

TABLES FOR PREDICTING ADULT HEIGHT FROM SKELETAL AGE: REVISED FOR USE WITH THE GREULICH-PYLE HAND STANDARDS

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IN 1946 one of us (N. B.) published in the JOURNAL "Tables for Predicting Adult Height From Present Height and Skeletal Age."¹ These tables were developed for skeletal ages assessed according to the hand standards of T. Wingate Todd.² Recently the Todd *Atlas* has been completely revised by Greulich and Pyle.³ In their revision Greulich and Pyle have changed, somewhat, the criteria for determining normal skeletal age. As a result, readings from the two Atlases are not directly comparable, and predictions of growth from the two sets of standards will not be in perfect agreement. A given skeletal age as determined from the Greulich-Pyle *Atlas* will in most instances represent a different percentage of adult height than the same skeletal age read from the Todd *Atlas*. Put another way, in the two sets of standards a given x-ray will have different skeletal age ratings, even though they represent the same percentage of mature height. Since we may expect the revised Greulich-Pyle *Atlas* to replace the Todd *Atlas* in clinical practice, it has seemed desirable to revise the prediction tables

Our system of prediction is based on the fact that there is a high correlation between the skeletal ages, as read from hand x-rays on this type of standard, and the proportion of their adult stature achieved by children at the time their x-rays were taken. That is, SA (skeletal age) correlates with PMH (per cent of mature height) about .86 at most ages after 9 years, when chronological age is held constant.⁴ The new tables have been constructed from data gathered at the University of California Institute of Child Welfare, on 192 normal Berkeley children* (103 girls and 89 boys) who were measured and x-rayed every six months (with occasional exceptions) from 8 years through 18 years, or until all epiphyses of the hand were closed. The tables were then validated by applying them to a different group of 46 children† (23 boys and 23 girls).

Each child's height at maturity was taken as 100 per cent, and the fraction of his own mature height was computed for every earlier measuring. The average per cent of mature height (PMH) for a series of ages from one month to 18 years is shown in Fig. 1 and Table I for the Berkeley Growth Study children. The standard deviations from these means (shown by the shaded area in Fig. 1) indicate a wide

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We wish to thank Dr. Jean Walker Macfarlane who has made available for our use x-rays and anthropometric data from the Guidance Study. This material has been used in conjunction with similar data from the Berkeley Growth Study. This investigation was supported (in part) by a research grant from the Division of Research Grants and Fellowships of the National Institute of Health, U. S. Public Health Service.

*The subjects of the Guidance Study of the Institute of Child Welfare.

†The Berkeley Growth Study of the Institute of Child Welfare.

spread, among these normal children, in the speeds at which they progress toward their eventual heights. When regrouped according to skeletal age, however, the spread of percentages is greatly reduced during the period of pubescence, as may be seen by the nar-

fulness of skeletal age in predicting future growth.

DIRECTIONS FOR TAKING X-RAYS AND MEASURING HEIGHT

In using the tables it is necessary to have a good assessment of skeletal

TABLE I. MEANS AND STANDARD DEVIATIONS OF PER CENT OF MATURE HEIGHT ACHIEVED AT SUCCESSIVE AGES FROM BIRTH TO 18 YEARS BY THE CHILDREN OF THE BERKELEY GROWTH STUDY

C.A.		BOYS			GIRLS		
		N	MEAN	S.D.	N	MEAN	S.D.
Months	1	17	30.18	.77	20	32.40	1.44
	2	22	32.40	.93	21	34.51	1.56
	3	22	33.93	1.00	23	35.96	1.31
	4	22	35.21	.95	23	37.50	1.08
	5	22	36.50	.99	21	38.78	1.08
	6	22	37.67	.93	21	39.84	1.20
	7	22	38.44	.95	21	40.69	1.20
	8	22	39.22	1.10	23	41.79	1.37
	9	22	40.08	1.07	23	42.20	1.22
	10	22	40.80	1.14	23	43.09	1.37
	11	22	41.53	1.16	21	44.10	1.24
	12	22	42.23	1.04	21	44.67	1.42
	15	22	44.02	1.19	21	46.90	1.18
	18	20	45.64	1.34	19	48.76	1.37
	24	23	48.57	1.44	17	52.15	1.34
Years	30	23	51.14	1.40	18	54.75	1.22
	3.0	23	53.53	1.34	22	57.16	1.20
	4.0	22	57.72	1.38	22	61.84	1.45
	5.0	23	61.60	1.49	23	66.24	1.45
	6.0	23	65.31	1.58	23	70.29	1.60
	7.0	23	69.08	1.60	22	74.28	1.61
	8.0	22	72.40	1.68	23	77.57	1.87
	9.0	22	75.61	1.68	21	81.19	2.00
	9.5	21	77.21	1.66	20	83.03	2.13
	10.0	22	78.40	1.76	23	84.76	2.42
	10.5	23	79.82	1.77	22	86.85	2.71
	11.0	23	81.30	1.94	21	88.65	2.88
	11.5	23	82.54	2.00	21	90.81	3.06
	12.0	20	84.00	2.23	22	92.61	3.27
	12.5	21	85.43	2.49	21	94.72	2.61
	13.0	23	87.32	3.02	18	95.96	2.15
	13.5	21	89.22	3.57	18	97.17	1.70
	14.0	20	91.00	3.96	19	98.27	1.24
	14.5	20	92.60	3.85	19	98.74	.93
	15.0	20	94.60	3.74	21	99.31	.68
	15.5	21	96.00	3.31	21	99.54	.48
	16.0	22	97.09	2.71	21	99.62	.35
	16.5	20	97.95	2.12	20	99.75	.34
	17.0	20	98.79	1.43	22	99.95	.25
	17.5	20	99.28	1.01	19	99.91	.25
	18.0	21	99.55	.58	18	99.96	.11

rowness of the shaded area in the inset curves in Fig. 1. This is one indication of the close relationship between growth in size and the maturation of the skeleton, and demonstrates the use-

age from an x-ray of the hand, an accurate measurement of height, and a record of the child's age. The following directions are given to facilitate obtaining these data.

