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Another Approach to the Assessment of Growth in Early Infancy

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Introduction

Infants who rapidly gain weight in early infancy have been shown to have a greater propensity for obesity in childhood (Eid 1970). The need for correct nutrition can result in pressure being brought to bear on parents whose infants are gaining weight 'too rapidly'.

Light-for-dates infants are expected to have a more rapid weight gain than infants with normal birthweights because of the 'catch-up' phenomenon. The conventional definition of light for dates is a birthweight less then 2.5kg at term, but infants with birthweights *greater* than 2.5kg may also show signs of intra-uterine malnourishment, with subsequent neonatal hypoglycaemia; these have been termed 'thin-for-dates' babies (Oakley and Parsons 1977). These infants may also exhibit 'catch-up' growth which could lead to the suspicion that their mothers are over-feeding them.

The object of this paper is to ascertain the relationship between birthweights of thin-for-dates neonates and their weight gain during the first six weeks of life.

Material and Method

A total of 219 infants seen at the Jessop Hospital Well Baby Clinic between five and seven weeks of age were included in the study. All had been single births, with birthweights greater than 2.5kg. Gestations ranged from 37 to 42 weeks, and none of the infants had been ill. All had been botttle-fed and none had been fed cereals.

At the time of the study, standard instructions about feeding were given to mothers. No particular preparation of artificial milk was used, but all mothers had been instructed to feed milk in the volume of 2½oz/lb/day. Increasing amounts of milk were fed according to expected weight over the first six weeks of life; assuming a weight gain of 6oz per week. Mothers had been instructed to use half a scoop less of milk powder than was stated on the packet.

The gestation of each infant was calculated from the mother's last menstrual period unless this was in doubt, when a clinical assessment of gestation was made (Dubowitz *et al.* 1970). Birthweights had been recorded by midwives, using beam scales.

The mid-triceps and subscapular skinfold of each infant was measured by a single observer (JRO) within the first 24 hours of life, and again at five to seven weeks of age, using the method of Oakley *et al.* (1977). A repeatability study, using this same method and comprising 40 pairs

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of duplicate measurements by a single observer, gave 95 per cent confidence limits at the triceps site of ±4.6 per cent of the mean triceps skinfold, at the subscapular site of ±2.5 per cent of the mean subscapular skinfold, and of ±2.5 per cent of the mean skinfold for the average of the two sites. The actual weight gain and increase in the average of the triceps and subscapular skinfold thickness were calculated for each infant and corrected to the value which would have been observed at the age of six weeks.

Statistical Analysis and Results

Separate analyses were carried out for male (114) and female (105) infants. The preliminary analysis involved fitting regressions to weight data, then to skinfold data, using the measurements at birth as independent variables. Figures 1 to 4 show the graphs of the regression lines. The model fitted in all cases was:

$$Y = a_0 + a_1 Y + a_2 X^2$$

the dependent variable being the measurement at age six weeks. Estimates of the parameters are given in Table I.

The regression model for female weights is not adequately described by a straight line. A significant contribution is made by the quadratic term, the linear

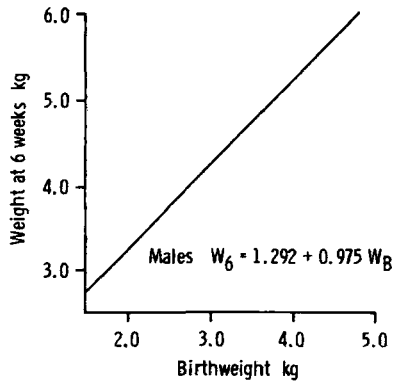

Fig. 2. Regression of birthweight against weight at six weeks for male infants.

