}O were used as tracers and calculations were based on zero-time enrichments obtained from isotope disappearance curves. Corrections for non-aqueous exchange were made and total body water was the average of results obtained for the two isotopes. s.c. ATV-MRI was assessed with a precision of 1·6 % (Olhager *et al.* 2003). The following ten skin folds were assessed (Harrison *et al.* 1988) and their average was calculated: triceps; biceps; forearm; subscapula; mamilla; abdomen; calf; buttock; back and front of thigh. All skin folds were assessed in duplicate and, on the basis of these estimates, the technical error of measurement (Ulijaszek & Kerr, 1999) was calculated to be 0·3–0·5 mm for all skin folds except back of thigh and buttock where this error was 0·7–0·9 mm. Together with estimates of arm, leg, head and trunk circumferences and arm, leg, crown-rump and body lengths, these skin folds were used to calculate s.c. ATV (s.c. ATV-Kabir) using a modification of the method described by Dauncey *et al.* (1977). In this calculation a model of the infant body is made up of a sphere (the head), a large cylinder (the trunk) and two pairs of smaller cylinders (arms and legs). The head is assumed to contain no s.c. ATV. The amount of s.c. ATV on the trunk (A) is the trunk length (crown-rump length minus head circumference divided by 3·14) times trunk circumference (average of chest and hip circumference) times the average of ten skin folds/2 minus 0·1. The amount of s.c. ATV on the arm (B) is the length of the arm times arm circumference (average of lower and upper arm circumferences) times the average of ten skin folds/2 minus 0·1. The amount of s.c. ATV on the leg (C) is the length of the leg (body length minus crown-rump length) times leg circumference (average of calf and thigh circumferences) times the average of ten skin folds/2 minus 0·1. All estimates were expressed in cm and obtained using a tape measure, a length board or a Harpenden skin fold caliper (Practical Metrology, Lancing, UK). s.c. ATV-Kabir was calculated as $A + 2B + 2C$.

Ethics

The data reported in the present paper were obtained from studies (Olhager & Forsum, 2003; Olhager *et al.* 2003; Löf & Forsum, 2004, 2006; Löf *et al.* 2005) approved by the ethics committee of the University of Linköping.

Statistics

Values are means and standard deviations. Linear and multiple regression analyses were performed as described by Hassard (1991). Significance was accepted at the $P<0.05$ level. All statistical analyses were carried out using Statistica software, version 6.0 (StatSoft, Scandinavia AB, Uppsala, Sweden). Estimates of s.c. ATV-Kabir were evaluated according to Bland & Altman (1995). Thus the average and limits of agreement (2 SD) for the difference between s.c. ATV-Kabir and s.c. ATV-MRI, as well as the correlation between this difference and the average of s.c. ATV-Kabir plus s.c. ATV-MRI, were calculated.

Results

Subjects

Information regarding infants in the study of validity of the Kabir s.c. ATV assessment method is presented in Table 1, while Table 2 shows characteristics of the subjects in the mother–infant study.

Study of the validity of the Kabir subcutaneous adipose tissue volume assessment method

For infants in the study of validity of the Kabir s.c. ATV assessment method, a significant correlation was obtained between the average of ten skin folds and s.c. ATV-MRI in ml (r 0·78, $P=0·000089$) and in ml/kg infant body weight (r 0·77, $P=0·000131$) but not between the average of ten skin folds and TBF (%) (r 0·37, $P>0·05$). Nor was there a significant correlation between TBF (%) and s.c. ATV-MRI (ml/kg infant body weight) (r 0·40, $P>0·05$). s.c. ATV-Kabir (ml, x) was significantly correlated with s.c. ATV-MRI (ml, y), $y = 1·25x + 260$, r 0·84, $P=0·000007$. A comparison according to Bland & Altman (1995) showed that s.c. ATV-MRI minus s.c. ATV-Kabir was 373 ml on average and the limits of agreement was 171 (2 SD) ml. Furthermore, the following significant linear relationship was found: [(s.c. ATV-MRI) − (s.c. ATV-Kabir)] = 0·428 [(s.c. ATV-MRI) + (s.c. ATV-Kabir)]/2 + 99·9 (r 0·60, $P=0·0063$).

