Obesity Prognosis: A Longitudinal Study of Children From the Age of 6 Months to 9 Years

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Abstract: The development of body fatness and leanness is examined in an ongoing prospective nutrition and growth study. Individual skinfold thicknesses, relative weights, weight gains, activity levels, and caloric intakes were examined at seven ages between 6 months and 9 years. Changes in body fatness in this group of children provide evidence that the obese infant usually does not become the obese child. Weight gain in infancy is also a poor predictor of 9-year old obesity. Changes from obese to non-obese or lean are often not linear. There is evidence that impending or actual obesity begins at ages 6 to 9 years with some predictability provided as early as age 2 years for girls, age 3 years for boys. (*Am J Public Health* 1984; 74:968–972.)

Introduction

Concern with obesity prevention has prompted interest in its prediction and early detection. Two key questions, "Does the obese infant become an obese child?" and "Does the obese child become an obese adult?" have not yet been answered, but certain research evidence has suggested affirmative answers.[1,2] Rapid weight gain as well as obesity in infancy and early childhood have been considered predictive of later obesity.[3-5] Zack concluded from studying data from two cycles of the Health Examination Survey that childhood fatness was highly predictive of adolescent fatness.[1] A longitudinal study of teenagers from junior high school through senior high school revealed that subjects who were obese at age 14 tended to remain obese to the ages of 17 and 18 years.[2] Continuous longitudinal studies of obesity development, starting with an infant population, have not been reported, however.

This report from an ongoing study traces the development of body fatness and leanness as indicated by skinfold thickness, relative weight, and weight gain during successive years in a cohort of children from the time they were 6 months old to the age of 8 years, 9 months.* In addition, physical activity and caloric intake patterns of the subjects are compared with their subsequent body fatness.

Methods

The original sample consisted of 450 six-month old infants living in the Berkeley, California area. The sample was selected from among the 1,193 infants whose birth certificates were filed at the Berkeley Health Department in 1969. Parents who could be located six months later were asked to participate in a longitudinal nutrition and growth study if the family planned to be in the Berkeley area for a minimum of three years. Parents were contacted only if the certificate indicated a normal birth and absence of birth defects and was not stamped: "Requests omission from solicitation." Resulting recruitment was as follows: 450 (38 per cent) *in study;* 526 (44 per cent) *excluded from study* (did not meet eligibility criteria or had moved from area); 217 (18 per cent) *refusals* (working mother or too busy or other reason).

The sample consisted of 227 boys and 223 girls. The ethnic distribution was 319 White (71 per cent), 85 Black (19 per cent), 28 Japanese and Chinese (6 per cent), and a group of Others (4 per cent) which included Mexican Americans, Native Americans, East Indians, Filipinos, and Vietnamese. Sampling details have been given in previous publications.[6-8]

Data were collected at timed intervals, within one month of the child's birth date. Numbers of children measured at succeeding ages are: 6 months, 450; 1 year, 386; 2 years, 312; 3 years, 270; 4 years, 242; 6 years, 186; and 9 years, 170. Not all children remaining in the study at 9 years of age had been measured at every preceding interval. As is almost universally the case in longitudinal studies, the sample became increasingly unrepresentative of the population with the passage of time. Our more important concern was that the sample be representative in terms of obesity and leanness. Measurements of children subsequently lost to attrition indicated that such children were neither more nor less obese than the children remaining in the study. Attrition after age 2 was primarily due to those moving out of the geographic area of the study. The children in this study were compared annually with national norms for anthropometry.[9] At no age were the children in our study dissimilar to the age- and sex-specific US norms.

Anthropometry included weight, height, five circumferences (head, chest, waist, biceps, calf), and four skinfolds (triceps, subscapular, suprailiac, and chest). All measurements were taken by a highly trained technician and measurement was replicated. Detailed anthropometric methodology is described in previous publications.[6-8]

Three-day measured food intake records were obtained for each child. Parents were trained to record exact amounts of food consumed in household units as well as methods of preparation, and brand names where indicated. Food records were checked for details by a registered dietitian in the presence of the parent. When children were 9 years of age, they were trained to record their own information in a manner similar to that described above.

Activity records were collected in a way similar to that of diet records. One-day activity records with type of

*Children aged 8 years 9 months are hereafter referred to as 9-year old children.