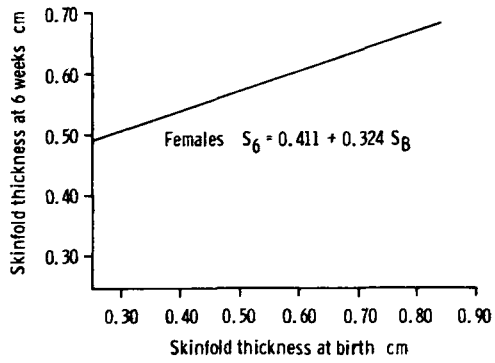

Fig. 3. Regression of skinfold thickness at birth against skinfold at six weeks for female infants.

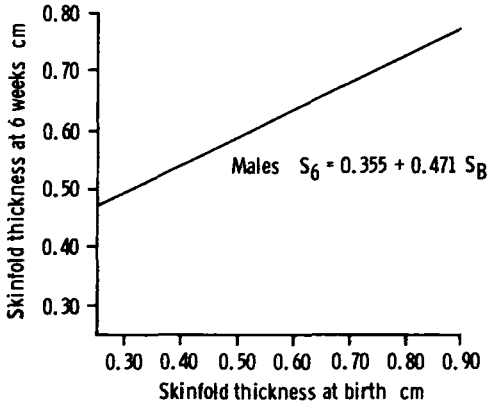

Fig. 1. Regression of skinfold thickness at birth against skinfold at six weeks for male infants.

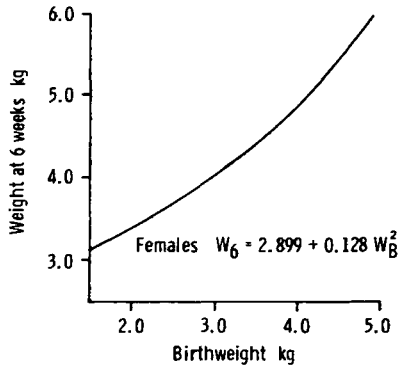

Fig. 4. Regression of birthweight against weight at six weeks for female infants.

TABLE I
Numerical parameters of regression lines shown in Figures 1 to 4

Fig. no.	Y	X	a_0	a_1	a_2	*SE or variable coefficient*
1 Male	S_6	S_B	0·355	0·471	*	0·139
2	W_6	W_B	1·292	0·975	*	0·070
3 Females	S_6	S_B	0·411	0·324	*	0·133
4	W_6	W_B	2·899	*	0·128	0·008

Model fitted: $Y = a_0 + a_1X + a_2X^2$

W_6 = weight (kg) at six weeks; W_B = weight (kg) at birth; S_6 = skinfold thickness (cm) at six weeks; S_B = skinfold thickness (cm) at birth.

*Term not necessary.

TABLE II
Values of net increase, and increase as percentage of birthweight, during first six weeks of life

Males			*Females*		
W_B	$W_G=W_6-W_B$	W_G/W_B (%)	W_B	$W_G=W_6-W_B$	W_G/W_B (%)
2·5	1·23	49·2	2·5	1·20	48·0
3·0	1·22	40·7	3·0	1·05	35·0
3·5	1·20	34·3	3·5	0·98	28·0
4·0	1·19	29·8	4·0	0·95	23·8
4·5	1·18	26·2	4·5	1·00	22·2

W_6 = weight (kg) at six weeks; W_B = weight (kg) at birth; W_G = weight gain.

TABLE III
Values of net increase of skinfold, and increase as percentage of skinfold thickness at birth, during first six weeks of life

Males			*Females*		
S_B	$S_G=S_6-S_B$	S_G/S_B (%)	S_B	$S_G=S_6-S_B$	S_G/S_B (%)
0·3	0·20	66·7	0·35	0·17	48·6
0·4	0·15	37·5	0·4	0·14	35·0
0·5	0·10	20·0	0·5	0·07	14·0
0·6	0·04	6·7	0·6	10·01	11·7
0·7	0·00	0·0	0·65	−0·03	−4·6

S_6 = skinfold (cm) at six weeks; S_B = skinfold (cm) at birth; S_G = increase in skinfold (cm).

term then not being significant. In all other cases, fitting a quadratic term does not explain the data better than the straight line at a significance level of 5 per cent.