Mother–infant study

Size at birth v. maternal body weight and composition. Table 3 shows correlation coefficients for linear relationships between infant birth weight and maternal body weight and composition before and during pregnancy. Fig. 1 shows birth weight *v*. maternal TBF (%) before pregnancy (Fig. 1 (a)) and *v*. net gestational weight gain (Fig. 1 (b)). Before pregnancy and in gestational week 32, significant correlations with maternal body weight and TBF, in kg and as a percentage, were obtained. Neither retention of body weight nor of TBF during pregnancy was significantly correlated with birth weight. Furthermore, as also shown in Table 3, birth weight of the infants was significantly correlated with their gestational age at birth. In addition, TBF (%) before pregnancy was significantly (r 0·50, $P=0·014$) correlated with TBF (kg) mobilized between gestational week 32 and 2 weeks postpartum while the correlation between TBF gained during the entire pregnancy (kg) and the amount (kg) mobilized between gestational week 32 and 2 weeks postpartum was not significant. The maternal TBF content (%), both before pregnancy and in gestational week 32, was not significantly correlated with the length of the infant at birth. As shown in Table 4, TBF (%) before pregnancy and gestational age at birth explained 45 % of the variation in birth weight. When either TBF (kg) retained during the entire pregnancy or the net gestational weight gain (kg) was added to this model, this figure was 42 % or 44 %, respectively.

Fetal growth and birth weight v. subcutaneous adipose tissue volume of infants. Table 5 shows correlation coefficients for linear relationships between birth weight of infants *v*. the amount and thickness of their sc ATV. s.c. ATV-Kabir in ml and in ml/kg infant body weight was significantly correlated with birth weight. Also, birth weight was significantly correlated with the average of ten skin folds and with each individual skin fold. Fetal growth (g) between gestational week 31 and birth was significantly correlated (r 0·66, $P=0·00060$) with the average of ten skin folds. Neither s.c. ATV-Kabir (in ml or in ml/kg infant body weight) nor the average of ten skin folds was significantly correlated ($P>0·05$) with maternal TBF (kg or %) at any of the measurements before, during and after pregnancy. Likewise, neither

Table 1. Characteristics of full term and preterm infants participating in the study of validity of the Kabir subcutaneous adipose tissue volume (s.c. ATV-Kabir) assessment method*

(Mean values, standard deviations and ranges for nineteen subjects)

	Full term†		Preterm‡		Full term and preterm		
	Mean	SD	Mean	SD	Mean	SD	Range
Age at the day of investigation (d)	16	12	63	10	36	26	
Body weight							
At birth (g)	3460	425	1850	300	2780	895	
At the day of investigation (g)	3765	300	3350	250	3540	320	
s.c. ATV-MRI§ (ml)	836	186	810	91	825	150	505–1119
s.c. ATV-Kabir‖ (ml)	462	117	436	78	451	101	287–590
Total body fat (%)	16·5	5·6	15·8	3·1	16·2	4·6	9·0–28·2
Average of ten skin folds (mm)	7·6	1·3	7·8	0·9	7·7	1·2	5·8–9·3

* For details of procedures, see p. 409.
† Four boys and seven girls.
‡ Six boys and two girls, born at a gestational age of 221 (SD 7) d.
§ Assessed using magnetic resonance imaging (Olhager *et al.* 1998, 2003; Olhager & Forsum, 2003).
‖ Assessed according to Kabir & Forsum (1993).

Table 2. Characteristics of subjects in the mother–infant study*
(Mean values, standard deviations and ranges for twenty-three women–infant pairs)

