Weight gain in infancy and physical development between 7 and 10½ years of age*

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Mellbin, T. and Vuille, J.-C. (1976). *British Journal of Preventive and Social Medicine*, **30**, 233-238. **Weight gain in infancy and physical development between 7 and 10½ years of age.** Heights and weights were measured in 963 10-year-old children, whose weight data from the first year of life were available. Rapid weight gain in infancy was arbitrarily defined on the basis of sex-specific percentiles of weight gain at four-month intervals and from birth to 12 months. In girls, no significant association between rapid weight gain in infancy and overweight at 10½ years was found. In boys, the association was significant for severe overweight (> 120% of standard weight for height). An estimation of the possible benefit of an intervention programme (food restriction in all male infants with rapid weight gain) showed, however, that at the very best 12% of the boys treated in this way could be expected to gain some benefit. The results of a correlation analysis between weight gain in infancy and change in height and relative weight between 7 and 10½ years suggested that the factors which determined weight gain in infancy were no longer operative at ages between 7 and 10½ years.

That infantile overnutrition may be a precursor of later obesity is still a matter of dispute. Experimental studies have tended to support the hypothesis of an important relationship between these two factors (Knittle and Hirsch, 1968; Hirsch, 1975), although contradictory observations have also been made (Bruch and Voss, 1974). Conclusions from studies on humans generally confirm this hypothesis when groups of obese patients are examined (Brook, 1972; Brook, Lloyd, and Wolf, 1972; Sjöström and Björntorp, 1974), whereas surveys of unselected populations reveal a rather weak relationship (Mellbin and Vuille, 1973; Hernesniemi, Zachmann, and Prader, 1974; Dahlmann, 1975). The issue is important, since the hypothesis has prompted recommendations for more rigid infant feeding practices in order to prevent obesity later in life (Adebonojo, 1974; Fomon *et al.*, 1975; Knittle, 1975). Such practices might produce more psychological harm than benefit if the biological basis is not sufficiently strong.

The present report adds further evidence to earlier observations (Mellbin and Vuille, 1973) that if an association between rapid weight gain in infancy and later overweight does exist, it is of little practical importance in a representative population of schoolchildren and is significant only in boys.

Specifically, the analysis will focus on the questions whether the predictive value of rapid weight gain in infancy is the same for overweight at 10½ years as has been found for overweight at 7 years, and to what degree the changes in height and weight occurring between 7 and 10½ years are correlated to the pattern of weight gain in infancy.

MATERIAL

The original sample of seven-year-olds whose weight data from the first year of life were available in 1970 comprised 972 children—465 boys and 507 girls (Mellbin and Vuille, 1973). Of these, 459 boys and 504 girls (99% of the sample) could be traced in 1973/74, when they were aged between 9 years 10 months and 11 years 2 months (mean: 10½ years).

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Of these, 895 still lived in the city or in the suburbs of Uppsala; 68 were examined in other parts of Sweden; one had died in the meantime. The remaining eight children were abroad at the time of the current survey; two of these belonged to the category *rapid weight gain* (see below), but all had a normal weight at the age of seven years.

METHODS

Heights and weights were recorded using the same methods as in the 1970 survey (Mellbin and Vuille, 1973). Children residing in the city of Uppsala were all measured by one examiner who also checked the reliability of the scales.

The anthropometric data for the other children were submitted by the respective school nurses after written instruction. The heights and weights were compared with the corresponding figures from 1970; in the case of unlikely changes the original documents and routine school health records were consulted. In this way all major errors were excluded.

Measured *height* was converted to *corrected height* at 10½ years, assuming linear growth of 6 cm a year between the age at which the measurement was taken and the age of 10½ years (Tanner, Whitehouse, and Takaishi, 1966).

As a means of estimating *standard weight for height*, the regression formula $y = a + bx + cx^2$ (x = height) was fitted to the present data—separately for boys and girls, using the method of least squares. The following functions were obtained:

$$\text{boys: } y = -12.86 + 6.29x + 18.48x^2$$

$$\text{girls: } y = -6.30 - 8.16x + 25.36x^2$$

The standard weight was then calculated for each child and his *relative weight*—that is, measured weight in percent of standard weight—was obtained. *Underweight* is defined as a relative weight of 90% or less, *normal weight* as a relative weight of over 90% but less than or equal to 110%, and *moderate* and *severe overweight* as relative weights of 111–120%, and more than 120%, respectively.