On the basis of the results in Table I, the values were tabulated for net increase and for increase as a percentage of birth measurement for weight and skinfold thickness (Tables II and III).

The slope of the line in Figure 2 is not significantly different from that in Figure 1: it follows, therefore, that the weight gain (W_G) for males should be approximately constant over the first six weeks, reflecting the fact that weight gain is independent of birthweight. However, this is not true for females (Fig. 4). Table II shows that the lighter and heavier female babies gain more weight than average babies.

The final statistical analysis was designed to determine whether the skinfold thickness at birth can be used to predict weight at six weeks, in order to discover whether babies with low skinfold thicknesses for their birthweights grow faster than other babies. This was done by fitting a regression of the type:

$$W_6 = a_0 + a_1 W_B^2 = a_3 S_B$$

We then wanted to know whether the above model explained the data more adequately than those described by the models in Figures 2 and 4. For females the above model is not a significant improvement on that in Figure 4, but for males a significant contribution (significance level 0.3 per cent) is made by the addition of skinfold, the resultant model being:

$$W_6 = 1.304 = 1.582 S_B + 1.165 W_B$$

The standard error of the coefficient of S_B is 0.640; that of the coefficient of W_B is 0.103.

Table IV gives the implications of this model for net weight gain, and weight gain as a percentage of birthweight, for four typical skinfold measurements. It can be seen that skinfold thickness at birth is not a useful indicator of weight increase for females, but for male babies of a given weight, those with low skinfold thickness gain more weight than those with higher skinfold thickness.

TABLE IV

Values of net increase, and increase as percentage of birthweight, during first six weeks of life for varying skinfold thicknesses at birth (male infants)

W_B	S_B	$W_G = W_6 - W_B$	W_G/W_B (%)
2·5	0·3	1·40	56·0
	0·4	1·16	46·4
	0·5	1·01	40·4
	0·6	0·85	34·0
3·0	0·3	1·40	46·7
	0·4	1·25	41·7
	0·5	1·09	35·3
	0·6	0·93	31·0
3·5	0·3	1·49	42·6
	0·4	1·33	38·0
	0·5	1·17	33·4
	0·6	1·01	28·9
4·0	0·3	1·57	39·3
	0·4	1·41	35·3
	0·5	1·25	31·1
	0·6	1·09	27·3
4·5	0·3	1·65	36·7
	0·4	1·49	33·1
	0·5	1·34	29·8
	0·6	1·18	26·2

W_B = weight (kg) at birth; W_6 = weight (kg) at six weeks; W_G = weight gain (kg); S_B = skinfold (cm) at birth

Discussion

Using weight alone as a parameter, male infants in this study had an approximately uniform weight gain during the first six weeks of life, regardless of birthweight, but the lighter infants could be said to be catching up, as they had greater increases in bodyweight when expressed in percentage terms (see Table II).

Female infants with both lighter and

heavier birthweights gained more weight than average babies, but again the lighter infants could be regarded as catching up in percentage terms.

When skinfold thickness was considered in isolation, infants of both sexes with reduced skinfolds at birth exhibited 'catch-up' of skinfold thickness in both absolute and percentage terms. Infants with thicker skinfolds showed very little change in thickness during the first six weeks, the female infants even tending to reduce their skinfolds slightly (see Table III).

Obesity can be defined as a condition in which the adipose organ is enlarged out of proportion to other body tissues (Wolff and Lloyd 1974). As bodyweight may become greater either by increase in the size of the adipose organ or by increase in lean body mass, measurement of the adipose organ, together with bodyweight, provides a more meaningful assessment of obesity than does bodyweight alone. Measurement of either skinfold or birthweight alone may not distinguish the normally nourished infant of 2.7kg birthweight from the relatively malnourished infant of 3kg who was genetically destined to weigh 3.5kg at birth. This latter infant can be called 'thin for dates'.

