Persistence of Juvenile-Onset Obesity over Eight Years: The Bogalusa Heart Study

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Abstract: The persistence of obesity and overweight over eight years was assessed in a biracial (Black-White) cohort of 1,490 two- to 14-year-olds. Initial levels of triceps skinfold thickness (TRSF) and Rohrer index (weight/height^3) were moderately predictive of subsequent levels: r = 0.54 and 0.67, respectively. However, TRSF and Rohrer index tended to track most strongly in Black females (r = 0.64 and 0.72) and less well in both White females (r = 0.45 and 0.57) and preschool children (r = 0.45 and 0.54). Based on elevated levels of TRSF or Rohrer index, children were classified as obese or overweight, respectively. Of the 222 children who were initially above the 85th percentile for TRSF, 43 per cent remained obese after eight years. Persistence of overweight was slightly greater at follow-up, with 50 per cent of initially overweight children staying above the 85th percentile for Rohrer index. Severe, initial obesity/overweight (>95th percentile) and consecutively elevated levels increased the probability of remaining obese/overweight. Results indicate that moderate, juvenile-onset obesity is malleable, but that the child who is extremely obese over consecutive examinations is likely to become an obese adult. (*Am J Public Health* 1987; 77:588–592.)

Introduction

An estimated[1] 30 million obese Americans are at increased risk for diabetes, coronary heart disease, hypertension, and other clinical complications.[2,3] Because successful, long-term treatment of adult obesity is difficult,[4] several studies have examined the development of obesity in early life. If juvenile-onset obesity persists (tracks) into adulthood, then early treatment[5] could be initiated in children likely to become obese adults.

Although body fatness at birth may be related to subsequent obesity[6–8] and excessive weight gain[9] during early childhood, negative findings have also been reported.[10] Adiposity at six months of age, however, has been consistently related to obesity at two[7], five[8], seven,* and nine[11] years of age with reported correlations ranging from 0.2 to 0.4. Nevertheless, six-month-old infants who are in the upper quintile for subscapular skinfold thickness show only a slightly increased tendency (observed 25 per cent vs expected 20 per cent) to become obese seven-years-olds.*

Severe obesity in later childhood, however, is more predictive of body fatness at subsequent examinations.[6,8,10,12–16] Of 366 overweight adults, 36 per cent were above the 90th percentile for weight in the first six months of life.[17] In addition, as compared with moderately obese women, twice as many severely overweight (relative weight >155 per cent) women reported being obese as children.[18] Additional prospective studies are needed to increase the understanding of the natural history of obesity.

The current study assesses continuities in triceps skinfold thickness (TRSF) and Rohrer index (weight/height^3) in a biracial (Black-White) cohort of 1,490 children and adolescents over an eight-year period. In addition to examining longitudinal correlations, the predictive value and sensitivity of a classification of obesity are considered prospectively.

*Harsha DW, Nicklas TS, Webber LS, Berenson GS: Cardiovascular risk factors from birth to seven years of age: The Bogalusa Heart Study. II. Tracking of body composition variables. (manuscript submitted for publication)

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Methods

Population

The Bogalusa Heart Study is a community-based study of cardiovascular disease risk factors in early life.[19] The eligible population consists of all children and young adults living in Ward 4 of Washington Parish, which includes the city of Bogalusa, Louisiana. In 1980, the population of this biracial (70 per cent White, 30 per cent Black) community was approximately 20,000.

Four cross-sectional examinations of school-aged children, each with over 80 per cent participation, were conducted between 1973 and 1983. The 1973–74 (year 1) survey included 4,238 two- to 14-year-olds, and the 1976–77 (year 4) survey involved 4,074 five- to 17-year-olds. Young adults were also examined in the 1978–79 (year 6) and 1981–83 (year 9) surveys, both with 70 per cent (overall) participation rates. In year 6, 3,785 five- to 20-year-olds were examined; 4,252 five- to 24-year-olds were examined in year 9.