X-rays are taken of the left hand, which is placed "palm down, hand flat on the film holder, with fingers slightly separated, and the axis of the hand, wrist, and forearm in a straight line. Center the tube half way between the tips of the fingers and distal end of the radius. The radiograph should include the complete fingers and at least $11\frac{1}{2}$ inches of the radius, since all the hand epiphyses as well as those of the distal

accurately calibrated solid vertical surface. (A good quality two-meter stick or similar rule calibrated in inches can be firmly affixed beside a vertical board.) Heels and back are touching the wall, the head held in the Frankfort plane (the lower edge of the eye socket and the upper edge of the ear-hole on a horizontal line). A Baldwin square,⁶ which is essentially two boards joined at right angles and held

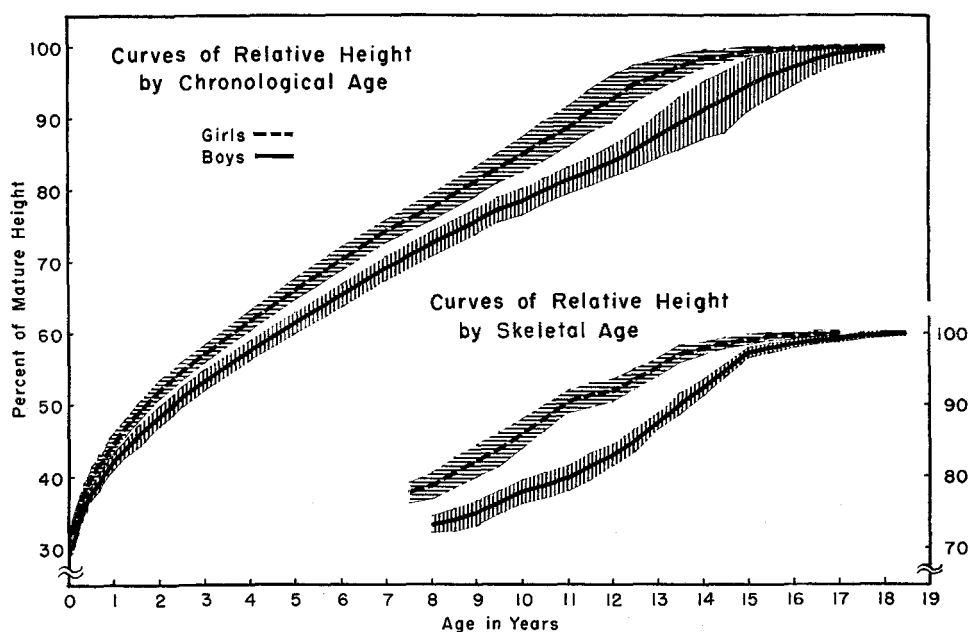


Fig. 1.—Curves of relative height: Mean per cent of mature height, boys and girls separately, by chronological age and by skeletal age. The shaded areas indicate plus and minus one standard deviation, or the middle 68 per cent of a normal distribution.

end of the arm are very important in the skeletal age reading.”⁵ For children over 6 years of age we have used no-screen cardboard holders. Good results may be obtained with a tube distance of 36 inches, time 1 second, 100 MA, 45-50KV. For use with these tables we recommend reading for SA by the Greulich-Pyle Standards,³ according to their directions.

Height is measured without shoes, the child “standing tall” against an

in place by a cross piece, is brought down so that it rests firmly against the measuring scale and comes in firm contact with the top of the head. The height measurement is then read off of the scale at the lower edge of the square.

DIRECTIONS FOR USING THE TABLES

The Greulich-Pyle prediction tables are set up in the same way as the 1946 tables for the Todd standards, with

TABLE IID. ACCELERATED BOYS. PERCENTAGES AND ESTIMATED MATURE HEIGHTS FOR BOYS WITH SKELETAL AGES ONE YEAR OR MORE ADVANCED OVER THEIR CHRONOLOGICAL AGES:

SKELETAL AGES 12 THROUGH 17 YEARS																						
Skeletal Age	12-0	12-3	12-6	12-9	13-0	13-3	13-6	13-9	14-0	14-3	14-6	14-9	15-0	15-3	15-6	15-9	16-0	16-3	16-6	16-9	17-0	
% of Mature Height	80.9	81.8	82.8	83.9	85.0	86.3	87.5	89.0	90.5	91.8	93.0	94.3	95.8	96.7	97.1	97.6	98.0	98.3	98.5	98.8	99.0	
Ht. (inches)																						
49	60.6																					
50	61.8	61.1	60.4																			
51	63.0	62.3	61.6	60.8	60.0																	
52	64.3	63.6	62.8	62.0	61.2	60.3																
53	65.5	64.8	64.0	63.2	62.4	61.4	60.6															
54	66.7	66.0	65.2	64.4	63.5	62.6	61.7	60.7														
55	68.0	67.2	66.4	65.6	64.7	63.7	62.9	61.8	60.8													
56	69.2	68.5	67.6	66.7	65.9	64.9	64.0	62.9	61.9	61.0	60.2	61.3	60.4									
57	70.5	69.7	68.8	67.9	67.1	66.0	65.1	64.0	63.0	62.1	61.3	60.4	61.5	60.5	60.0							
58	71.7	70.9	70.0	69.1	68.2	67.2	66.3	65.2	64.1	63.2	62.4	61.5	60.6	60.0	61.8	60.5	60.2	60.0	60.9	60.7	60.6	
59	72.9	72.1	71.3	70.3	69.4	68.4	67.4	66.3	65.2	64.3	63.4	62.6	61.6	61.0	61.8	61.5	61.2	61.0	60.9	60.7	60.6	
60	74.2	73.4	72.5	71.5	70.6	69.5	68.6	67.4	66.3	65.4	64.5	63.6	62.6	62.0	61.8	61.5	61.2	61.0	60.9	60.7	60.6	
61	75.4	74.6	73.7	72.7	71.8	70.7	69.7	68.5	67.4	66.4	65.6	64.7	63.7	63.1	62.8	61.5	61.2	61.0	60.9	60.7	60.6	
62	76.6	75.8	74.9	73.9	72.9	71.8	70.7	69.7	68.5	67.5	66.7	65.7	64.7	64.1	63.9	62.5	62.2	62.1	61.9	61.7	61.6	
63	77.9	77.0	76.1	75.1	74.1	73.0	72.0	70.8	69.6	68.6	67.7	66.8	65.8	65.1	64.9	63.5	63.3	63.1	62.9	62.8	62.6	
64	79.1	78.2	77.3	76.3	75.3	74.2	73.1	71.9	70.7	69.7	68.8	67.9	66.8	66.2	65.9	64.5	64.3	64.1	64.0	63.8	63.6	
65	80.3	79.5	78.5	77.5	76.5	75.5	74.5	73.5	72.5	71.8	70.8	69.9	68.9	67.8	66.9	65.6	65.3	65.1	65.0	64.8	64.6	
66		80.7	79.7	78.7	77.6	76.5	75.4	74.2	72.9	71.9	71.0	70.0	68.9	68.3	68.0	66.6	66.3	66.1	66.0	65.8	65.7	
67			80.9	79.9	78.8	77.6	76.6	75.3	74.0	73.0	72.0	71.1	69.9	69.3	69.0	67.6	67.3	67.1	67.0	66.8	66.7	
68				80.0	78.8	77.7	76.4	75.1	74.1	73.1	72.1	71.0	70.3	70.0	68.6	68.4	68.2	68.0	67.8	67.7		
69					80.0	78.9	77.5	76.2	75.2	74.2	73.2	72.0	71.4	71.1	69.7	69.4	69.2	69.0	68.8	68.7		
70						80.0	78.7	77.3	76.3	75.3	74.2	73.1	72.4	72.1	70.7	70.4	70.2	70.0	69.8	69.7		
71							80.0	78.7	77.3	76.3	75.3	74.1	73.4	73.1	71.7	71.4	71.2	71.1	70.8	70.7		
72								80.9	79.6	78.4	77.4	76.4	75.2	74.5	74.2	72.7	72.4	72.2	72.1	71.9	71.7	
73									80.7	79.5	78.5	77.4	76.2	75.5	75.2	73.8	73.5	73.2	73.1	72.9	72.7	
74										80.6	79.6	78.5	77.2	76.5	76.2	74.8	74.5	74.3	74.1	73.9	73.7	
75											80.6	79.5	78.3	77.6	77.2	75.8	75.5	75.3	75.1	74.9	74.7	
76												80.6	79.3	78.6	78.3	76.8	76.5	76.3	76.1	75.9	75.8	
77													80.4	79.6	79.3	77.9	77.6	77.3	77.2	76.9	76.8	
78														80.7	80.3	78.9	78.6	78.3	78.2	77.9	77.8	
																79.9	79.6	79.3	79.2	78.9	78.8	