Rapid weight gain in infancy: Data presented in an earlier publication (Mellbin and Vuille, 1973) suggested that continuous rapid weight increase throughout the first year and short spurts of rapid weight gain during one or several limited periods might be associated with different aspects of physical development later in life. The following criteria were therefore used to define the *rapid weight gain* cohort children:

Period (months)	Percentiles
(a) 0–4, 1–5, etc., through 8–12	>97
(b) 0–12	>90
(c) 0–4	91–97
(d) 8–12	91–97
(e) if the weight attained at 12 months was above the 90th percentile even though none of the criteria (a–d) was fulfilled, the child was nevertheless included in the <i>rapid weight gain</i> group, because these children were always heavy at birth and thus presented evidence of rapid fetal growth. This subgroup, however, comprised only 17 children (= 7% of the <i>rapid weight gain</i> cohort).	

Sex-specific percentiles were derived from the present material. Any child fulfilling one or more of the above criteria was assigned to the *rapid weight gain* cohort, and all the other children to the *normal weight gain* cohort. Altogether 25.1% of the boys and 27.2% of the girls fulfilled the criteria for *rapid weight gain*.

RESULTS

Table I presents mean values and standard deviations of the anthropometric data. It is noteworthy that the girls, who had been shorter at 7 years, grew more rapidly than the boys between 7 and 10½ years. The population of girls appears also to be less homogeneous than that of boys, as shown by the significantly increased variance ratio F for the variables relative weight (7 and 10½ years), height increment, and change of relative weight. Otherwise the figures were similar for the two sexes.

Table II shows the *risk ratios* (formerly called relative risk) of *rapid* versus *normal weight gain* children for the two degrees of overweight at 7 and at 10½ years of age. Whereas in the girls, the values which were already low at 7 years remained relatively stable between the two measurements, a substantial decrease from high initial values was noted in the boys. At 10½ years the risk ratio for moderate overweight was not significantly higher than 1.0 in either sex, but in boys the increased risk of severe overweight was still evident.

The detailed analysis of subgroups within the *rapid weight gain* cohort showed that at 10½ years of age boys had a higher risk of being overweight than girls even when the same absolute values (weight gain of more than 7.6 or 8.3 kg during first year) were chosen as selection criteria, instead of the sex-specific percentiles used as criteria for the overall *rapid weight gain* group.

TABLE I
ANTHROPOMETRIC DATA

Variable	Boys (No. = 459) Mean SD		Girls (No. = 504) Mean SD		t
Measured weight (kg)					
7 years	24.1	3.29	23.9	3.51	1.27
10½ years	33.9	5.37	34.0	6.00	0.35
Corrected height (cm)					
7 years	124.9	5.42	124.1	5.39	2.48*
10½ years	143.2	5.98	143.6	6.36	0.92
Relative weight (%)					
7 years	100.1	8.87†	100.5	10.34†	0.71
10½ years	99.6	10.53‡	99.6	12.25‡	0.04
Height increment (cm)					
7-10½ years	19.5	2.16§	20.6	2.85§	7.17***
Change of relative weight (%)					
7-10½ years	-0.4	6.88	-0.9	7.43	1.03

†F = 1.36, P < 0.01 ‡F = 1.35, P < 0.01 §F = 1.74, P < 0.005 ||F = 1.16, P < 0.05 *P < 0.025 ***P < 0.001

TABLE II
RISK RATIOS OF RAPID WEIGHT GAIN VERSUS NORMAL WEIGHT GAIN CHILDREN WITH DIFFERENT DEGREES OF OVERWEIGHT AT 7 AND AT 10½ YEARS

Degree of Overweight	Age (Years)	Boys	Girls
Moderate (111-120%)	7	2.63***	1.67*
	10½	1.65	1.39
Severe (> 120%)	7	8.97***	1.65
	10½	3.32**	1.61
All degrees (> 110%)	7	3.31***	1.67*
	10½	2.05**	1.48

*P < 0.05 **P < 0.01 ***P < 0.001

Asterisks indicate the probability of the computed values being different from 1.0

$$\text{Risk ratio} = \frac{\text{number with overweight in rapid weight gain cohort}}{\text{total number in rapid weight gain cohort}} \div \frac{\text{number with overweight in normal weight gain cohort}}{\text{total number in normal weight gain cohort}}$$

The details of the fate of the *rapid weight gain* and the *normal weight gain* cohorts between 7 and 10½ years are presented in Table III. In both cohorts and for both sexes there was a tendency for the extreme categories of relative weight (underweight and severe overweight) to become more prevalent at 10½ years. Apart from this, the weight status remained remarkably stable. Thus 74% of both sexes remained in the same category, 25% changed to the adjacent category, and only 1% made a jump of two categories. In the *rapid weight gain* cohort the proportion of children with a stable weight status was 68%, as opposed to 76% in the *normal weight gain* cohort. This difference is statistically significant ($\chi^2 = 6.08$, df = 1, $P < 0.05$).