	Mean	SD	Range
Women			
Before pregnancy			
Age (years)	30	4	23–37
Body weight (kg)	67·4	12·1	51·1–95·0
Height (m)	1·67	0·07	1·54–1·76
BMI (kg/m^2)	24·2	4·8	18·0–30·0
Total body fat (kg)	22·6	8·9	11·7–40·8
Total body fat (%)	32·6	7·8	17·2–49·8
Fat-free weight (kg)	44·6	5·5	35·3–51·8
Gestational week 32			
Body weight (kg)	79·3	15·6	58·1–101·5
Total body fat (kg)	27·0	9·5	11·4–46·2
Total body fat (%)	33·3	7·3	16·9–47·7
Two weeks postpartum			
Body weight (kg)	73·5	13·1	51·9–96·6
Total body fat (kg)	26·7	8·5	14·4–44·7
Total body fat (%)	35·5	6·0	30·2–50·1
During pregnancy			
Gestational weight gain† (kg)	18·1	6·6	7·9–29·1
Net gestational weight gain‡ (kg)	6·1	5·2	−3·2–15·4
Gain in total body fat‡ (kg)	3·9	3·7	−1·3–8·8
Infants§			
Fetal weight‖ (g)	1658	175	1339–1993
Birth weight (g)	3735	510	2600–4470
Birth length (cm)	51	2	46–57
Gestational age at birth (d)	280	10	256–296
s.c. ATV-Kabir¶ (ml)	357	137	173–600
Average of ten skin folds (mm)	6·4	1·3	4·4–8·7
Body weight** (g)	3550	465	2510–4220
Age** (d)	3	2	1–7

* For details of procedures, see p. 409.
† Body weight before delivery minus body weight before pregnancy.
‡ Value 2 weeks postpartum minus value before pregnancy.
§ Nine boys and fourteen girls.
‖ In gestational week 31.
¶ Subcutaneous adipose tissue volume estimated according to Kabir & Forsum (1993).
** When assessing subcutaneous adipose tissue volume according to Kabir & Forsum (1993).

s.c. ATV-Kabir (in ml or in ml/kg infant body weight) nor the average of ten skin folds was significantly correlated ($P > 0·05$) with the amount of TBF retained by the mother during pregnancy or with the amount of TBF she mobilized between gestational week 32 and 2 weeks after delivery. Table 4 shows that in a multiple regression analysis, the average of ten skin folds in the infants and the maternal TBF content (%) before pregnancy were both significantly related to birth weight. Together, these two independent variables explained 61 % of the variation in birth weight while the average of ten skin folds explained only 55 % of this variation. Similar results were obtained when TBF (%) in gestational week 32 was used in the multiple regression analysis instead of the maternal TBF content before pregnancy (Table 4).

Discussion

It is of relevance to compare the women in our mother–infant study with the women studied by Butte *et al.* (2003). The present study contained only twenty-three mother–infant pairs, while the study of Butte *et al.* (2003) was based on at least sixty observations. On average, the women in the present study were a little heavier, gained slightly more weight during pregnancy and delivered babies with a somewhat higher birth weight. However, in both studies, significant correlations were found for birth weight *v.* maternal body weight and TBF (kg) before pregnancy. Butte *et al.* (2003) found significant correlations for birth weight *v.* gestational weight gain and the coefficients of correlation, 0·35 for gestational weight gain and 0·26 for net gestational weight gain, were very similar to the corresponding figures in the present study. However, due to the small number of subjects, the power of the present study was insufficient to identify correlation coefficients below 0·42 as significant. Nevertheless, the similarity between results obtained in the present study and in the study reported by Butte *et al.* (2003) supports the conclusion that the present results represent valid reflections of how maternal weight and body composition affect fetal growth and birth weight. It should also be noted that the technical error of measurement associated with our skin folds may appear large, especially for two of the skin folds (back of thigh and buttock). We have been unable to find any studies in the literature that report on the precision of the skin folds measured in the present study in a similar population of very young infants. Nevertheless, as discussed later, there were strong correlations between s.c. ATV-MRI and skin fold results.

Table 3. Correlation coefficients (r) for linear relationships between infant birth weight (g) *v.* maternal body weight, maternal body composition variables and gestational age at birth of infants, based on twenty-three mother–infant pairs*

Independent variable	r	P
Before pregnancy		
Body weight (kg)	0·44	0·038
Total body fat (kg)	0·46	0·027
Total body fat (%)	0·48	0·021
Fat-free weight (kg)	0·20	NS
Gestational week 32		
Body weight (kg)	0·49	0·017
Total body fat (kg)	0·51	0·013
Total body fat (%)	0·49	0·017
Fat-free weight (kg)	0·26	NS
At delivery		
Gestational age of infants (d)	0·60	0·002
During the complete pregnancy		
Gestational weight gain† (kg)	0·38	NS
Net gestational weight gain‡ (kg)	0·25	NS
Net gain in total body fat‡ (kg)	−0·12	NS
During late pregnancy		
Mobilized total body fat§ (kg)	0·49	0·018

* For details of procedures, see p. 409.
† Body weight before delivery minus body weight before pregnancy.
‡ Value obtained 2 weeks postpartum minus value obtained before pregnancy.
§ Value obtained in gestational week 32 minus value obtained 2 weeks postpartum.