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activity recorded every 5 minutes by a parent were collected at ages 6 months and 1, 2, 3, 4 years. At age 9 years the child actively assisted with the quantification of daily activity. Activities were quantified using Durnin and Passmore's caloric expenditure chart.[10]

The skinfold values in our population, as well as their distribution, were similar to those found in the Health and Nutrition Examination Survey.[9] The classic problem of defining obesity was avoided by using these norms of obesity: upper 15 per cent of the population defined as *obese;* lowest 15 per cent of the study population defined as *lean,* middle 70 per cent as *non-obese.*** Specific cutoff points are listed in Table 1. However, because the grouping of obesity by definition eliminates those near the cutoff, most correlations were done using the continuum of skinfold values of all children. The case study approach was also used whereby each child's measurements were looked at longitudinally.

When subjects were 9 years of age, they were weighed under water to determine body density and, by derivation, body fat.[8] At that age body fat was most highly correlated with sum of four skinfolds and triceps skinfold (Table 2). Other studies corroborate the finding that sum of skinfolds best reflects actual per cent body fat as measured by under water weighing.[11,12] To facilitate longitudinal comparisons, values for sum of skinfolds were standardized as follows: values of 0 represent mean fatness/leanness, increasing negative values represent increasing leanness, and increasing positive values represent increasing fatness.

Results

Prognosis of Infantile Obesity

The fattest 6-month old infants were compared with their own subsequent annual measurements to age 9 years (Table 3). The mean standardized values for sum of skinfolds for fat infants of both sexes decreased from year to year. The mean for both boys and girls was nearly zero, the point of average fatness/leanness by age 9.

A similar comparison for infants obese at 1 year (Table 3) revealed that the group of obese 1-year olds also became progressively less obese. For the group of 1-year old boys, the thinning process was more gradual than that observed in the 6-month group. For the groups of girls obese at 6 months and 1 year, no difference in pattern was observed.

Correlations between skinfolds of individual subjects at 9 years and 6 prior ages are shown in Table 4, indicating that predictability based on sum of skinfolds increases at successive ages and is greater for girls than for boys.

A case study approach was used in an effort to gain further understanding of predictability and to reveal possible differences between boys and girls. Twenty-six of the 34 boys obese at 6 months remained in the study for at least two years. Of these 26 boys obese at 6 months, 13 were not obese at any subsequent age, while an equal number were obese for varying periods of time, either continuously or at intervals while in the study. At the age of 6 years, four of the 15 measured at that age were still obese. Of the 17 in the study at the age of 9 years, none was obese at that age.

Twenty-one of the 30 girls obese at 6 months remained in the study to the age of 2 years. At 2 years, 17 had decreased in fatness while four had increased. Of the 10 obese 6-month girls in the study at the age of 6 years, four were still obese. Nine girls were measured at both 6 months and 9 years, and only one was obese at 9 years. She had shown varying degrees of obesity at successive ages.

Of the 25 children (17 boys and 8 girls) who had been obese at 6 months and were no longer obese at 9 years, seven exhibited the "yo-yo syndrome," i.e., a pattern of alternating in and out of the obese grouping in successive years. This phenomenon was not peculiar to specific ages and showed no clear direction over time.

In an attempt to elucidate the mechanism of thinning which occurred in 25 of the 26 obese infants, we examined each case individually. Rather than attempt to present

**A careful re-examination of the raw data led us to the conclusion that changing the obesity cutoff point from 15 per cent to 10 per cent or 5 per cent would not change the predictors of the outcome of infant obesity.

TABLE 1—Cutoff Points to Define Obesity by Sum of Skinfolds at Seven Ages

	Cutoff Points for Sum of Skinfolds					
	Boys			Girls		
Age	Value in mm	Standard Value*	Actual % of Population**	Value in mm	Standard Value*	Actual % of Population**
6 months	28	1.09	16	29	1.00	14
1 year	27	1.16	14	28	1.16	13
2 years	24	0.97	16	26	0.98	15
3 years	24	1.30	13	26	0.83	16
4 years	26	1.24	14	28	0.81	13
6 years	26	1.01	15	31	0.99	17
9 years	29	1.14	14	35	0.81	15

$* \frac{\text{value} - \text{mean}}{\text{standard deviation}}$

** not exactly equal to 15 per cent because skinfolds were measured to accuracy of 1mm and several children had the same values close to the cutoff.

