Height, Weight, and Lines of Arrested Growth in Young Guatemalan Children [1]

RICARDO A. BLANCO,[2] ROY M. ACHESON,[3,4] CIPRIANO CANOSA [5] AND JOAO B. SALOMON [6]
The Institute of Nutrition of Central America and Panamá and the Department of Epidemiology and Public Health, Yale University, New Haven, Connecticut 06510

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ABSTRACT A cross-sectional study of height, weight and skeletal maturity as judged from radiographs of hand and wrist, of 1,412 children under seven years of age (694 boys and 718 girls) living in rural Guatemala was performed. Height and weight were compared to standards prepared by the Institute of Nutrition of Central America and Panama (INCAP). Skeletal age was assessed by the Tanner-Whitehouse and the Greulich and Pyle methods. All x-rays were read by the senior author.

The children surveyed were significantly shorter and lighter than well nourished Guatemalan children. Differences were evident by age six months and at a maximum by age five years.

Both methods showed skeletal age to lag behind chronological age so that the Guatemalan rural children mature at slower rates than either the British children or the Ohio, U. S. A., children, from whom the two sets of standards were developed.

Children of both sexes with radio-opaque transverse lines at the metaphysis showed a consistent tendency to be shorter than children without such lines. Boys but not girls showed similar trends for weight.

In general, the data are consistent with the view that the physical development in boys is more severely retarded by an adverse environment than that of girls.

Individual and population differences in growth and maturation are the results of interaction between genes and environment; in all probability the two act differently at different developmental levels and in different children. It is now widely believed that each individual has a genetically predetermined potential for the velocity at which he will grow and mature (Pryor, '07; Gould and Gould, '32; Reynolds, '43; Garn and Rohmann, '62, '66), and this velocity may be modified by environmental factors (Stuart and Kuhlmann, '42; Robinson, Janney and Grande, '42; Jones and Dean, '56; Acheson and MacIntyre, '58; Dreizen, Snodgrasse, Parker, Currie and Spies, '54; Acheson, '59; Prader, Tanner and von Harnack, '63).

Taking as a working hypothesis the view that malnutrition produces not only physical impairment but permanent impairment of mental function also, the Division of Human Development at the Institute of Nutrition of Central America and Panama (INCAP) developed an experimental design for a longitudinal study to be performed in a rural area of Guatemala,

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[2] Medical Officer of the Institute of Nutrition of Central America and Panama (INCAP), on study leave.

[3] Director, Centre for Extension Training in Community Medicine, London School of Hygiene and Tropical Medicine, London WC1E 7HT, England.

[4] Address reprint requests to: Dr. Roy M. Acheson.

[5] Director, Clinica Infantil, Ciudad Sanitaria de la S.S. "LaFe," Valencia, España. Formerly Director of the Growth and Development Unit, INCAP.

[6] Dean of Research and Postgraduate Education, University of Brazilia, Brazil. Formerly Sub-Director of the Growth and Development Unit, INCAP.

where malnutrition is prevalent. The present report is concerned only with a small part of the initial longitudinal program which, in addition to the measurement of physical and psychological development, involves surveys of the biochemical, nutritional and health status of the community.

MATERIAL AND METHODS

The present sample consists of 1,412 children of both sexes (694 boys and 718 girls) from nine Guatemalan rural villages, from 0 to 84 months of age, who were studied cross-sectionally. Age was confirmed in the Local Civil Register and children whose names did not appear in this were excluded from the study. Radiographs were taken of the left hand and wrist of the entire sample, with General Electric portable equipment, using a tube-film distance of 91.4 cm. The central ray was directed towards the distal end of the third metacarpal. All the films were read by the senior author and the data were noted on precoded forms. The score for individual centers and skeletal age were assessed by the Tanner and Whitehouse method (Tanner, Whitehouse and Healy, '62) and by the method of Greulich and Pyle (Greulich and Pyle, '59) for each child. A note was made of the presence or absence of lines of arrested growth (Harris, '26) at the distal end of the radius. Stature was measured with the child lying down without shoes using an infant scale graduated in centimeters and millimeters. Weight was recorded on a Toledo Scale with a sensitivity of 20 gm; each child was supplied with clothes of known weight which was subtracted in order to obtain the child's real weight. Records of height and weight were available in only 564 children, that is, 40% of the sample (38.5% boys and 41.6% girls). The proportion of children with this information was equally distributed in each age-sex group; t-tests were used to compare skeletal maturation between children with height and weight information and those without these measurements. None of the t tests were significant so the conclusion was drawn that the growth of the 40% of children with complete information was, in respect of age, sex and skeletal maturity, representative of the total sample. The analysis is presented by sex and six-month age groups, with the exception of the youngest children in whom the age range went from 0 to 2 months for both sexes.