supplementary tables for retarded and accelerated children at the younger ages. In each table the skeletal ages, by three-month intervals, are given across the top, with the corresponding PMH directly under its SA. Mature heights may be computed from these percentages, by dividing the child's height by the percentage which corresponds to his SA. Or predicted height may be read off directly from the tables. It is important, for reliable prediction from the tables, to use the correct table for the child's sex (Tables II for boys and Tables III for girls), and to select the table suitable for his rate of maturing. When within one year of a child's chronological age, use Tables IIA or IIB for boys, IIIA or IIIB for girls; when accelerated a year or more, use Tables IIC and IID or IIIC and IIID; and when retarded a year or more, use Tables IIE or IIIE and IIIF.

The most frequent mature heights have been computed for SA intervals of three months and height intervals of one inch. These predictions are given in the body of the tables. For example: A 13-year-old boy with an SA of 13 years 3 months is 60 inches tall. From Table IIB we find 60 inches in the left-hand column and follow across this row to the SA column of 13-3. The figure at this intersection, 67.4 inches, is the predicted mature height for this boy. If the measures or SA's do not fall exactly at the one-inch or three-month intervals, or are outside the range of prediction given in the table, we may interpolate, or make direct computations. For example, if the 13-year-old boy is only 51.5 inches tall, his mature height may be computed by dividing his present

height by 89.0, which is the PMH for SA 13-3. This will predict an eventual height (or 100 per cent) of 57.9 inches.

Another boy may be 14 years old, 67½ inches tall, and have an SA of 15½ years. From Table IID we would predict a mature height from the 15-6 SA column at a point half way between 69 and 70 inches, or 69½ inches.

To take another example: A girl who is 12 years old has an SA of 10 years 3 months, and is 55 inches tall. Using Table IIIE, the intersection of the 10-3 column and the 55 inch row gives a probable mature height of 62.2 inches.

Predictions for ages younger than those given in the tables are subject to large errors. But it is sometimes desirable to make some prediction at an early age. Adult heights could then be estimated from the percentages given in Table I.

INTERPRETATION

The predictions from the tables are not perfectly accurate, even though after 9 years of age they are far better than estimates made on the basis of age without regard to maturational status.¹ There are several sources of error which must be kept in mind when making any predictions.

(a) X-rays may be inaccurately read. Accuracy can be increased by practice in the use of the standards, but such assessments always remain approximations. It is, therefore, very desirable to reduce the error by making several independent readings (by the same or different persons) and then to take the average of these readings.

(b) These prediction tables were developed from the Greulich-Pyle stand-

TABLE IIID. ACCELERATED GIRLS. PERCENTAGES AND ESTIMATED MATURE HEIGHTS FOR GIRLS WITH SKELETAL AGES ONE YEAR OR MORE
ADVANCED OVER THEIR CHRONOLOGICAL AGES;
SKELETAL AGES 12 THROUGH 17 YEARS