TABLE 2—Correlation between Per Cent Body Fat Based on Underwater Weighing and Anthropometry at Age 9 years

Measurement	Boys	Girls
Sum of Four Skinfolds	.80	.77
Triceps Skinfold	.79	.75
Subscapular Skinfold	.76	.70
Suprailiac Skinfold	.73	.73
Chest Skinfold	.71	.68
Biceps Circumference	.67	.68
Relative Weight	.76	.66
Weight	.60	.58

TABLE 3—Mean Standardized Sum of Skinfolds at Subsequent Ages for Obese Infants by Sex

	Obese Boys at				Obese Girls at			
	6 Months		1 Year		6 Months		1 Year	
Age	N	Mean	N	Mean	N	Mean	N	Mean
6 months	36	1.65			30	1.67		
1 year	30	1.16	27	1.73	26	1.28	24	1.74
2 years	27	.72	22	1.34	20	1.20	20	1.08
3 years	23	.75	21	1.20	19	.64	17	.77
4 years	22	.57	20	1.14	14	.55	14	.52
6 years	18	.44	17	.75	10	.45	12	.44
9 years	18	.06	15	.44	9	.18	10	.15

TABLE 4—Correlation Coefficients for Sum of Skinfolds at Age 9 Years and Sum of Skinfolds at Six Previous Ages

Ages for Sum of Skinfolds	All Cases (n = 170)	Boys (n = 83)	Girls (n = 87)
6 months	.22**	.10	.29**
1 year	.28**	.18*	.36**
2 years	.54**	.29*	.66**
3 years	.62**	.41**	.69**
4 years	.65**	.49**	.69**
6 years	.84**	.80**	.85**

*p < .05
**p < .005

"typical" cases, we have presented in Figure 1 standardized skinfolds over time for the four most obese infants in the study at 6 months. Three of these cases were in fact "typical" and the fourth was unique in our sample. Case D was the only obese infant to remain obese through age 9 years. Measurements for the first three subjects illustrate the degree of change in fatness from year to year, as well as actual outcome. By looking at the individual cases, we can see that obese infants actually do become non-obese and do not merely cross over an arbitrary obesity cut-off point.

Prediction of Obesity from Assessment of Early Weight Gain and Relative Weights

To test further the predictive value of early anthropometric measure for later obesity, correlation coefficients were determined for sum of skinfolds at age 9 years with weight gain at earlier ages and relative weight at 6 previous ages.

Weight gain in infancy was found not to be a good predictor of obesity at 9 years. Figure 2 presents correlation coefficients for weight gains at each age (6-12 months, 1-2 years, 2-3 years, 3-4 years, 4-6 years and 6-9 years) and 9-year obesity as defined by sum of skinfolds. Correlation coefficients are usually higher for girls than for boys. As illustrated by the slope of the lines, weight gain between 1 and 2 years for the girls, and between 2 and 3 years and 4 and 6 years for the boys show these ages to be the earliest times highly related to later obesity. A second significant period of weight gain for both boys and girls is between 6-9 years.

Weight gain to later obesity was studied further by grouping subjects according to low, middle and high weight gain (Table 5). Infants were grouped by weight gain in two 6-month periods—birth to 6 months and 6 months to 1 year. The lowest 15 per cent were classified as the low weight gain group; the highest 15 per cent as the high weight gain group; and the 70 per cent in between were the middle weight gainers. While there was a trend toward a relationship in all groupings, it is not a strong one. The amount of weight gain was positively related to the sum of skinfolds at age 9 years, although not very predictive. Similarly, early relative weights are only mildly predictive of 9-year sum of skinfolds (Table 6).