Of the 4,238 participants at year 1, 1,511 were examined in all three subsequent surveys. (The number of years between the year-1 and year-9 examinations ranged from 7 to 9 years, with a mean of 8.4 years.) Only persons (n = 1,490) with four sets of anthropometric measurements were included in the current analyses. Participants ranged in initial age from two to 14 years (mean, 7.3 years), while year-9 age ranged from 10 to 24 years (mean 15.7 years). This cohort represents 35 per cent (1,490/4,238) of all persons examined at year 1. Levels of TRSF and Rohrer index in the study cohort were similar to levels observed in persons examined only at year 1 (see Results).

General Examinations

Sexual maturation, based on female breast or male genitalia appearance, was determined by a physician.[20] Children were divided into five stages, ranging from prepubescence (Tanner Stage 1) to complete development (Tanner Stage 5).

As previously reported,[21] height and weight were measured to the nearest 0.1 cm and 0.1 kg, respectively, and TRSF was assessed to the nearest 1 mm with Lange Skinfold Calipers in all four examinations. Subscapular skinfold thickness was measured only in years 6 (for 1,305 school-aged children) and 9. Skinfold thicknesses were measured three times during each examination, and mean values are used in all analyses. Based on a 10 per cent random sample of reexamined children during the year-9 survey (323 pairs), the intra-observer reproducibility of the skinfold measurements was very high: intraclass correlation coefficients were 0.975 (triceps) and 0.985 (subscapular).

Two weight/height indices, Rohrer index and relative weight, were calculated.[22] As compared with the Quetelet Index (kg/m^2), the Rohrer index is only weakly correlated with height in early life (r = −0.07 vs. 0.59), but is similarly associated with both subscapular skinfold thickness (r = 0.75 vs 0.86) and TRSF (r = 0.69 vs 0.64). Relative weight was calculated by dividing a person's weight by the median weight of each race, sex, and 5 cm-height group; this value was then multiplied by 100.

Rohrer index and relative weight were strongly correlated (r = 0.86) and both were equivalently associated with TRSF (r = 0.70). (The 85th percentile for Rohrer index was approximately equal to 110 per cent relative weight.) In most analyses, TRSF and Rohrer index were used as measures of obesity and overweight, respectively. Subscapular skinfold thickness was used as another measure of obesity between years 6 and 9.

Statistical Analyses

Because height, weight, Rohrer index, and the skinfold thicknesses varied according to race, sex, and age, Z-scores (in standard deviation units) were first constructed. These normalized values, which represent a person's level with respect to his race, sex, and age peers, are useful in examining longitudinal continuities in obesity[23–25] because normal growth strongly affects absolute levels. Race, sex, and age differences in the anthropometric variables have been previously reported.[21,26]

To assess the representativeness of the study cohort, mean levels of the anthropometric variables at year 1 were contrasted between persons participating at all four examinations and those children examined only at year 1. Pearson correlation coefficients were then used to assess the relationship between initial and subsequent levels of the anthropometric variables. (Spearman correlations yielded similar results.) Continuities in obesity (assessed by TRSF) and overweight (assessed by Rohrer index) were also examined within categories defined by: <15th percentile (lean), 15th to 85th percentiles, and >85th percentile (obese/overweight). The probabilities that: 1) a child identified as obese/overweight in year 1 will remain obese/overweight at subsequent examinations (the predictive value), and 2) an obese/overweight person at year 9 would have been identified as obese/overweight in a prior examination (the sensitivity) were examined. Serial measurements and further subdivisions of obesity/overweight (>95th percentile) were also studied.

Results

Study Cohort Characteristics

At the initial examination, children who subsequently participated in the three follow-up examinations tended to be younger than children seen only at year 1 (mean age 7.3 vs 9.5 years). The study cohort was also composed of larger proportions of Blacks (41 per cent) and females (52 per cent) as compared with children seen only at year 1 (33 per cent and 46 per cent, respectively). However, after covariance-adjustment for these differences, mean levels at year 1 for TRSF (12 mm) and Rohrer index (13.1 kg/m^3) were identical in the two groups. Mean weights of participants and persons lost to follow-up were also very similar: 32.7 vs 32.6 kg.