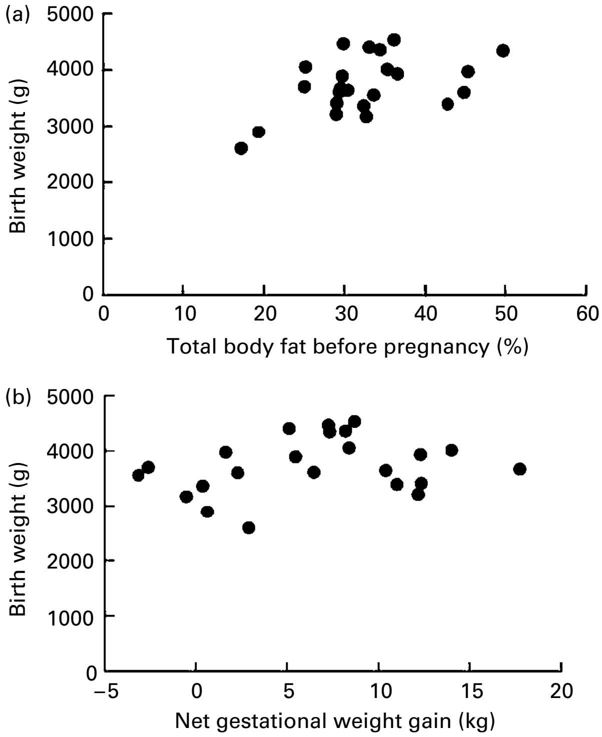

Fig. 1. Birth weight (g) *v.* maternal total body fat before pregnancy (%) (a) and *v.* net gestational weight gain in kg (b). For details of procedures, see p. 409. Data are for twenty-three mother–infant pairs; net gestational weight gain equals maternal weight 2 weeks postpartum minus maternal weight before pregnancy.

The present data suggest that in a group of well-nourished women, such as those in the present study, gestational weight gain had a negligible effect on birth weight while, instead, the maternal TBF content influenced fetal growth and consequently birth weight. This interpretation is based on the present findings that both the TBF content before pregnancy and in gestational week 32 were correlated with birth weight, and that the net gestational weight gain, or the retention of TBF during pregnancy, explained no additional fraction of the variation in birth weight other than the fraction of this variation explained by TBF (%) before pregnancy in combination with gestational age at birth. It should certainly be emphasized that this interpretation is based on a study with a small number of subjects and therefore needs to be confirmed in future studies. Nevertheless, a likely implication of the present results is that a reduction in the prevalence of overweight and obesity in girls and young women will be needed to counteract the increase in infant birth weight that was mentioned earlier (Meeuwisse & Otterblad Olausson, 1998; Kramer *et al.* 2002; Odlind *et al.* 2003).

s.c. ATV-MRI has previously been found to represent about 90 % of all adipose tissue in the infant body (Olhager & Forsum, 2003; Olhager *et al.* 2003). Estimates of s.c. ATV are therefore relevant when considering relationships between the maternal nutritional status and intrauterine origins of obesity. The results of the study of validity of the Kabir s.c. ATV assessment method show that s.c. ATV-Kabir was increasingly lower than s.c. ATV-MRI with increasing s.c. ATV in the infant body. However, in the present study there was a strong correlation between the two estimates of s.c. ATV as well as between the average of ten skin folds and s.c. ATV-MRI while there was no correlation between TBF (%) and s.c. ATV-MRI. Therefore s.c. ATV-Kabir and the average of ten skin folds reflect the amount and thickness of s.c. adipose tissue rather than the TBF content of the infant body.