Skeletal Age % of Mature Height Ht. (inches)	12-0	12-3	12-6	12-9	13-0	13-3	13-6	13-9	14-0	14-3	14-6	14-9	15-0	15-3	15-6	15-9	16-0	16-3	16-6	16-9	17-0	17-6
90.1	91.3	92.4	93.5	94.5	95.5	96.3	96.8	97.2	97.7	98.0	98.3	98.6	98.8	99.0	99.2	99.3	99.4	99.5	99.7	99.8	99.95	
51.1	51.5																					
52.2	52.6	51.9	51.3																			
53.3	53.7	53.0	52.4	51.9	51.3	50.9	51.7	51.4	51.2	51.0												
55.5	54.8	54.1	53.5	52.9	52.4	51.9	52.7	52.5	52.2	52.0	51.9	51.7	51.6	51.5	51.4	51.4	51.3	51.3	51.2	51.1	51.0	
56.6	55.9	55.2	54.5	54.0	53.4	53.0	52.7	52.5	52.2	52.0	52.9	52.7	52.6	52.5	52.4	52.4	52.3	52.3	52.2	52.1	52.0	
57.7	57.0	56.3	55.6	55.0	54.5	54.0	53.7	53.5	53.2	53.1	53.9	53.8	53.6	53.5	53.4	53.4	53.3	53.3	53.2	53.1	53.0	
58.8	58.1	57.4	56.7	56.1	55.5	55.0	54.8	54.5	54.2	54.1	54.9	54.8	54.7	54.5	54.4	54.4	54.3	54.3	54.2	54.1	54.0	
59.9	59.1	58.4	57.8	57.1	56.5	56.1	55.8	55.6	55.3	55.1	56.0	55.8	55.7	55.5	55.4	55.4	55.3	55.3	55.2	55.1	55.0	
61.0	60.2	59.5	58.8	58.2	57.6	57.1	56.8	56.6	56.3	56.1	57.0	56.8	56.7	56.5	56.5	56.4	56.3	56.3	56.2	56.1	56.0	
62.2	61.3	60.6	59.9	59.3	58.6	58.2	57.9	57.6	57.3	57.1	58.0	57.8	57.7	57.6	57.5	57.4	57.3	57.3	57.2	57.1	57.0	
63.3	62.4	61.7	61.0	60.3	59.7	59.2	58.9	58.6	58.3	58.2	59.2	58.9	58.7	58.6	58.5	58.4	58.3	58.3	58.2	58.1	58.0	
64.4	63.5	62.8	62.0	61.4	60.7	60.2	59.9	59.7	59.4	59.2	60.2	60.0	59.8	59.7	59.6	59.5	59.4	59.4	59.3	59.2	59.1	
65.5	64.6	63.9	63.1	62.4	61.8	61.3	61.0	60.7	60.4	60.2	61.0	60.9	60.7	60.6	60.5	60.4	60.4	60.3	60.2	60.1	60.0	
66.6	65.7	64.9	64.2	63.5	62.8	62.3	62.0	61.7	61.4	61.2	62.1	61.9	61.7	61.6	61.5	61.4	61.4	61.3	61.2	61.1	61.0	
67.7	66.8	66.0	65.2	64.6	63.9	63.3	63.0	62.8	62.4	62.2	63.1	62.9	62.8	62.6	62.5	62.4	62.4	62.3	62.2	62.1	62.0	
68.8	67.9	67.1	66.3	65.6	64.9	64.4	64.0	63.8	63.5	63.3	64.1	63.9	63.8	63.6	63.5	63.4	63.4	63.3	63.2	63.1	63.0	
69.9	69.0	68.2	67.4	66.7	66.0	65.4	65.1	64.8	64.5	64.3	65.1	64.9	64.8	64.6	64.5	64.4	64.4	64.3	64.2	64.1	64.0	
71.0	70.1	69.3	68.4	67.7	67.0	66.5	66.1	65.8	65.5	65.3	66.1	65.9	65.8	65.7	65.5	65.5	65.4	65.3	65.2	65.1	65.0	
72.1	71.2	70.3	69.5	68.8	68.1	67.5	67.1	66.9	66.5	66.3	67.1	66.9	66.8	66.7	66.5	66.5	66.4	66.3	66.2	66.1	66.0	
73.3	72.3	71.4	70.6	69.8	69.1	68.5	68.2	67.9	67.6	67.3	68.2	68.0	67.8	67.7	67.5	67.5	67.4	67.3	67.2	67.1	67.0	
74.4	73.4	72.5	71.7	70.9	70.2	69.6	69.2	68.9	68.6	68.4	69.2	69.0	68.8	68.7	68.6	68.5	68.4	68.3	68.2	68.1	68.0	
74.5	73.6	72.7	72.0	71.2	70.6	70.2	70.0	69.6	69.4	69.2	70.0	69.8	69.7	69.6	69.5	69.4	69.3	69.2	69.1	69.0	68.9	
74.7	73.8	73.0	72.3	71.7	71.3	71.0	70.6	70.4	70.2	70.0	70.8	70.7	70.6	70.5	70.4	70.3	70.2	70.1	70.0	69.9	69.8	
74.9	74.1	73.3	72.7	72.1	71.5	71.1	70.7	70.4	70.2	70.0	70.8	70.7	70.6	70.5	70.4	70.3	70.2	70.1	70.0	69.9	69.8	
75.1	74.3	73.7	73.3	73.0	72.7	72.4	72.2	72.0	71.9	71.7	72.6	72.5	72.4	72.3	72.2	72.1	72.0	71.9	71.8	71.7	71.6	
75.3	74.5	73.9	73.5	73.2	73.0	72.9	72.7	72.6	72.5	72.4	73.3	73.2	73.1	73.0	72.9	72.8	72.7	72.6	72.5	72.4	72.3	
75.5	74.7	74.1	73.7	73.3	73.0	72.9	72.7	72.6	72.5	72.4	73.3	73.2	73.1	73.0	72.9	72.8	72.7	72.6	72.5	72.4	72.3	
75.7	74.9	74.3	73.9	73.5	73.2	73.0	72.9	72.7	72.6	72.5	73.4	73.3	73.2	73.1	73.0	72.9	72.8	72.7	72.6	72.5	72.4	
75.9	75.1	74.5	74.1	73.7	73.4	73.1	72.9	72.8	72.7	72.6	73.5	73.4	73.3	73.2	73.1	73.0	72.9	72.8	72.7	72.6	72.5	