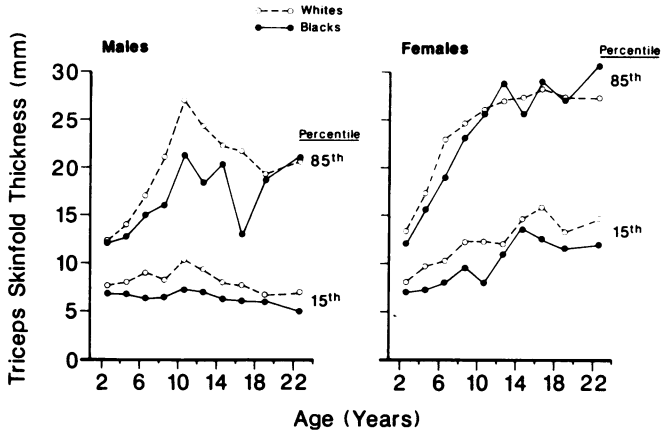

FIGURE 1—Selected percentiles of triceps skinfold thickness in 2- to 24-year-olds by race, sex, and age

Classifications of obesity (TRSF >85th percentile) and overweight (Rohrer index >85th percentile) differed according to race, sex, and age (Figure 1). The 85th percentile for TRSF ranged from 12 mm (two- to three-year-old boys) to 31 mm (21- to 24-year-old Black women), whereas the 85th percentile for Rohrer index (data not shown) ranged from 14 kg/m^3 (12- to 13-year-old Black males) to 20 kg/m^3 (21- to 24-year-old Black women).

Tracking of Obesity and Overweight

Over the eight-year period, height showed the greatest tracking (r = 0.76), followed by weight (r = 0.72), Rohrer index (r = 0.67), and relative weight (r = 0.66). Tracking of TRSF was more moderate, with initial levels explaining 29 per cent (0.54^2) of the year-9 variation. Although only measured in the last two surveys, the correlation of subscapular skinfold thickness values between years 6 and 9 was 0.80, slightly higher than the corresponding value for TRSF (r = 0.74).

Substantial tracking of both TRSF and Rohrer index was evident within each race-sex and age group (Table 1). Longitudinal correlations tended to be lowest in White females and higher in Blacks, particularly Black females. Tracking was also low among children who were initially two to four years of age. (Stratifying height into quintiles yielded similar results: tracking was lowest (r = 0.41 for TRSF) among very short (<108 cm at year 1) children.) Two- to four-year-old White girls (n = 101) showed the weakest tracking for both TRSF (r = 0.34; 95 per cent confidence interval (0.16, 0.50) and Rohrer index (r = 0.42; 95% CI (0.24, 0.57), whereas tracking was strongest in 11- to 14-year-old Black girls (n = 57) (r = 0.65; 95% CI 0.47, 0.78) for TRSF and (r = 0.83; 95% CI 0.73, 0.90) for Rohrer index.

Sexual maturation also influenced the tracking of TRSF and Rohrer index (Table 2). Tracking of TRSF increased with stage of sexual maturation at follow-up for both males and females who were in Tanner Stage 1 at the initial examination

TABLE 1—Stratified Analyses of Body Fatness Correlations over Eight Years; by Race, Sex, and Age: Bogalusa Heart Study

Stratum	N	Triceps Skinfold Thickness (95% CI)	Rohrer Index (95% CI)
Total	1490	.54 (.50, .57)	.67 (.64, .70)
Race-Sex			
White Males	440	.52 (.45, .59)	.70 (.65, .74)
White Females	432	.45 (.37, .52)	.57 (.50, .63)
Black Males	281	.59 (.51, .66)	.72 (.66, .77)
Black Females	337	.64 (.57, .70)	.72 (.66, .77)
Initial Age (years)			
2–4	317	.45 (.35, .54)	.54 (.45, .61)
5–6	351	.58 (.51, .65)	.69 (.63, .73)
7–8	279	.55 (.46, .63)	.65 (.58, .71)
9–10	255	.56 (.47, .64)	.76 (.70, .81)
11–14	288	.57 (.49, .64)	.72 (.66, .77)

(approximately 75 per cent of the children). Although the magnitude of tracking for Rohrer index decreased, particularly in males, between (year-9) Tanner Stages 1 and 3, children who were in Tanner Stage 4 or 5 at follow-up showed strong tracking for Rohrer index. A low correlation for TRSF (but not Rohrer index) was seen in females who were initially in Tanner 4 (r = 0.33), but the 95% CI of this estimate was wide.