The results of the mother–infant study show that the thickness as well as the amount of s.c. adipose tissue in the infant body increased with increasing birth weight. This observation is of interest in relation to the discussion concerning the intrauterine origins of obesity, since a high s.c. ATV at birth may well be a risk factor for developing excessive amounts of adipose tissue later in life. However, the present data did not show any association between the maternal TBF content and the amount of s.c. adipose tissue in the infant. The present finding that TBF (%) of the mother explained a fraction of the variation in birth weight, independent of that explained by the average of ten skin folds, rather suggests that a high maternal TBF content causes a general stimulation in the growth of the entire body of the fetus rather than specific stimulation in the growth of its adipose tissue. It is of interest to note that this interpretation of the present data can be reconciled with the concept of the so-called thin–fat Indian infant (Yajnik *et al.* 2002) who has a light, thin mother, but who nevertheless has a comparatively thick layer of s.c. adipose tissue. The lack of association between the maternal TBF content and the amount and thickness of infant s.c. adipose tissue may even call into question whether a high birth weight resulting from a high maternal TBF content really represents an increased risk of obesity later in life. In fact, recent findings (Singhal *et al.* 2003; Kensara *et al.* 2005) suggest that a

Table 4. Multiple regression analysis with birth weight (g) as the dependent variable, based on twenty-three mother–infant pairs*

	Independent variables†	Intercept	Regression coefficient (*B*)	*P* for *B*	Adjusted coefficient of determination (R^2)	*P* for R^2
I		−4870			0·45	0·00 107
	Total body fat before pregnancy‡ (%)		24·27	0·033		
	Gestational age at birth§ (d)		27·89	0·004		
II		1423			0·61	0·00 003
	Total body fat before pregnancy‡ (%)		19·33	0·044		
	Average of ten skin folds§ (mm)		264·7	0·000089		
III		1323			0·63	0·00 002
	Total body fat in gestational week 32‡ (%)		22·1	0·028		
	Average of ten skin folds§ (mm)		263·8	0·000071		

* For details of procedures, see p. 409.
† The independent variables were correlated in the following way: total body fat before pregnancy *v.* total body fat in gestational week 32, *r* 0·98, $P=2{\cdot}1\times10^{-16}$; total body fat before pregnancy *v.* gestational age at birth, *r* 0·20, $P>0{\cdot}05$; total body fat before pregnancy *v.* average of ten skin folds, *r* 0·27, $P>0{\cdot}05$; total body fat in gestational week 32 *v.* gestational age at birth, *r* 0·31, $P>0{\cdot}05$; total body fat in gestational week 32 *v.* average of ten skin folds, *r* 0·26, $P>0{\cdot}05$; gestational age at birth *v.* average of ten skin folds; *r* 0·42, $P=0{\cdot}048$.
‡ In women.
§ In infants.

high birth weight is associated with increased fat free weight rather than with a high body fat content later in life. Furthermore, since infant adipose tissue apparently contains quite variable amounts of fat (Baker, 1969; Olhager & Forsum, 2006), more comprehensive studies are needed to obtain a clear picture of how the maternal nutritional situation influences aspects of fetal growth and birth weight that are relevant in relation to intrauterine origins of obesity. Nevertheless, a likely interpretation of the present findings is that the association between the maternal TBF content and infant birth weight represents an adaptation to a situation where dietary energy has been highly available for a long period of time and where, therefore, the offspring is allowed to develop a large body, a situation that will require a comparatively large amount of food in the future, since body size has an important impact on dietary energy requirements (Food and Agricultural Organization of the United Nations, 2004). This interpretation can be reconciled with the observation by Baker *et al.* (2004), who reported that the pre-pregnant BMI of women was related to the amount of weight gained by their babies during the first year of life.

Table 5. Correlation coefficients (*r*) for linear relationships between birth weight of infants (g) *v.* the amount and thickness of their subcutaneous adipose tissue, based on twenty-three infants*

Independent variable	*r*	*P*
s.c. ATV-Kabir† (ml)	0·81	0·0000031
s.c. ATV-Kabir† (ml/kg)‡	0·66	0·00 056
Average of ten skin folds (mm)	0·75	0·000033
Individual skin folds (mm)		
Triceps	0·71	0·00 017
Biceps	0·43	0·043
Forearm	0·67	0·00 052
Subscapular	0·74	0·000054
Umbilicus	0·60	0·0022
Front of thigh	0·74	0·000061
Back of thigh	0·66	0·00 088
Mamillae	0·57	0·0044
Buttock	0·53	0·0089
Calf	0·51	0·014

* For details of procedures, see p. 409.
† Subcutaneous adipose tissue volume estimated according to Kabir & Forsum (1993).
‡ Infant body weight estimated when assessing subcutaneous adipose tissue volume.

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