TABLE 1

Height and weight by age and sex

Range in months	N	Age Mean	Age S.D.	N	Height Mean	Height S.D.	N	Weight Mean	Weight S.D.
		months			*cms*			*kgs*	
Boys									
0–2	6	1.2	0.4	0			0		
3–8	66	5.2	1.6	20	61.0	4.2	20	6.1	1.1
9–14	61	11.4	1.7	18	69.0	3.0	18	8.1	0.9
15–20	53	17.9	1.7	22	74.2	3.3	22	8.5	1.0
21–26	35	23.7	1.7	11	78.5	3.7	11	10.1	1.2
27–32	39	29.9	1.7	12	80.9	1.4	12	10.5	0.7
33–38	59	35.7	1.7	25	85.2	4.7	25	12.1	1.6
39–44	57	41.4	1.6	23	88.6	4.9	23	12.7	1.2
45–50	49	47.3	1.5	21	90.6	5.3	21	13.9	1.9
51–56	43	53.7	1.6	15	97.0	5.5	15	15.2	1.3
57–62	60	59.6	1.7	27	95.0	5.7	27	14.7	1.7
63–68	42	65.7	1.6	15	100.1	7.2	15	15.8	2.0
69–74	48	72.0	1.7	21	102.1	7.0	21	16.4	1.7
75–80	39	77.3	1.7	17	105.8	5.2	17	18.0	1.4
81–86	37	82.4	1.5	18	108.1	8.3	18	18.6	2.9
Total	694			265	38.3%		265	38.3%	
Girls									
0–2	10	1.8	0.4	3	55.3	3.2	3	4.6	0.5
3–8	69	5.8	1.4	27	60.7	4.1	27	6.1	1.5
9–14	57	11.4	1.6	23	66.5	3.2	23	7.2	1.0
15–20	37	17.2	1.7	15	72.6	4.3	15	8.3	1.0
21–26	37	23.0	1.7	10	76.9	2.9	10	9.0	0.9
27–32	59	29.5	1.6	19	81.6	4.3	19	10.3	1.4
33–38	50	35.9	1.4	24	84.6	5.6	24	11.6	1.3
39–44	46	41.2	1.6	23	87.0	4.9	23	12.3	1.5
45–50	53	47.9	1.4	16	90.7	4.1	16	13.2	1.7
51–56	69	53.3	1.7	34	93.9	6.7	34	13.8	1.8
57–62	54	59.6	1.7	18	97.3	7.5	18	14.5	1.4
63–68	63	65.2	1.8	27	100.6	4.9	27	15.4	1.6
69–74	51	71.4	1.7	27	104.1	6.6	27	16.5	1.8
75–80	34	77.7	1.7	17	102.3	9.9	17	17.0	2.3
81–86	29	83.1	1.6	16	108.7	5.3	16	18.3	2.1
Total	718			299	41.6%		299	41.6%	

RESULTS

Table 1 shows the age-specific groups with the number of children in each age group, and mean and standard deviations for age, height and weight. Figure 1 shows the mean heights and weights plus and minus one standard deviation together with mean values for well nourished children from Central America (Estandartes de Peso y Estatura, INCAP). Differences between our observed values and the standards were calculated. They are significant for weight at the 5% level for both sexes, and for height at the 5% level in boys and 10% level in girls.

Table 2 shows the percentage of children, on an age and sex specific basis, who showed lines of arrest of growth (Harris' lines) on the x-ray. An incidence of 10% of girls in the age group 0–2 months seems