The persistence of extreme (<15th or >85th percentile) levels of TRSF was then examined (Table 3). Of 222 persons originally identified as obese, 96 (43 per cent, the predictive value) remained obese in year 9, with the remainder classified as between the 15th and 85th percentiles (n = 119) or lean (n = 7). Twenty-nine (13 per cent) of the initially obese children were below the 50th percentile for TRSF at year 9. Similar to results from the correlational analyses, the predictive value of obesity was lowest in White females: 35 per cent (22/63). Of the 223 obese persons in year 9, 96 had been initially classified as obese, yielding a sensitivity of 43 per cent (96/223).

Rohrer index and subscapular skinfold thickness were more stable than was TRSF (data not shown). Over the eight-year period, the predictive value of a Rohrer index level above the 85th percentile was 50 per cent (vs 43 per cent for TRSF). Of the 195 persons with high levels of subscapular skinfold thickness in year 6, 136 (70 per cent) remained above the 85th percentile at year 9, as compared with a three-year predictive value for TRSF of 59 per cent (131/223).

Factors Predictive of Subsequent Obesity/Overweight

Figure 2 shows the year-9 distribution of TRSF for persons initially identified as lean, moderately obese (86th to 95th percentiles), or very obese (>95th percentile). At year 1, TRSF values of obese children ranged from one to two standard deviations above the race-, sex-, and age-specific means, whereas the very obese children were two or more standard deviations above these mean values. Although only 32 per cent (47/148) of moderately obese children stayed above the 85th percentile at year 9, 66 per cent (49/74) of the very obese children remained obese. Of the children who were very overweight (>95th percentile for Rohrer index) at year 1, 72 per cent (53/74) remained above the 85th percentile in year 9.

The value of serial measurements is shown in Figure 3. The predictive value of a single, prior classification of obesity increased from 43 per cent (year 1) to 59 per cent (year 6). Consecutively elevated levels of TRSF also improved the prediction of subsequent obesity, with 68 per cent (65/96) of persons defined as obese in years 1, 4, and 6 remaining above the 85th percentile in year 9. Consecutively elevated levels of Rohrer index, however, yielded smaller increases in the predictive value: 76 per cent of persons overweight in year 6 remained above the 85th percentile for Rohrer index at year nine, as compared with 80 per cent (89/112) of persons who were overweight in years 1, 4, and 6. As expected, consecutive classifications of obesity also decreased the sensitivity: only 28 per cent of persons obese in year 9 had been classified as obese in all three prior examinations.

Discussion

The current findings extend our earlier reports,[15,27] and indicate that TRSF and Rohrer index in children are moderately predictive of levels eight years later: r = 0.54 and 0.67, respectively. However, tracking of obesity/overweight differs according to race-sex group and age: correlations are weakest in White females and preschool children, and strong-

TABLE 2—Stratified Analyses of Body Fatness Correlations over Eight Years; by Sex and Tanner Stage: Bogalusa Heart Study

Tanner Stage*		Sex					
		Males			Females		
			Correlation			Correlation	
Year 1	Year 9	n	TRSF† (95% CI)	Rohrer Index (95% CI)	n	TRSF (95% CI)	Rohrer Index (95% CI)
1	1	94	.46 (.28, .60)	.71 (.59,.80)	43	.43 (.15, .65)	.62 (.39, .77)
1	2	74	.49 (.29, .65)	.57 (.39, .66)	77	.43 (.23, .60)	.52 (.34, .66)
1	3	55	.56 (.35, .72)	.44 (.20, .63)	98	.56 (.41, .68)	.56 (.41, .68)
1	4	72	.60 (.43, .73)	.64 (.48, .76)	109	.58 (.44, .69)	.66 (.54, .75)
1	5	307	.58 (.50, .65)	.77 (.72, .81)	226	.62 (.53, .70)	.64 (.56, .71)
2	5	67	.61 (.43, .74)	.79 (.68, .87)	62	.62 (.44, .75)	.77 (.65, .86)
3	5	21	.53 (.12, .78)	.85 (.66, .94)	55	.40 (.15, .60)	.74 (.59, .84)
4	5	23	.61 (.26, .82)	.69 (.39, .86)	71	.33 (.10, .54)	.65 (.49, .77)
5	5	0	—	—	24	.72 (.45, .87)	.69 (.40, .86)