When a combination of birthweight and skinfold thickness was used it was found that, for babies of a given weight, those with low skinfold thicknesses gained more weight than those with greater thicknesses. In other words, thin-for-dates infants 'catch-up' to approach their genetic potential. However, this applied less to female than to male infants.

Female infants have been shown to have thicker skinfolds than males of a given birthweight (Gampel 1965, Oakley *et al.* 1977), and it could be speculated that this is due to increased effect of maternal hormones upon the female fetus. The female neonatal skinfold might be expected to be a poor indicator of postnatal growth if it reflects a hormonal effect in addition to that of intra-uterine nutrition. The supposition that maternal hormones may have an effect on female skinfold is supported by the fact that fat female neonates tended to reduce their skinfolds by six weeks of age, *i.e.* when they were removed from the effect.

Skinfold calipers provide a measurement of subcutaneous fat (Lee and Ng 1965), although the measurement of skinfold thickness is subject to variation (Oakley *et al.* 1977). The methods used in this study provide acceptable repeatability (±2.5 per cent of the mean) and allowed for representation of both trunk and limb fat.

Obesity may be due to environmental and/or genetic factors. The twin studies of Brook *et al.* (1975) emphasised genetic influences on growth. Over-strength artificial feeding, with early introduction of solids, predisposes to accelerated weight gain (Taitz and Harris 1972), but more recent data suggest that *correct* artificial feeding does not (Taitz 1976, Oakley 1977). Environmental factors are reflected in the finding that, despite a similar weight gain, breast-fed infants may have more subcutaneous fat at six weeks of age than formulae-fed infants (Oakley 1977). Because of these variations in weight gain and skinfold thickness between breast-fed, bottle-fed and cereal-fed infants, we have included only bottle-fed infants in this study.

Long-term treatment of obesity is difficult and the results are disappointing (Lloyd *et al.* 1961), so it is important that correct nutrition be started early in life to prevent obesity.

Whitelaw (1976) has pointed out that obese mothers have fatter babies at birth than normal mothers, suggesting a familial tendency to obesity and presenting the problem of infants who are already at

birth fatter than normal. The present study has shown a different problem, in that some babies of more than 2.5kg birthweight who show rapid weight gain in early infancy may be doing so as a 'catch-up' phenomenon, and not because of overfeeding. This implies that some mothers may be right when they say they cannot 'fill' their babies, who may be demanding extra food in order to catch up.

Holmes *et al.* (1977) have shown that American babies of greater than 2.5kg birthweight and with low ponderal indices have accelerated weight gain, while short infants have slow postnatal growth. We believe that both ponderal indices and skinfold calipers are research tools and are difficult to use in the primary care environment; however, they do highlight the fact that some infants with birthweights over 2.5kg who cross weight centiles in an upward direction are not becoming fat, but are striving to reach their true somatic potential.

The relative thinness or fatness of a baby could be demonstrated by showing that his length is on a higher or lower centile than his weight, but measurements of length tend to vary in inexperienced hands. In practice, it should be possible merely to look at an infant who is gaining weight quickly and to judge whether he is becoming obese, before chastising the mother for feeding him too much.

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AUTHORS' APPOINTMENTS

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SUMMARY

The object of this study was to ascertain the relationship between birthweights of thin-for-dates neonates and their weight gain during the first six weeks of life. 219 term, bottle-fed infants with birthweights greater than 2.5kg were measured for weight and for triceps and subscapular skinfold thickness at birth and at six weeks of age.

For babies of a given birthweight, those with low skinfold thicknesses gained more weight than those with greater thicknesses. Babies with reduced skinfold thickness for their birthweight may have suffered intra-uterine malnourishment, can be termed 'thin for dates', and can exhibit increased weight gain during early infancy as a 'catch-up' phenomenon.