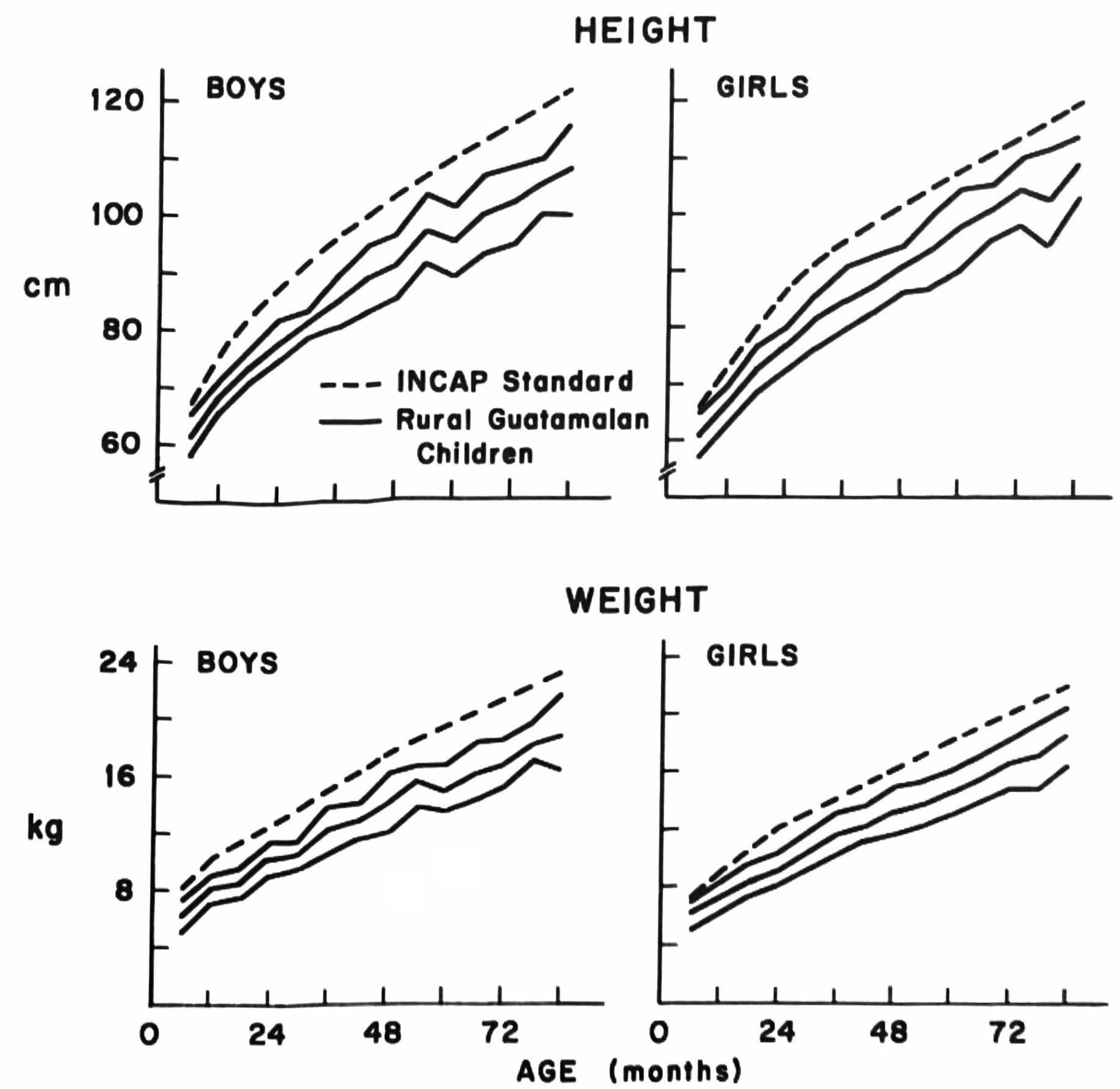

Fig. 1 Mean height and weight ± 1 standard deviation for study population shown by three continuous lines, compared with standards for Guatemalan children indicated by the discontinuous line, prepared by the Institute of Nutrition of Central America and Panama.

TABLE 2

Percentage of lines of arrest of growth by age and sex

Age in months	Boys N	Boys % showing lines	Girls N	Girls % showing lines
0–2	6	0.0	10	10.0
6	66	0.0	69	1.4
12	61	9.8	57	12.3
18	53	18.9	37	32.4
24	35	28.5	37	35.1
30	39	33.3	59	32.2
36	59	47.5	50	42.0
42	57	54.4	46	45.6
48	49	34.7	53	35.8
54	43	48.5	69	39.1
60	60	45.0	54	24.1
66	42	33.3	63	39.7
72	48	41.7	51	35.3
78	39	41.0	34	35.3
84	37	29.7	29	24.1