*Includes information for 713 (of 721) males and for 765 (of 769) females
†Triceps Skinfold Thickness

TABLE 3—Persistence of Triceps Skinfold Thickness Categories*: Bogalusa Heart Study

Year of Examination	Initially Lean			Initially between the 15th and 85th Percentiles			Initially Obese		
	Lean (%)	Average (%)	Obese (%)	Lean (%)	Average (%)	Obese (%)	Lean (%)	Average (%)	Obese (%)
1	223 (100)	0	0	0	1045 (100)	0	0	0	222 (100)
4	130 (58)	92 (41)	1 (0.5)	94 (9)	866 (83)	85 (8)	0	85 (38)	137 (62)
6	111 (50)	108 (48)	4 (2)	110 (11)	836 (80)	99 (9)	2 (1)	100 (45)	120 (54)
9	91 (41)	123 (55)	9 (4)	125 (12)	802 (77)	118 (11)	7 (3)	119 (54)	96 (43)

*Lean defined as <15 percentile triceps skinfold thickness, obese as >85th percentile.

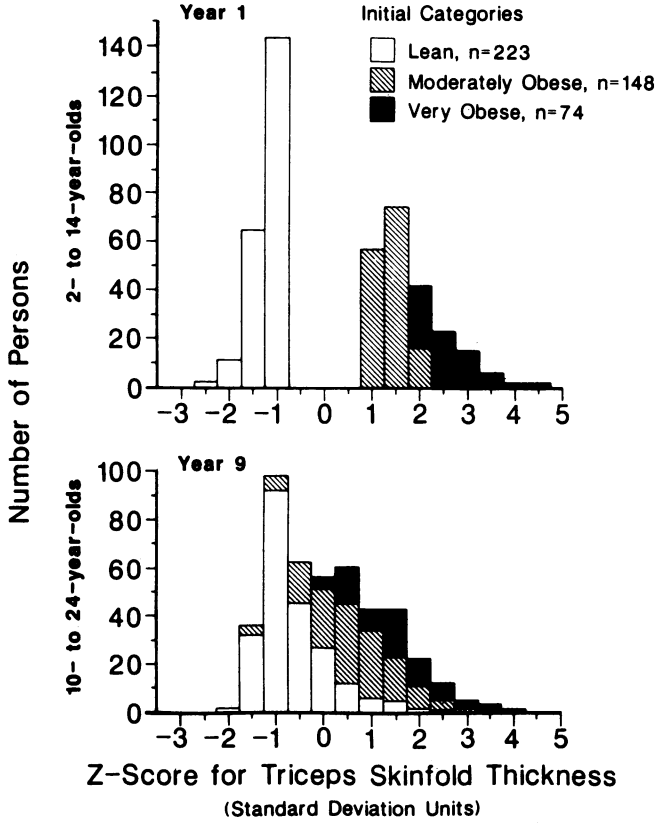

FIGURE 2—Triceps skinfold distributions of lean and obese children over an average length of follow-up of 8.4 years (range = seven to nine years). Based on race-, sex-, and age-specific levels of triceps skinfold thickness at year 1, children were classified as lean (<15th percentile), moderately obese (86th to 95 percentiles), or very obese (>95th percentile).

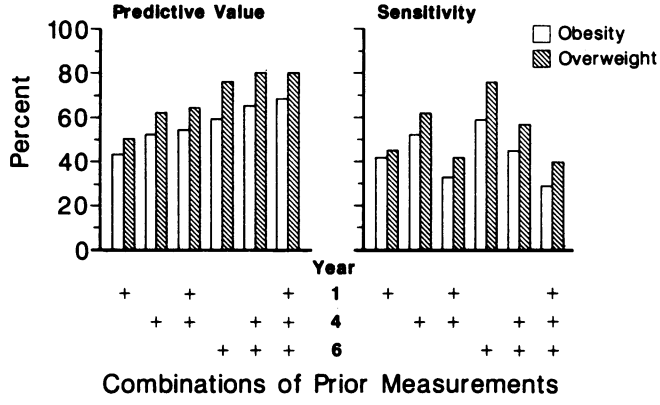

FIGURE 3—Predictive value and sensitivity of prior obesity/overweight over eight years. Obesity/overweight was defined as a TRSF/Rohrer index level above the 85th percentile.

est in Black females. Although almost one-half (43 per cent) of initially obese children remain obese after eight years, many (13 per cent) fall below the 50th percentile at follow-up. Marked obesity and consecutively elevated levels both increase the likelihood of remaining obese. As compared with TRSF, levels of Rohrer index and subscapular skinfold thickness show slightly stronger tracking.