Some infants with birthweights greater than 2.5kg and who cross weight centiles in an upward direction are not becoming fat, but are striving to reach their genetic potential for growth.

RÉSUMÉ

Croissance durant la toute première enfance; une autre approche

L'objet de l'étude a été d'apprécier la relation entre l'état des nouveaux-nés 'minces pour le terme' et le gain de poids durant les six premières semaines de vie.

219 nourrissons, nés à terme, nourris au biberon, de plus de 2.5kg de poids de naissance ont été observés sur le poids, l'épaisseur du triceps et du pli cutané sous-scapulaire à la naissance et à six semaines. Pour les bébés d'un poids de naissance donné, ceux qui présentaient une épaisseur de pli cutané plus faible ont pris plus de poids que ceux avec pli

plus épais. Les nourrissons avec un pli cutané réduit pour leur poids de naissance peuvent avoir souffert d'une malnutrition intra-utérine, méritent le terme 'minces pour le terme' et présentent un accroissement du gain de poids durant la première enfance comme phénomène de 'rattrapage'. Quelques nourrissons d'un poids de plus de 2.5kg qui croisent les centiles de poids vers le haut ne sont pas en train de devenir gras mais s'efforcent d'atteindre leur potentiel de croissance.

ZUSAMMENFASSUNG

Wachstum im Säuglingsalter–L aus anderer Perspektive

Gegenstand dieser Untersuchung war es, die Beziehung zwischen untergewichtigen (thin for dates) Neugeborenen und Gewichtszuwachs in den ersten sechs Lebenswochen festzustellen.

Bei 219 am Termin geborenen Kindern, die bei der Geburt mehr als 2.5kg wogen und die mit der Flasche gefüttert wurden, wurden bei der Geburt und im Alter von sechs Wochen das Gewicht, und die Hautfaltendicke über dem Triceps und unter dem Schulterblatt gemessen. Für Kinder eines bestimmten Geburtsgewichtes zeigte sich, dass die Kinder mit geringer Hautfaltendicke mehr an Gewicht zunahmen als die mit einer grösseren Hautfaltendicke. Säuglinge mit verminderter Hautfaltendicke haben wahrscheinlich eine intrauterine Managelernährung durchgemacht und sollten unter dem Begriff 'zu mager für das Gestationsalter' (thin for dates) zusammengefasst werden. Sie nehmen in den ersten Lebenswochen sehr rasch an Gewicht zu infolge eines Aufholbedarfes. Einige Kinder mit einem Geburtsgewicht über 2.5kg, deren Gewichtskurve die Percentilen nach oben hin überschneidet, werden nicht fett, sie versuchen nur ihr vorgegebenes Wachstumspotential zu erreichen.

RESUMEN

Crecimiento en la primera infancia: un nuevo aspecto

El objeto de este estudio fue asegurar la relación entre los recién nacidos 'delgados por su edad' y el aumento de peso durante las seis primeras semanas de vida.

219 niños nacidos a término y alimentados con biberon de más de 2.5kg de peso al nacer fueron pesados y se les midió el espesor del pliegue cutáneo en el triceps y en zona subescapular al nacer y a las seis semanas de edad. Para niños con un determinado peso de nacimiento, aquellos que tenían un espesor de pliegue más bajo ganaron más peso que los que tenían un espesor mayor. Los niños que con un espesor de pliegue reducido en relación con su peso de nacimiento pueden haber sufrido desnutrición intrauterina y pueden ser llamados 'derogados por su edad' y exhibir un incremento en la ganancia de peso durante los primeros tiempos de la lactancia como un fenómeno de reatrapamiento ('catch-up'). Algunos niños de un peso de nacimiento superior a 2.5kg que cruzaron la linea de los centiles en dirección hacia arriba no se van volviendo gordos sino alternando su peso de acuerdo con el crecimiento.

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