high but could well be due to sampling variation because the number of children in that age category is small (n = 10). It can be seen that before the age of 30 months the prevalence of Harris' lines is higher in girls and subsequently higher in boys. Only at age 60 months is the excess of lines in boys significant, with X^2 (1 d.f.) = 5.46 and $P < 0.025$. Based on these data we made two further comparisons between groups: the first one was in children aged 0 to 24 months and showed no significant differences between boys and girls. The second considered children of 30 months and older and gave a X^2 between sexes (1 d.f.) = 3.76 ($P < 0.054$), and indicated that the incidence of such lines was greater in boys. The next step was to find out if the children with lines of arrested growth were more affected in other aspects of their development than the children without such lines. Comparisons between these two populations, by age and sex, can be seen for height and weight in table 3. When all age groups are considered together with the exception of weight for girls, where no clear trend is evident, the means for those with lines are always less than for those without. Few of the age-specific differences are significant, but all of those which are show a trend which is consistent with the hypothesis that transverse lines in the metaphysis are indices of an overall arrest of growth. Boys with lines have a standing height that is 2.2 cm less than those without lines, a difference which is equivalent to four months growth in the whole male study population. Differences for stature in girls are in the same direction, but are less striking.

Table 4 gives the mean and standard deviations of skeletal age estimated by the Tanner-Whitehouse method (Tanner, Whitehouse and Healy, '62) and the method of Greulich and Pyle (Greulich and Pyle, '59), for boys and girls. It also gives the mean scores for the round and long bones separately, as well as the correlations between these two groups of bones. Figure 2 shows the deviations from the "expected" skeletal age, that is to say, the maturational status of the healthy Caucasian children upon whom the standards were based. It can be seen that the values for skeletal age by the Greulich and Pyle method are "lower" than those for the Tanner-Whitehouse method; this is due to the fact that the two techniques were standardized against different populations (Acheson, Vicinus and Fowler, '66).

DISCUSSION

It is known that in conditions of poverty in Guatemala the average child receives breast milk alone for about 15 to 24 months with a median of 20 months (Habicht, '72) and then the diet is supplemented by cereal gruels, starchy roots and overdiluted cow's milk. Such children do not have what are generally considered to be the minimum nutrient requirements after the third month of life. From age 1 to 4 years, they are also exposed to a wide variety of infections and parasites, at a time when they are newly weaned but are not yet old enough to cope for themselves, a time when immunity to many pathogens has not been acquired and susceptibility to infection may be enhanced by a poor state of nutrition. Physical development is nearly always impaired, but in the individual case it is difficult to determine whether the origin of growth retarded below the usual genetic potential is due primarily to infection, to other disease, to malnutrition, or a combination of the three.

The stature of an individual is a composite measurement and is determined by the length of a variety of bones. In developing countries in general and, of particular

TABLE 3

Comparison between mean height and weight of children with and without lines of arrested growth by age and sex

Age in months	Mean height: Without lines	Mean height: With lines	Number	Mean weight: Without lines	Mean weight: With lines
	cms			kgs	
Boys					
12	68.7	71.6	17	8.1	8.3
18	74.6	72.9	21	8.5	8.4
24	79.2	76.7	10	10.2	9.9
30	80.8	81.1	11	10.6	9.9
36	86.9	83.0 [1]	24	12.7	11.3 [1]
42	88.2	88.9	22	12.3	13.1
48	91.3	89.2	20	13.9	13.7
54	99.4	93.5 [1]	14	15.5	14.6
60	96.8	92.6 [1]	26	14.7	14.7
66	100.2	99.9	14	16.0	15.2
72	102.6	101.1	20	16.6	16.1
78	107.0	103.0	16	18.1	17.5
84	110.0	103.4	17	19.2	16.7
Mean	91.2	89.0		13.6	13.0
Girls					
12	66.1	68.3	22	7.1	8.0
18	72.6	72.6	14	8.1	8.3
24	76.2	78.7	9	8.8	9.7
30	82.3	79.3	18	10.5	9.7
36	84.6	84.6	23	11.6	11.7
42	87.5	86.3	22	12.4	12.4
48	91.1	88.0	15	13.0	14.4
54	94.6	92.3	33	13.9	13.7
60	95.8	102.5	17	14.3	15.5
66	101.5	99.2	26	15.4	15.3
72	104.9	100.9	26	16.8	15.6
78	103.8	99.6	16	17.2	16.6
84	109.0	107.3	15	18.0	19.0
Mean	90.0	89.2		12.8	13.1

[1] Significant at 5% level.