If the factors (genetic or environmental) which determine weight gain in infancy are still operative in the same sense during school age, a positive correlation will be expected between weight gain in infancy, on the one hand, and height increase and change in relative weight between 7 and 10½ years, on the other. Table IV shows that this was not the case. In boys, weight gain in infancy showed a very

weak positive correlation to height increase, but not to change in relative weight. In girls it was negatively correlated to this latter parameter.

This observation that a smaller proportion of the children in the *rapid weight gain* group than in the *normal weight gain* group maintained a stable weight status prompted a search for a possible correlation between weight gain in infancy and later weight instability. As a measure of this parameter the absolute value (that is, disregarding the sign) of the difference between relative weight at 10½ and at 7 years was used. The corresponding correlation coefficients were 0.142 ($P < 0.01$) for boys and 0.020 ($P > 0.5$) for girls. In order to control for the interaction with relative weight at 7 years and with height increase between 7 and 10½ years, partial correlations were computed. With this procedure, the remaining partial correlation coefficients between weight gain in infancy and the degree of weight instability in the interval between 7 and 10½ years were 0.077 ($P = 0.10$) and -0.032 ($P > 0.10$) for boys and girls, respectively. Thus, these results do not provide any evidence of a direct link between

TABLE III
PERCENTAL DISTRIBUTION OF RAPID WEIGHT GAIN AND NORMAL WEIGHT GAIN CHILDREN AMONG
FOUR DIFFERENT CATEGORIES OF RELATIVE WEIGHT

Boys					Girls								
Weight Gain in Infancy	7 Years		10½ Years		Weight Gain in Infancy	7 Years		10½ Years					
<i>Rapid</i>	UW	8·7	UW	5·2	UW	9·5	<i>Rapid</i>	UW	6·6	UW	5·8	UW	17·5
No. = 115 = 100%			NW	3·5						NW	0·8		
			MOW	—						MOW	—		
			SOW	—						SOW	—		
	NW	64·3	UW	4·3	NW	67·8	NW	69·3	UW	11·7	NW	63·3	
			NW	53·9						NW	54·0		
			MOW	5·2						MOW	3·6		
			SOW	0·9						SOW	—		
	MOW	19·1	UW	—	MOW	13·9	MOW	18·2	UW	—	MOW	10·2	
			NW	10·4						NW	8·0		
			MOW	5·2						MOW	4·4		
			SOW	3·5						SOW	5·8		
	SOW	7·8	UW	—	SOW	8·7	SOW	5·8	UW	—	SOW	8·7	
			NW	—						NW	0·7		
			MOW	3·5						MOW	2·2		
			SOW	4·3						SOW	2·9		
<i>Normal</i>	UW	9·9	UW	7·6	UW	17·8	<i>Normal</i>	UW	15·8	UW	11·2	UW	11·2
No. = 344 = 100%			NW	2·3						NW	4·6		
			MOW	—						MOW	—		
			SOW	—						SOW	—		
	NW	82·0	UW	10·2	NW	70·9	NW	69·8	UW	8·4	NW	58·3	
			NW	64·8						NW	2·7		
			MOW	5·8						MOW	0·3		
			SOW	1·2						SOW	—		
	MOW	7·3	UW	—	MOW	8·4	MOW	10·9	UW	0·3	MOW	5·5	
			NW	3·8						NW	4·4		
			MOW	2·6						MOW	3·8		
			SOW	0·9						SOW	2·5		
	SOW	0·9	UW	—	SOW	2·7	SOW	3·5	UW	—	SOW	5·5	
			NW	0·3						NW	—		
			MOW	—						MOW	0·8		
			SOW	0·6						SOW	2·7		
<i>All</i>	UW	9·6	UW	7·0	UW	15·7	<i>All</i>	UW	13·3	UW	9·7	UW	19·7
<i>Rapid plus normal</i>			NW	2·6						NW	3·6		
			MOW	—						MOW	—		
			SOW	—						SOW	—		
	NW	77·6	UW	8·7	NW	70·3	NW	69·6	UW	9·3	NW	66·3	
			NW	62·1						NW	57·1		
			MOW	5·7						MOW	3·0		
			SOW	1·1						SOW	0·2		
	MOW	10·2	UW	—	MOW	9·9	MOW	12·9	UW	0·2	MOW	8·4	
			NW	5·4						NW	5·4		
			MOW	3·3						MOW	4·0		
			SOW	1·5						SOW	3·4		
	SOW	2·6	UW	—	SOW	4·1	SOW	4·2	UW	—	SOW	6·4	
			NW	0·2						NW	0·2		
			MOW	0·9						MOW	1·2		
			SOW	1·5						SOW	2·8		