These findings are based on a cohort constructed from a community-based study that has maintained a high participation rate since 1973. Although there was substantial loss to follow-up in the study cohort over the eight-year period, mean levels of TSRF and Rohrer index in participants were very similar to levels seen in persons examined in only the initial survey. Since levels of serum lipids[28] and blood pressure[29] in this cohort are also representative of levels in the community, it is unlikely that selection bias seriously influenced the current analyses.

In general, the current findings agree with results of two large studies based on national probability samples of American and British children. Zack,[13] using data collected in two cycles of the US Health Examination Surveys, examined the tracking of skinfold thicknesses (sum of triceps and subscapular) in 2,177 six- to 11-year-olds. Over a three- to four-year period, correlations ranged from 0.69 to 0.73 in the various race-sex groups, with 70 per cent of the children who were initially above the 80th percentile remaining obese at follow-up. (In the current study, 62 per cent of two- to 14-year-olds above the 85th percentile for TRSF remained obese after three years.) Stark[14] reported seven-year correlations for relative weight of 0.52 to 0.59 for persons who were initially seven years of age, slightly lower than the eight-year value of 0.66 observed in the current study.

Because weight, relative weight, and Rohrer index all track more strongly than does TRSF, previous studies that used only self-reported weight status[17,18] or various weight/height indices[6-8,12,14,17] may have overestimated the persistence of obesity. Weight/height indices do not distinguish between adipose tissue and lean body mass, and a high weight/height value may simply reflect increased lean mass[30] or shorter leg length.[24] In addition, the relation between overweight and obesity may be particularly low during growth and development: Griffiths, *et al*,[31] reported that more than 10 per cent of four-year-old boys above the 90th

percentile for TRSF were also below the 30th percentile for weight/height.

The current analyses also compare the persistence of obesity across race-sex groups and a wide range of initial ages. In agreement with the current results, previous studies[7,8,16] have consistently found that tracking in children increases with initial age. (Roche[32] cites the low probability of an obese infant becoming an obese adult as evidence against the adipocyte-number hypothesis.) In addition, tracking of obesity in the current study was strongest in Black females and weakest in White females. Although some data indicate that obesity in females may be more enduring than in males,[23,25] others have shown this to be true only for Blacks.[13] Speculatively, the weak tracking of obesity in White females in the current study may be due to increased dieting during adolescence.

It has also been suggested that the obese are more fat labile than are lean persons.[23,25] However, in the current study, the predictive values of these two classifications were almost identical: 43 per cent (obese) vs 41 per cent (lean). Although the obese generally lost body fatness, two-thirds of the very obese remained above the 85th percentile at follow-up because of greatly elevated initial levels.

Because the metabolic complications of obesity are already present during childhood[33,34] and adult obesity is intractable,[4] intervention may be most effective if started in early life. However, since a large proportion of obese children do not necessarily remain obese, additional characteristics that are predictive of subsequent obesity should be considered. Garn[35,36] showed that family members tend to resemble each other in fatness change. The current results indicate that the persistence of juvenile-onset obesity is increased by age (older than five years), the severity (>95th percentile) of obesity, and consecutively elevated levels of TRSF. Intervention in specific subgroups of children may therefore be an effective strategy for reducing the clinical complications of obesity in adulthood.

ACKNOWLEDGMENTS

The Bogalusa Heart Study is a joint effort involving many people. The authors thank Bettye Seal, the staff of the Bogalusa Heart Study, and the children and parents whose cooperation made this study possible. This research supported by grant HL-15103 (National Research and Demonstration Center—Arteriosclerosis) from the National Heart, Lung and Blood Institute of the US Public Health Service.

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