interest to this study, in Guatemala, the average length and weight of children at birth is close to the values for North American or European children (Scrimshaw and Béhar, '69). In our sample, girls at average age of 1.8 months are 55.4 cm long and weigh 4.6 kg. These values are close to North American standards (Stuart, '34; Jackson and Kelly, '45; Wetzel, '46). Gerber and Dean ('56) have shown that the newborn East African Negro baby is from four to eight weeks more physically mature than his Caucasian European counterpart. Extra utero the rate of growth decreases relative to the standard, however. As can be seen in figure 1, as early as six months of age Guatemalan rural children with whom this study is concerned are far below the norms for Guatemalan well nourished children. In general when environmental deprivation occurs it is accompanied by slowing of physical development and the effect on growth is greater than that of maturation (Acheson, '66).

Slowed development is associated with lines of arrest of growth caused by an interference with normal chondroplasia and a consequent slowing of growth in the length of the bones. Unusually dense deposits of calcium are laid down in the metaphysis and when growth restarts in the bone, a transverse line remains that is visible by x-rays. These lines have been

TABLE 4

Skeletal age rated by Tanner-Whitehouse and Greulich-Pyle methods by age and sex

Age in months	N	Tanner-Whitehouse							Greulich and Pyle	
		Skeletal age		Round bones		Long bones			Skeletal age	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	r	Mean	S.D.
Boys										
0–2	6	2.0	3.1	0.33	0.5	0.0	0.0		1.00	1.5
6	63	8.75	3.7	1.50	0.8	0.06	0.3	0.257	5.22	2.3
12	61	12.60	3.0	2.18	1.2	0.64	1.1	0.358	9.97	3.4
18	53	14.81	3.1	2.64	1.7	2.19	2.5	0.197	13.55	3.5
24	35	16.78	5.1	4.14	4.2	4.17	4.5	0.684	15.22	4.5
30	39	18.58	5.6	3.97	3.6	7.36	6.5	0.576	16.79	5.6
36	59	24.58	7.8	7.20	7.7	15.70	12.5	0.715	21.25	6.9
42	57	28.39	7.2	9.72	8.2	22.60	13.1	0.510	24.72	6.3
48	49	31.35	9.4	12.42	12.2	27.67	14.6	0.405	26.62	7.3
54	43	36.86	11.9	16.10	16.3	39.12	20.4	0.684	29.36	9.3
60	60	41.73	10.9	21.13	18.8	46.40	16.7	0.654	33.52	8.5
66	42	48.98	12.1	29.67	23.8	59.47	18.4	0.579	37.33	9.6
72	48	55.21	15.9	41.62	32.7	67.98	24.3	0.714	43.33	13.6
78	39	57.98	13.7	44.55	25.7	73.25	23.4	0.629	45.65	11.9
84	37	67.92	14.8	65.61	31.5	88.22	22.9	0.774	55.69	13.1
Girls										
0–2	10	2.70	2.3	1.10	0.7	0.0	0.0		2.40	1.7
6	69	5.00	2.5	1.82	0.5	0.26	1.3	0.786	5.32	2.2
12	57	9.00	5.6	3.09	5.3	3.12	7.9	0.882	9.36	4.8
18	37	13.46	4.9	4.46	3.7	8.24	8.4	0.332	13.00	4.7
24	37	16.08	5.7	4.47	5.6	14.84	12.2	0.571	15.29	5.8
30	59	21.33	6.5	8.80	8.0	26.28	16.8	0.540	19.87	6.1
36	50	24.88	6.2	13.71	11.5	33.61	14.5	0.478	23.35	5.7
42	46	28.57	5.8	17.30	11.3	43.21	14.8	0.338	25.66	6.1
48	53	35.64	8.7	27.83	20.1	58.62	16.7	0.590	30.89	7.6
54	69	38.01	11.9	33.28	29.5	63.16	19.6	0.726	33.22	11.4
60	54	44.54	11.6	47.16	27.7	74.71	22.7	0.635	37.89	10.9
66	63	52.02	15.1	63.13	35.9	86.45	25.4	0.826	45.50	15.6
72	51	62.37	14.9	85.55	31.2	103.51	26.8	0.770	56.59	16.4
73	34	65.86	19.0	87.86	39.3	111.94	32.4	0.802	59.43	19.5
84	29	73.04	10.9	105.85	22.5	122.38	21.3	0.423	67.88	12.2

r is the correlation between scores for maturity of round and long bones estimated by the Tanner-Whitehouse Method.