Relation of Activity and Caloric Intake to Obesity

We attempted to relate sum of skinfolds at each age to

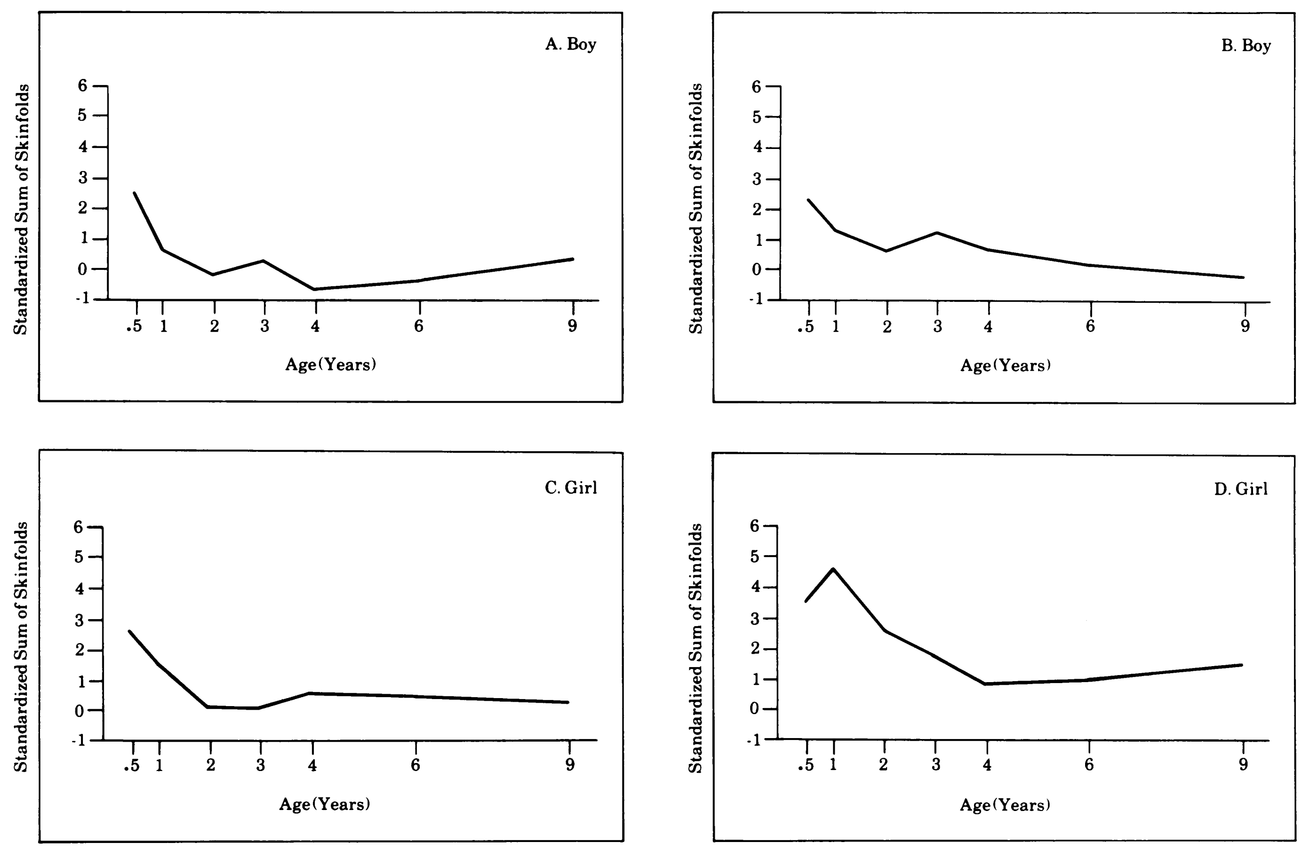

FIGURE 1—Standardized Sum of Skinfold Values Over Time for Four Most Obese Infants at 6 Months
NOTE: Infant D was the only one of 25 obese infants who remained obese for nine years.

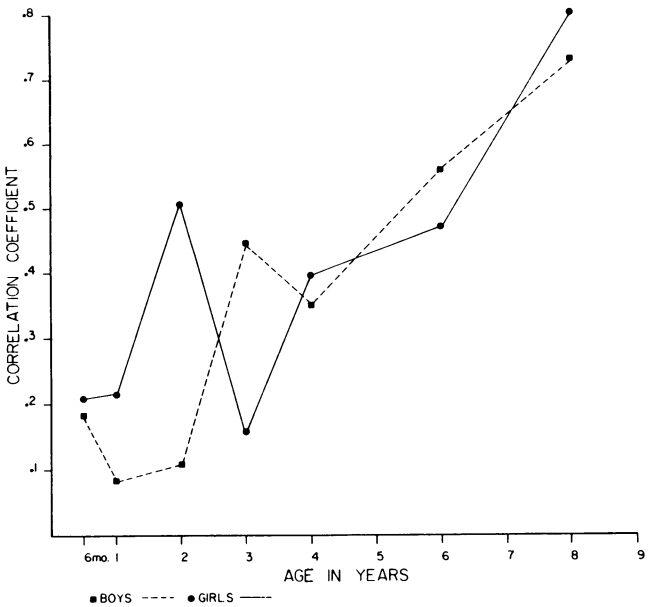

FIGURE 2—Correlation coefficients of Weight Gain and 9-Year Obesity (sum of skinfolds)
NOTE: Weight gains are calculated by subtracting last measured weight from each weight, i.e., weight gain at 6 months = 6-month weight minus birthweight; 1-year weight gain = weight at 1 year minus 6-months weight, etc.

caloric intake and activity score at the same age (Table 7). Activity scores were consistently negatively related to sum of skinfolds. The association between sum of skinfolds and caloric intake was less clear. At ages 3 and 9 years, there were slight negative correlations of statistical significance. A partial explanation is that the mean caloric intake of the lean children was greater than the mean caloric intake of the middle and the obese groups.