76.1	75.3	74.7	74.3	73.9	73.6	73.3	73.1	73.0	72.9	72.8	73.7	73.6	73.5	73.4	73.3	73.2	73.1	73.0	72.9	72.8	72.7	
76.3	75.5	74.9	74.5	74.1	73.8	73.5	73.3	73.2	73.1	73.0	73.9	73.8	73.7	73.6	73.5	73.4	73.3	73.2	73.1	73.0	72.9	
76.5	75.7	75.1	74.7	74.3	74.0	73.7	73.5	73.4	73.3	73.2	74.1	74.0	73.9	73.8	73.7	73.6	73.5	73.4	73.3	73.2	73.1	
76.7	75.9	75.3	74.9	74.5	74.2	73.9	73.7	73.6	73.5	73.4	74.3	74.2	74.1	74.0	73.9	73.8	73.7	73.6	73.5	73.4	73.3	
76.9	76.1	75.5	75.1	74.7	74.4	74.1	73.9	73.8	73.7	73.6	74.5	74.4	74.3	74.2	74.1	74.0	73.9	73.8	73.7	73.6	73.5	
77.1	76.3	75.7	75.3	74.9	74.6	74.3	74.1	74.0	73.9	73.8	74.7	74.6	74.5	74.4	74.3	74.2	74.1	74.0	73.9	73.8	73.7	
77.3	76.5	75.9	75.5	75.1	74.8	74.5	74.3	74.2	74.1	74.0	74.9	74.8	74.7	74.6	74.5	74.4	74.3	74.2	74.1	74.0	73.9	
77.5	76.7	76.1	75.7	75.3	75.0	74.7	74.5	74.4	74.3	74.2	75.1	75.0	74.9	74.8	74.7	74.6	74.5	74.4	74.3	74.2	74.1	
77.7	76.9	76.3	75.9	75.5	75.2	74.9	74.7	74.6	74.5	74.4	75.3	75.2	75.1	75.0	74.9	74.8	74.7	74.6	74.5	74.4	74.3	
77.9	77.1	76.5	76.1	75.7	75.4	75.1	74.9	74.8	74.7	74.6	75.5	75.4	75.3	75.2	75.1	75.0	74.9	74.8	74.7	74.6	74.5	
78.1	77.3	76.7	76.3	75.9	75.6	75.3	75.1	75.0	74.9	74.8	75.7	75.6	75.5	75.4	75.3	75.2	75.1	75.0	74.9	74.8	74.7	
78.3	77.5	76.9	76.5	76.1	75.8	75.5	75.3	75.2	75.1	75.0	75.9	75.8	75.7	75.6	75.5	75.4	75.3	75.2	75.1	75.0	74.9	
78.5	77.7	77.1	76.7	76.3	76.0	75.7	75.5	75.4	75.3	75.2	76.1	76.0	75.9	75.8	75.7	75.6	75.5	75.4	75.3	75.2	75.1	
78.7	77.9	77.3	76.9	76.5	76.2	75.9	75.7	75.6	75.5	75.4	76.3	76.2	76.1	76.0	75.9	75.8	75.7	75.6	75.5	75.4	75.3	
78.9	78.1	77.5	77.1	76.7	76.4	76.1	75.9	75.8	75.7	75.6	76.5	76.4	76.3	76.2	76.1	76.0	75.9	75.8	75.7	75.6	75.5	
79.1	78.3	77.7	77.3	76.9	76.6	76.3	76.1	76.0	75.9	75.8	76.7	76.6	76.5	76.4	76.3	76.2	76.1	76.0	75.9	75.8	75.7	
79.3	78.5	77.9	77.5	77.1	76.8	76.5	76.3	76.2	76.1	76.0	76.9	76.8	76.7	76.6	76.5	76.4	76.3	76.2	76.1	76.0	75.9	
79.5	78.7	78.1	77.7	77.3	77.0	76.7	76.5	76.4	76.3	76.2	77.1	77.0	76.9	76.8	76.7	76.6	76.5	76.4	76.3	76.2	76.1	
79.7	78.9	78.3	77.9	77.5	77.2	76.9	76.7	76.6	76.5	76.4	77.3	77.2	77.1	77.0	76.9	76.8	76.7	76.6	76.5	76.4	76.3	
79.9	79.1	78.5	78.1	77.7	77.4	77.1	76.9	76.8	76.7	76.6	77.5	77.4	77.3	77.2	77.1	77.0	76.9	76.8	76.7	76.6	76.5	
80.1	79.3	78.7	78.3	77.9	77.6	77.3	77.1	77.0	76.9	76.8	77.7	77.6	77.5	77.4	77.3	77.2	77.1	77.0	76.9	76.8	76.7	
80.3	79.5	78.9	78.5	78.1	77.8	77.5	77.3	77.2	77.1	77.0	77.9	77.8	77.7	77.6	77.5	77.4	77.3	77.2	77.1	77.0	76.9	
80.5	79.7	79.1	78.7	78.3	78.0	77.7	77.5	77.4	77.3	77.2	78.1	78.0	77.9	77.8	77.7	77.6	77.5	77.4	77.3	77.2	77.1	
80.7	79.9	79.3	78.9	78.5	78.2	77.9	77.7	77.6	77.5	77.4	78.3	78.2	78.1	78.0	77.9	77.8	77.7	77.6	77.5	77.4	77.3	
80.9	80.1	79.5	79.1	78.7	78.4	78.1	77.9	77.8	77.7	77.6	78.5	78.4	78.3	78.2	78.1	78.0	77.9	77.8	77.7	77.6	77.5	
81.1	80.3	79.7	79.3	78.9	78.6	78.3	78.1	78.0	77.9	77.8	78.7	78.6	78.5	78.4	78.3	78.2	78.1	78.0	77.9	77.8	77.7	
81.3	80.5	79.9	79.5	79.1	78.8	78.5	78.3	78.2	78.1	78.0	78.9	78.8	78.7	78.6	78.5	78.4	78.3	78.2	78.1	78.0	77.9	
81.5	80.7	80.1	79.7	79.3	79.0	78.7	78.5	78.4	78.3	78.2	79.1	79.0	78.9	78.8	78.7	78.6	78.5	78.4	78.3	78.2	78.1	
81.7	80.9	80.3	79.9	79.5	79.2	78.9	78.7	78.6	78.5	78.4	79.3	79.2	79.1	79.0	78.9	78.8	78.7	78.6	78.5	78.4	78.3	
81.9	81.1	80.5	80.1	79.7	79.4	79.1	78.9	78.8	78.7	78.6	79.5	79.4	79.3	79.2	79.1	79.0						