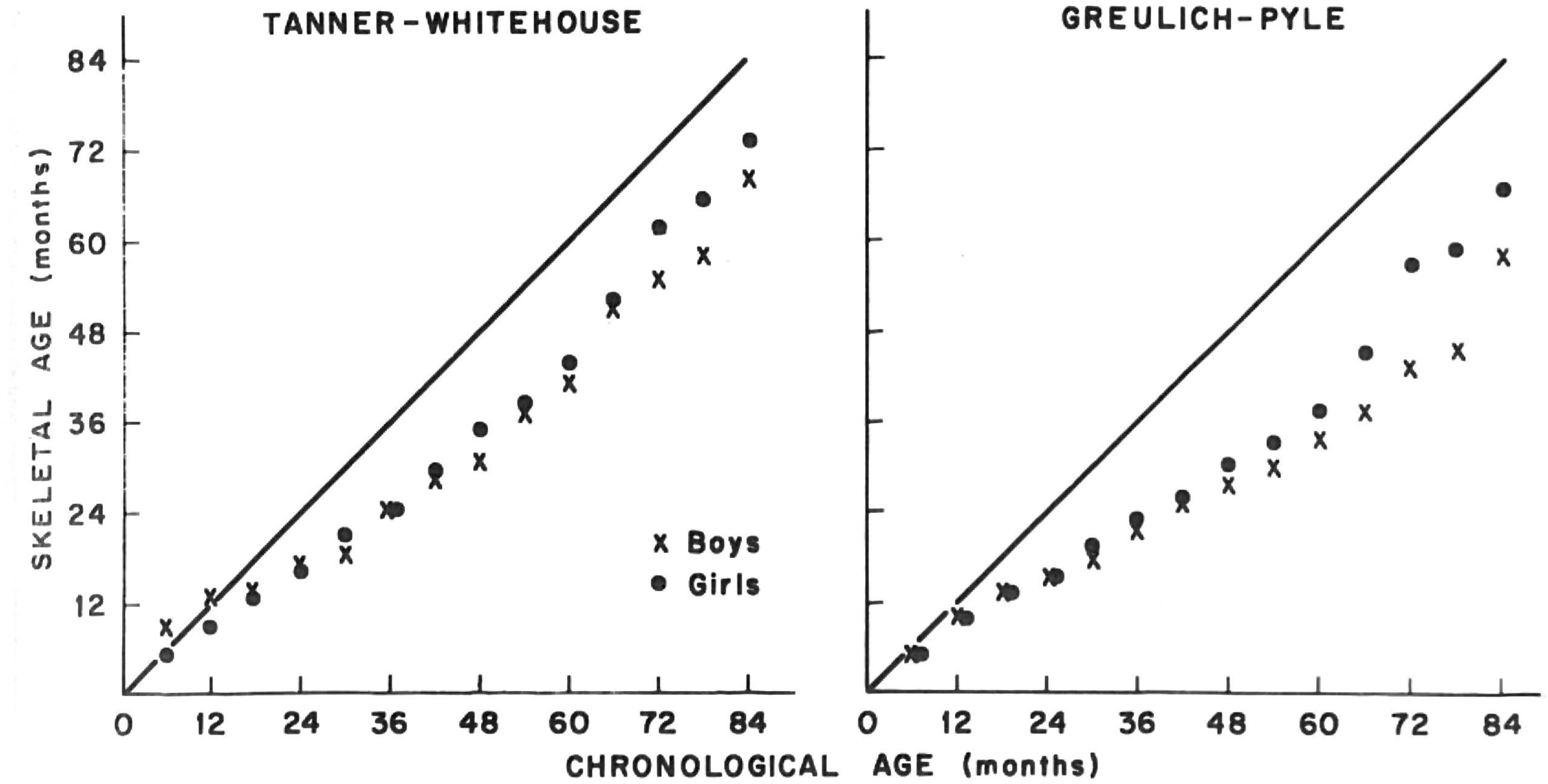

Fig. 2 Age and sex specific means for skeletal age assessed by the Tanner-Whitehouse and Greulich-Pyle methods. Both methods show that the study population has an increasing tendency to fall behind the standards for the two methods which are indicated by the continuous line on the graph. They also show that from the age of four years onwards this trend tends to be more pronounced among boys than girls. The differences between the standards can be attributed to the population upon which they were based.