UW = Underweight ($\leq 90\%$ SW) NW = Normal weight (91–110% SW) MOW = Moderate overweight (111–120% SW)
SOW = Severe overweight ($> 120\%$ SW) (SW = Standard weight for height)

TABLE IV
COEFFICIENTS OF CORRELATION BETWEEN WEIGHT GAIN IN INFANCY, RELATIVE WEIGHT AT 7 YEARS, CHANGE IN RELATIVE WEIGHT, AND HEIGHT INCREASE FROM 7 TO 10½ YEARS

	Weight Gain in Infancy	Relative Weight at 7 Years	Change in Relative Weight	Height Increase
BOYS				
Weight Gain in Infancy		0.290***	0.019	0.089*
Relative Weight at 7 Years	0.231***		-0.124**	0.156***
Change in Relative Weight	-0.103*	-0.078		-0.173***
Height Increase	0.034	0.215***	-0.218***	
GIRLS				

*P < 0.05

**P < 0.01

***P < 0.001

what happened in infancy with respect to the growth of the total body mass and the physical development during the first school years. Male infants who gain weight rapidly certainly appear to have a slightly increased risk of later weight instability, but most of this correlation can be explained by an interaction with relative weight at seven years.

DISCUSSION

The small differences in anthropometric data between boys and girls are in accord with earlier observations, and probably can be explained by the fact that at 10½ years many girls are already approaching puberty, whereas the pubertal growth spurt in boys does not start until about two years later.

This difference in maturity, however, does not explain the discrepancy between *rapid weight gain* in boys and in girls with respect to their risk of overweight, since a similar pattern had been observed when the children were only seven years old. At 10½ years the risk ratios of *rapid weight gain* versus *normal weight gain* girls were not significantly different from 1.0. In boys of this age, the risk ratio with respect to severe overweight was significantly greater, although considerably less so than at seven years.

To evaluate the practical consequences of such an increased risk, the proportion exposed to the risk factor *rapid weight gain* of the total population has also to be considered. The 'population attributable risk percent' (Cole and MacMahon, 1971) is a measure of the proportion of the total amount of disease in a population that is attributable to the investigated risk factor. Taking the risk factor to be rapid weight gain in infancy and the disease to be severe overweight in 10½-year-old boys this value is

37%; that is, at best only 37% of all cases would theoretically be avoidable by preventing male infants from gaining weight too rapidly. Since the *rapid weight gain* group contained 25% of all male infants, and since the prevalence of severe overweight was 4%, this means that food restriction would have to be imposed on 25% of all boys in order to prevent 1.5% from becoming overweight. In other words, only 6% of the treated boys (1.5% out of 25%) would eventually gain some benefit from the treatment. If moderate overweight is included, the corresponding figure for the treated boys is 12%.

Obviously, these odds would not justify rigorous feeding schedules, even if the relationship between weight gain in infancy and later weight status had already been shown to be a causal one. If a very rigorous definition of *rapid weight gain* is used, thereby including only a small proportion of all boys in the treated group, the odds for the individual infant can be somewhat improved, but on the other hand, the total impact of such a programme on the total prevalence of overweight in schoolchildren would be negligible.

The hypothesis that the development of obesity is a continuous process which in many cases starts in infancy (Fomon *et al.*, 1975; Knittle, 1975) would imply a positive correlation between weight gain in infancy and change in relative weight between 7 and 10½ years. This extension of the hypothesis was not corroborated by our data. Thus, the partial correlation analysis with change in relative weight between 7 and 10½ years of age as the dependent variable showed that the factors which determined weight gain in infancy were no longer operative after seven years of age. In our population the weight status was remarkably stable between 7 and 10½ years of age. This is in accord with other similar

results (Sohar, Scapa, and Ravid, 1973). Whether this stability is an expression of uniform environmental influences in the studied population, or due to a genetically determined resistance against environmental factors, cannot be decided on the basis of the present data.

Hitherto, only relative weight or change in relative weight has been used as a parameter of outcome. With respect to future health, an index of obesity or fatness would certainly be more important.

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