TABLE III. RETARDED GIRLS. PERCENTAGES AND ESTIMATED MATURE HEIGHTS FOR GIRLS WITH SKELETAL AGES ONE YEAR OR MORE RETARDED FOR THEIR CHRONOLOGICAL AGES:

		SKELETAL AGES 6 THROUGH 11 YEARS																							
Skeletal Age		6-0	6-3	6-6	6-10	7-0	7-3	7-6	7-10	8-0	8-3	8-6	8-10	9-0	9-3	9-6	9-9	10-0	10-3	10-6	10-9	11-0	11-3	11-6	11-9
% of Mature Height		73.3	74.2	75.1	76.3	77.0	77.9	78.8	79.7	80.4	81.3	82.3	83.6	84.1	85.1	85.8	86.6	87.4	88.4	89.6	90.7	91.8	92.2	92.6	92.9
Ht. (inches)																									
38		51.8	51.2																						
39		53.2	52.6	51.9	51.1																				
40		54.6	53.9	53.3	52.4	51.9	51.3																		
41		55.9	55.3	54.6	53.7	53.2	52.6	52.0	51.4																
42		57.3	56.6	55.9	55.0	54.5	53.9	53.3	52.7	52.2	51.7	51.0													
43		58.7	58.0	57.3	56.4	55.8	55.2	54.6	54.0	53.5	52.9	52.3	51.4	51.1											
44		60.0	59.3	58.6	57.7	57.1	56.5	55.8	55.2	54.7	54.1	53.5	52.9	52.4	52.0	51.5									
45		61.4	60.6	59.9	59.0	58.4	57.8	57.1	56.5	56.0	55.4	54.7	53.8	53.5	52.9	52.4	52.0	51.5							
46		62.8	62.0	61.3	60.3	59.7	59.1	58.4	57.7	57.2	56.6	55.9	55.0	54.7	54.1	53.6	53.1	52.6	52.0	51.3					
47		64.1	63.3	62.6	61.6	61.0	60.3	59.6	59.0	58.5	57.8	57.1	56.2	55.9	55.2	54.8	54.3	53.8	53.2	52.5	51.8	51.2	51.0		
48		65.5	64.7	63.9	62.9	62.3	61.6	60.9	60.2	59.7	59.0	58.3	57.4	57.1	56.4	55.9	55.4	54.9	54.3	53.6	52.9	52.3	52.1	51.8	51.7
49		66.9	66.0	65.2	64.2	63.6	62.9	62.2	61.5	60.9	60.3	59.5	58.6	58.3	57.6	57.1	56.6	56.1	55.4	54.7	54.0	53.4	53.1	52.9	52.7
50		68.2	67.4	66.6	65.5	64.9	64.2	63.5	62.7	62.2	61.5	60.8	59.8	59.5	58.8	58.3	57.7	57.2	56.6	55.8	55.1	54.5	54.2	54.0	53.8
51		69.6	68.7	67.9	66.8	66.2	65.5	64.7	64.0	63.4	62.7	62.0	61.0	60.6	59.9	59.4	58.9	58.4	57.7	56.9	56.2	55.6	55.3	55.1	54.9
52		70.9	70.1	69.2	68.2	67.5	66.8	66.0	65.2	64.7	64.0	63.2	62.2	61.8	61.1	60.6	60.0	59.5	58.8	58.0	57.3	56.6	56.4	56.2	56.0
53		72.3	71.4	70.6	69.5	68.8	68.0	67.3	66.5	65.9	65.2	64.4	63.4	63.0	62.3	61.8	61.2	60.6	60.0	59.2	58.4	57.7	57.5	57.2	57.1
54		73.7	72.8	71.9	70.8	70.1	69.3	68.5	67.8	67.2	66.4	65.6	64.6	64.2	63.5	62.9	62.4	61.8	61.1	60.3	59.5	58.8	58.6	58.3	58.1
55			74.1	73.2	72.1	71.4	70.6	69.8	69.0	68.4	67.7	66.8	65.8	65.4	64.6	64.1	63.5	62.9	62.2	61.4	60.6	59.9	59.7	59.4	59.2
56				74.6	73.4	72.7	71.9	71.1	70.3	69.7	68.9	68.0	67.0	66.6	65.8	65.3	64.7	64.1	63.3	62.5	61.7	61.0	60.7	60.5	60.3
57					74.7	74.0	73.2	72.3	71.5	70.9	70.1	69.3	68.2	67.8	67.0	66.4	65.8	65.2	64.6	63.6	62.8	62.1	61.8	61.6	61.4
58						74.5	73.6	72.8	72.1	71.3	70.5	69.4	69.0	68.2	67.6	67.0	66.4	65.6	64.7	63.9	63.2	62.9	62.6	62.4	
59							74.5	74.9	74.0	73.4	72.6	71.7	70.6	70.2	69.3	68.8	68.1	67.5	66.7	65.8	65.0	64.3	64.0	63.7	63.5
60								74.6	73.8			72.9	71.8	71.3	70.5	69.9	69.3	68.7	67.9	67.0	66.2	65.4	65.1	64.8	64.6
61										74.1	73.0	72.5	71.7	71.1	70.4	69.8	69.0	68.1	67.3	66.4	66.2	65.4	65.2	65.0	65.7
62											74.2	73.7	72.9	72.3	71.6	70.9	70.1	69.2	68.4	67.5	67.2	67.0	66.7	66.7	
63												74.2	73.7	72.9	72.3	71.6	70.9	70.1	69.2	68.4	67.5	67.2	67.0	66.7	
64													74.2	73.7	72.9	72.3	71.6	70.9	70.1	69.2	68.4	67.5	67.2	67.0	66.7
65														74.2	73.7	72.9	72.3	71.6	70.9	70.1	69.2	68.4	67.5	67.2	67.0
66															74.2	73.7	72.9	72.3	71.6	70.9	70.1	69.2	68.4	67.5	67.2
67																74.2	73.7	72.9	72.3	71.6	70.9	70.1	69.2	68.4	67.5
68																	74.2	73.7	72.9	72.3	71.6	70.9	70.1	69.2	68.4
69																		74.2	73.7	72.9	72.3	71.6	70.9	70.1	69.2

TABLE III. RETARDED GIRLS. PERCENTAGES AND ESTIMATED MATURE HEIGHTS FOR GIRLS WITH SKELETAL AGES ONE YEAR OR MORE RETARDED FOR THEIR CHRONOLOGICAL AGES:
SKELETAL AGES 12 THROUGH 17 YEARS