produced in experimental animals by a number of authors (Acheson, '59; Platt and Stewart, '62), in response to such environmental insults as acute infection, protein-calorie malnutrition, and complete starvation. Harris ('31) in a study of individual case histories concluded that episodes of severe illness can induce these lines in man. Subsequently Hewitt, Westropp and Acheson ('55), in a longitudinal study of some 500 children from the general population of Oxford, England, showed that the incidence of the lines bore a strong, but not a one-to-one, relationship to acute illnesses such as measles. They also showed that a *new* Harris' line was related to a reduced increment in stature during the six-month period during which the line appeared. An analysis of longitudinal data collected in Southern Ohio by Garn, Silverman, Hertzog and Rohmann ('68) has indicated that immunizations and minor surgery can cause these lines to appear in the bones of healthy American children. Some studies published in recent years have failed to establish an association between stature achieved by a given age and the presence of lines in the metaphysis at that age (Dreizen, Spirakis and Stone, '64; Gindhart, '69). This is not surprising, nor is it incompatible with the work of Harris, Platt, Acheson, Garn and their colleagues, because compensatory acceleration of growth and differences in genetic growth potential could readily eclipse, in some children, a temporary arrest of growth (Prader, Tanner and Harnack, '63). In epidemiological terms, an incidence, or prospective study is much more powerful and sensitive a method of relating cause to effect than is a prevalence study. However, despite the fact that the present data were gathered in a prevalence study, the trends they show are consistent with the original view of Harris that such lines are an index of an overall interference with physical development. This seems to be of special significance because it suggests that the general state of nutriture of these Guatemalan children is even less robust than that of the poor children from the southern United States described by Dreizen and his colleagues ('64) or of Gindhart ('69). Consistent with this suggestion is the fact that the incidence of new lines, as far as can be judged from the examination of a single x-ray film of each child, is at a maximum during the fourth year of life when the intake of animal protein relative to body weight is probably lowest, for it is then that few if any children are receiving breast milk or getting a fair share of the family diet.

It has already been observed that the values for skeletal age by the Greulich and Pyle method are systematically lower than those for the Tanner-Whitehouse method, due to the different populations to which the two methods were originally standardized. Nevertheless, for both methods the differences between the observed and expected skeletal age in the two sexes were statistically significant, with $P < 0.001$. Although these differences were greater for boys than for girls (average retardation in months: Tanner-Whitehouse method — boys, 10.4, girls 8.8; Greulich and Pyle method — boys 16.3, girls 11.9) the between-sex differences are not statistically significant.

A third point is that these data provide further evidence that when physical development is affected by the environment, the effects tend to be more marked in boys than in girls (Acheson and Hewitt, '54; Acheson, '66; Blanco, Acheson, Canosa and Salomón, '72a,b). The boys lag further behind the standards than the girls in terms of skeletal maturation, have a higher incidence of lines of arrested growth after age 24 months, and are relatively a little shorter after 42 months; there is no clear difference, however, between the sexes compared with the standards for weight. This sex difference is also evident in the association between lines of arrested growth and the episodes which cause them; Garn, Silverman, Hertzog et al. ('68) showed coefficients of contingency between episodes and lines to be lower in girls than boys, a finding which could be interpreted as showing that the growth process is more robust in the former.

LITERATURE CITED

Acheson, R. M. 1959 Effects of starvation, septicaemia and chronic illness on the growth cartilage plate and metaphysis of the immature rat. J. Anat., *93:* 123–130.

——— 1966 Maturation of the skeleton. In: Human Development. F. Falkner, ed. Chapter 16. W. B Saunders Company, Philadelphia, pp. 465–502.

Acheson, R. M., and D. Hewitt 1954 Oxford Child Health Survey. Stature and skeletal maturation in the pre-school child. Brit. J. Prev. Soc. Med., *8:* 59–65.

Acheson, R. M., and M. N. MacIntyre 1958 The effects of acute infection and acute starvation on skeletal development. Brit. J. Exp. Pathology, *39:* 37–45.

Acheson, R. M., J. H. Vicinus and G. B. Fowler 1966 Studies in the reliability of assessing skeletal maturity from x-rays. Part III. Greulich-Pyle Atlas and Tanner-Whitehouse methods contrasted. Human Biology, *38:* 204–218.

Blanco, R. A., R. M. Acheson, C. Canosa and J. B. Salomón 1972a Retardation in appearance of ossification centers in deprived Guatemalan children. Human Biology, *44:* 525–536.