Similar correlation coefficients were determined for sum of skinfolds at age 9 with activity scores and caloric intake for all 7 ages between 6 months and 9 years. The rationale is that skinfold measurement at 9 years is a cumulative value resulting from ratios, over time, of energy intake to energy expenditure. This summing did not improve the correlation (Table 7). A computerized predictive regression equation*** based on 9-year sum of skinfolds, sums of caloric intakes, and activity scores likewise did not improve the correlation (r = .22).

***9 year sum of skinfolds = −.0013 × sum of calories − .0108 × sum of activities + 62.8.

TABLE 6—Correlation Coefficients for Sum of Skinfolds at Age 9 Years and Relative Weights at Six Previous Ages

Ages for Relative Weights	All Cases (n = 170)	Boys (n = 83)	Girls (n = 87)
6 months	.22**	.29**	.18*
1 year	.23**	.24*	.24*
2 years	.41**	.27*	.49**
3 years	.50**	.47**	.51**
4 years	.52**	.53**	.51**
6 years	.66**	.67**	.68**
9 years	.79**	.80**	.79**

*p < .05
**p < .005

Discussion

Data from this longitudinal study indicate that the obese infant is not predestined to become an obese child. Obese infants of both sexes became less obese with time although not necessarily in regular progression from year to year. Whether the change from obese to non-obese or lean occurred in one sustained change or in an alternating pattern, obese infants were more likely to become non-obese or lean than to be still obese at 9 years. In an examination of six longitudinal growth studies, Roche, *et al*, described rapid changes in obesity quartile ranking during the first four years of life thus substantiating the difficulties of early prediction of obesity.[13]

In an earlier publication, we showed that infant obesity was strongly associated with early rapid weight gain.[6] By the time subjects were 9 years old, however, this relationship no longer held. A comparison of sum of skinfolds at 9 years with weight gain at previous ages did not bear out our earlier finding. The strikingly higher correlation of 9-year skinfolds with weight gain at 1 to 2 years for girls and 2 to 3 and 4 to 6 years for boys suggests that the child who is gaining weight rapidly at these ages may be at high risk for becoming an obese child, and that intervention may be appropriate. The highest correlations of 9-year skinfolds were with weight gain between ages 6 to 9 for both sexes, an indication that for the group of obese 9-year olds obesity was a recent development.

Because the two most readily manipulated known factors in obesity are food and physical activity, we posed the question, "How well do our caloric and physical activity estimates relate to our anthropometric assessments?" The answer, as shown in Table 6, is clearly "Not very well." We do not challenge the relationship of physical activity and food intake as major factors in the development and mainte-

TABLE 5—Mean 9-Year Sum of Skinfolds ± Standard Deviation for Low, Middle, and High Weight Gain Groups of Infants

0–6 months	N	All Cases*	N	Boys	N	Girls
Low weight gain	26	19.4 ± 5.5	10	17.5 ± 4.2	16	20.6 ± 6.1
Middle weight gain	116	22.4 ± 11.7	59	19.6 ± 8.4	57	25.3 ± 13.8
High weight gain	28	26.5 ± 8.0	14	23.3 ± 6.7	14	29.7 ± 8.1
6 months to 1 year	N	All Cases	N	Boys	N	Girls
Low weight gain	19	20.6 ± 11.0	10	16.7 ± 6.0	9	25.0 ± 13.7
Middle weight gain	121	21.9 ± 9.5	59	20.0 ± 8.1	62	23.9 ± 10.0
High weight gain	30	26.6 ± 13.5	14	22.7 ± 7.4	16	30.0 ± 16.7

*p = <.05, using Analysis of Variance

TABLE 7—Correlation Coefficients for Sum of Skinfolds at Each Age with Activity Score and Caloric Intake at the Same Age

Age	N	Correlation Coefficients of Sum of Skinfolds with	
		Activity Score	Caloric Intake
6 months	450	−.11**	.05
1 year	382	−.04	.02
2 years	312	−.08	−.05
3 years	269	−.10	−.11*
4 years	242	−.06	−.01
6 years	180	—	.03
9 years	170	−.16*	−.14*
Sum of all years	149	−.18*	−.16*

*p < .05.
**p < .01.

nance of body fatness; we feel that methods for obtaining activity and dietary information about individuals must be further refined. Small differences in caloric intake of individuals can be overshadowed by small differences in energy utilization. Similarly, estimation of physical activity, in the absence of specific measurement by direct or indirect methods, may conceal important differences in energy expenditure, a major influence on body fatness. The consistently negative correlations between activity scores and skinfold thickness support the well known relationship of physical activity and body fatness, but it is not yet a predictive tool in individual cases.

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