Skeletal Age	12-0	12-3	12-6	12-9	13-0	13-3	13-6	13-9	14-0	14-3	14-6	14-9	15-0	15-3	15-6	15-9	16-0	16-3	16-6	16-9	17-0
% of Mature Height	93.2	94.2	94.9	95.7	96.4	97.1	97.7	98.1	98.3	98.6	98.9	99.2	99.4	99.5	99.6	99.7	99.8	99.9	99.9	99.95	100.0
Ht. (inches)																					
48	51.5	51.0																			
49	52.6	52.0	51.6	51.2	51.9	51.5	51.2	51.0	51.9	51.7	51.6	51.4	51.3	51.3	51.2	51.2	51.1	51.1	51.1	51.0	51.0
50	53.6	53.1	52.7	52.2	52.9	52.5	52.2	52.0	52.9	52.7	52.6	52.4	52.3	52.3	52.2	52.2	52.1	52.1	52.1	52.0	52.0
51	54.7	54.1	53.7	53.3	53.9	53.6	53.2	53.0	53.9	53.8	53.6	53.4	53.3	53.3	53.2	53.2	53.1	53.1	53.1	53.0	53.0
52	55.8	55.2	54.8	54.3	55.0	54.6	54.2	54.0	54.9	54.8	54.6	54.4	54.3	54.3	54.2	54.2	54.1	54.1	54.1	54.0	54.0
53	56.9	56.3	55.8	55.4	56.0	55.6	55.3	55.0	55.9	55.8	55.6	55.4	55.3	55.3	55.2	55.2	55.1	55.1	55.1	55.0	55.0
54	57.9	57.3	56.9	56.4	56.9	56.6	56.3	56.1	56.0	55.8	55.6	55.4	55.3	55.3	55.2	55.2	55.1	55.1	55.1	55.0	55.0
55	59.0	58.4	58.0	57.5	58.1	57.7	57.3	57.1	57.0	56.8	56.6	56.5	56.3	56.3	56.2	56.2	56.1	56.1	56.1	56.0	56.0
56	60.1	59.4	59.0	58.5	59.1	58.7	58.3	58.1	58.0	57.8	57.6	57.5	57.3	57.3	57.2	57.2	57.1	57.1	57.1	57.0	57.0
57	61.2	60.5	60.1	59.6	59.9	59.7	59.4	59.1	59.0	58.8	58.6	58.5	58.3	58.3	58.2	58.2	58.1	58.1	58.1	58.0	58.0
58	62.2	61.6	61.1	60.6	60.2	60.0	60.4	60.1	60.0	59.8	59.7	59.5	59.4	59.3	59.2	59.2	59.1	59.1	59.1	59.0	59.0
59	63.3	62.6	62.2	61.7	61.2	60.8	60.4	60.1	60.0	59.8	59.7	59.5	59.4	59.3	59.2	59.2	59.1	59.1	59.1	59.0	59.0
60	64.4	63.7	63.2	62.7	62.2	61.8	61.4	61.2	61.0	60.9	60.7	60.5	60.4	60.3	60.2	60.2	60.1	60.1	60.1	60.0	60.0
61	65.5	64.8	64.3	63.7	63.3	62.8	62.4	62.2	62.1	61.9	61.7	61.5	61.4	61.3	61.2	61.2	61.1	61.1	61.1	61.0	61.0
62	66.5	65.8	65.3	64.8	64.3	63.9	63.5	63.2	63.1	62.9	62.7	62.5	62.4	62.3	62.2	62.2	62.1	62.1	62.1	62.0	62.0
63	67.6	66.9	66.4	65.8	65.3	64.9	64.5	64.2	64.1	63.9	63.7	63.5	63.4	63.3	63.3	63.2	63.1	63.1	63.1	63.0	63.0
64	68.7	67.9	67.4	66.9	66.4	65.9	65.5	65.2	65.1	64.9	64.7	64.5	64.4	64.3	64.3	64.2	64.1	64.1	64.1	64.0	64.0
65	69.7	69.0	68.5	67.9	67.4	66.9	66.5	66.3	66.1	65.9	65.7	65.5	65.4	65.3	65.3	65.2	65.1	65.1	65.1	65.0	65.0
66	70.8	70.1	69.5	69.0	68.5	68.0	67.6	67.3	67.1	66.9	66.7	66.5	66.4	66.3	66.3	66.2	66.1	66.1	66.1	66.0	66.0
67	71.9	71.1	70.6	70.0	69.5	69.0	68.6	68.3	68.2	68.0	67.7	67.5	67.4	67.3	67.3	67.2	67.1	67.1	67.1	67.0	67.0
68	73.0	72.2	71.7	71.1	70.5	70.0	69.6	69.3	69.2	69.0	68.8	68.6	68.4	68.3	68.3	68.2	68.1	68.1	68.1	68.0	68.0
69	74.0	73.2	72.7	72.1	71.6	71.1	70.6	70.3	70.2	70.0	69.8	69.6	69.4	69.3	69.3	69.2	69.1	69.1	69.1	69.0	69.0
70		74.3	73.8	73.1	72.6	72.1	71.6	71.4	71.2	71.0	70.8	70.6	70.4	70.4	70.3	70.2	70.1	70.1	70.1	70.0	70.0
71			74.8	74.2	73.7	73.1	72.7	72.4	72.2	72.0	71.8	71.6	71.4	71.4	71.3	71.2	71.1	71.1	71.1	71.0	71.0
72					74.7	74.2	73.7	73.4	73.3	73.0	72.8	72.6	72.4	72.4	72.3	72.2	72.1	72.1	72.1	72.0	72.0
73								74.7	74.4	74.3	74.0	73.8	73.6	73.4	73.3	73.2	73.1	73.1	73.1	73.0	73.0
74											74.8	74.6	74.4	74.4	74.3	74.2	74.1	74.1	74.1	74.0	74.0

ards for hands, with the expectation that they will be used in conjunction with these standards. They have not been tested for readings made from other areas of the skeleton, or other methods of assessing degree of skeletal maturing. Such usage might yield less accurate predictions.*

(c) Also, there is some inaccuracy in measurements of height. Both diurnal variations in stature, and careless measuring techniques, could account for some of the error in prediction.

Aside from these technical factors, we must consider the variations in children's developmental processes. Patterns of growth may be influenced to some extent by illnesses, accidents, changes in diet, or certain hormone imbalances. For these reasons one must, in clinical practice, assess every prediction of future growth against the background of all available knowledge about the particular child and his own growth history.⁸

In setting up the tables it has been necessary to take into consideration the differences in growth rates of accelerated and retarded children. In general, there is a relationship between the intensities of maturation and growth. Children who are accelerated in physical maturity tend to grow with exceptional vigor, and children who are retarded in their maturation tend to grow in a more subdued manner than the average. As a result, the accelerated child, though he has achieved a greater PMH than the average child his age, will have achieved less than

the average for his skeletal age. Conversely, the retarded child, though behind his age peers, will be closer to his eventual height than the average for his degree of skeletal maturity. In other words, the younger the child for a given SA the more chance he has for further growth.