——— 1972b Sex differences in retardation of skeletal development in rural Guatemala. Pediatrics, *50:* 912–915.

Dreizen, S., R. M. Snodgrasse, G. S. Parker, C. Currie and T. D. Spies 1954 Maturation of bone centers of hand and wrist of children with chronic nutritive failure. Amer. J. Dis. Child., *87:* 429–439.

Dreizen, S., C. N. Spirakis and R. E. Stone 1964 The influence of age and nutritional status on "bone scar" formation in the distal end of the growing radius. Am. J. Phys. Anthrop., *22:* 295–306.

Estandartes de Peso y Estatura. Instituto de Nutrición de Centro America y Panamá. Guatemala.

Garn, S. M., and C. G. Rohmann 1962 Parent-child similarities in hand-wrist ossification. Amer. J. Dis. Child., *103:* 603–607.

——— 1966 Interaction of nutrition and genetics in the timing of growth and development. The Pediatric Clinics of North America, *13:* 353–379.

Garn, S. M., P. N. Silverman, K. P. Hertzog and C. G. Rohmann 1968 Lines and bands of increased density. Medical radiography and photography, *44:* 58–88.

Gerber, M., and R. A. F. Dean 1956 The psychological changes accompanying kwashiorkor. Courrier., *6:* 3–15.

Gindhart, P. S. 1969 The frequency of appearance of transverse lines in the tibia in relation to childhood illnesses. Am. J. Phys. Anthrop., *31:* 17–22.

Gould, H. N., and M. R. Gould 1932 Age of first menstruation in mothers and daughters. J.A.M.A., *98:* 1349–1352.

Greulich, W. W., and S. I. Pyle 1959 Radiographic Atlas of Skeletal Development of the Hand and Wrist. (2nd Ed.) Stanford University Press, Stanford, California.

Habicht, J. P. 1972 Personal communication.

Harris, H. A. 1926 The growth of the long bones in childhood with special reference to certain bony striations of the metaphysis and to the role of the vitamins. Arch. Int. Med., *38:* 785–806.

——— 1931 Lines of arrested growth in long bones in childhood; correlation of histological and radiographic appearances in clinical and experimental conditions. Brit. J. Radiol., *4:* 562–588, 622–640.

Hewitt, D., C. K. Westropp and R. M. Acheson

1955 Oxford child health survey. Effect of childish ailments on skeletal development. Brit. J. Prev. Soc. Med., *9:* 179–186.

Jackson, R. L., and H. G. Kelly 1945 Growth charts for use in pediatric practice. J. Pediat., *27:* 215–229.

Jones, P. R. M., and R. F. A. Dean 1956 The effects of kwashiorkor on the development of the bones of the hand. J. Trop. Pediat., *2:* 51–68.

Platt, B. S., and R. J. C. Stewart 1962 Transverse trabeculae and osteoporosis in bones in experimental protein-calorie deficiency. Brit. J. Nutr., *16:* 483–495.

Prader, A., J. M. Tanner and G. A. von Harnack 1963 Catch-up growth following illness or starvation. An example of developmental canalization in man. J. Pediat., *62:* 646–659.

Pryor, J. W. 1907 The hereditary nature of variation in the ossification of bones. Anat. Rec., *1:* 84–88.

Reynolds, E. L. 1943 Degree of kinship and pattern of ossification. Am. J. Phys. Anthrop., *1:* 405–416.

Robinson, W. D., J. H. Janney and F. Grande 1942 Studies of the physical characteristics of selected children in Madrid, Spain, in 1941. J. Pediat., *20:* 723–739.

Scrimshaw, N. S., and M. Béhar 1969 Malnutrition. In: Human Ecology and Public Health. Fourth ed. E. D. Kilbourne and W. G. Smillie, eds. MacMillan Co., New York.

Stuart, H. C. 1934 Standards of physical development for reference in clinical appraisement. J. Pediat., *5:* 194–209.

Stuart, H. C., and D. Kuhlmann 1942 Studies of the physical characteristics of children in Marseilles, France, in 1941. J. Pediat., *20:* 424–453.

Tanner, J. M., R. H. Whitehouse and M. J. R. Healy 1962 A new system for estimating skeletal maturity from the hand and wrist, with standard derived from a study of 2.600 healthy British children. Part II. The scoring system. International Children's Centre, Paris.

Wetzel, N. C. 1946 The baby grid: An application of the grid technique to growth and development in infants. J. Pediat., *29:* 439–454.