The supplementary tables take care of the differences in growth rate for the ages where the predictions will be affected. For example, at 10 years the average girl has completed 86.2 per cent of her eventual height; but the accelerated 8½-year-old with an SA of 10 years has completed 82.8 per cent, and the retarded 12-year-old with an SA of 10 years has achieved 87.4 per cent of her adult stature. The percentages for these deviant cases may be compared with the normal expectancy for their chronological ages: 81.0 per cent at 8½ and 92.2 per cent at 12. Even these supplementary tables may not be adequate for the more extreme deviates. The children who are retarded more than two years will probably reach shorter adult heights, and those who are accelerated more than two years are likely to become taller than the prediction tables indicate.

The need for supplementary tables is probably also related to the fact that the development of the skeleton is only one part of the process of physical maturation, and is not perfectly correlated with the other parts. Those children selected as most retarded (or advanced) in one area are likely to be somewhat nearer the average in the other areas. Therefore, a fair proportion of the children selected as skeletally deviant can be expected to have a *general* physical maturity age which

*The accuracy of determination of skeletal age, and hence of prediction, should however be increased by the inclusion of additional areas of the skeleton, if the skeletal ages for these other areas were derived in the same manner as the hands (Bayley,⁴ Simmons⁷).

TABLE IV. MEANS AND STANDARD DEVIATIONS OF THE ERRORS IN PREDICTION OF HEIGHT FOR TWO GROUPS OF GIRLS

AGE IN YEARS AND MONTHS	STANDARDIZATION SAMPLE*			VALIDATING SAMPLE†		
	NO. OF CASES	MEAN	S.D.	NO. OF CASES	MEAN	S.D.
8-0	20	-.12	1.18	20	-.86	1.73
8-6	34	+.12	1.09			
9-0	47	-.09	1.13	20	-.65	1.46
9-6	56	-.11	1.10	20	-.58	1.33
10-0	65	-.01	1.15	22	-.49	1.37
10-6	74	+.09	1.16	21	-.37	1.20
11-0	77	+.10	1.09	21	-.36	1.15
11-6	76	+.21	.97	21	-.22	.94
12-0	79	+.18	.92	21	-.13	1.06
12-6	75	+.07	.89	21	-.09	.78
13-0	78	+.01	.72	18	-.21	.62
13-6	77	-.03	.55	18	-.15	.55
14-0	77	-.03	.48	18	+.10	.42
14-6	71	-.02	.37	19	+.001	.40
15-0	72	+.03	.29	19	+.08	.38
15-6	58	-.03	.26	21	+.04	.32
16-0	63	-.02	.24	21	-.02	.26
16-6	59	-.02	.02	16	-.07	.25
17-0	63	-.02	.02	18	+.02	.20
17-6	46	-.02	.01	10	-.08	.22
18-0				11	-.05	.11

*The Guidance Study.

†The Berkeley Growth Study.

TABLE V. MEANS AND STANDARD DEVIATIONS OF THE ERRORS IN PREDICTION OF HEIGHT FOR TWO GROUPS OF BOYS

AGE IN YEARS AND MONTHS	STANDARDIZATION SAMPLE*			VALIDATING SAMPLE†		
	NO. OF CASES	MEAN	S.D.	NO. OF CASES	MEAN	S.D.
8-0	15	+.05	1.62	21	-.13	1.47
8-6	26	+.17	1.84			
9-0	36	-.24	2.10	20	+.02	1.27
9-6	43	+.14	1.89	20	-.41	1.13
10-0	53	+.20	1.45	20	+.002	1.33
10-6	56	+.01	1.49	21	+.06	1.11
11-0	57	+.01	1.98	22	-.04	1.14
11-6	52	+.01	1.41	22	-.12	1.15
12-0	54	+.07	1.49	19	+.16	1.09
12-6	52	-.05	1.45	20	+.23	1.09
13-0	54	-.11	1.79	22	+.01	1.21
13-6	53	-.18	1.14	20	+.05	1.32
14-0	52	-.04	1.06	20	+.13	1.21
14-6	50	+.03	.91	20	-.23	.85
15-0	52	+.01	.59	20	+.03	.88
15-6	47	+.02	.46	21	+.07	.65
16-0	44	+.01	.28	22	+.01	.49
16-6	45	+.02	.29	18	+.12	.35
17-0	44	+.02	.26	20	+.19	.41
17-6	33	-.05	.21	20	+.14	.30
18-0				16	+.14	.38

*The Guidance Study.

†The Berkeley Growth Study.

is nearer the norm than is their SA. Whatever the reason, we find as a matter of practice, that accuracy of prediction is increased by use of the supplementary tables.

Tables IV and V give the actual error in prediction found for two groups of normal Berkeley, Calif., children. These predictions are based on Greulich-Pyle skeletal ages and the

single x-ray and height measurement made before 12 or 14 years. After these ages the error in prediction on single x-rays is rapidly reduced to less than half an inch for the majority of children. This is illustrated in Fig. 2 for one normal boy. His growth in height has been plotted in two ways, by his chronological age (solid line) and by his SA (broken line). He is

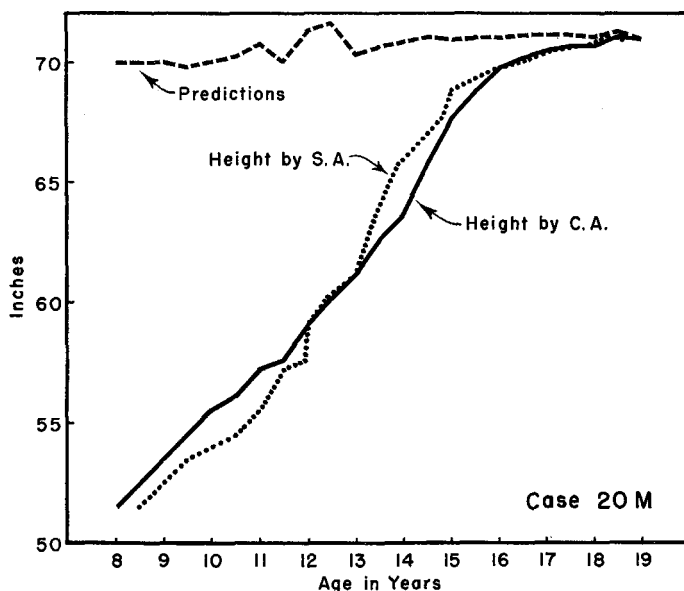


Fig. 2.—The growth record of one boy. Height is plotted by chronological age (solid line) and by skeletal age (dotted line). Successive predictions of adult height are shown in the broken line.

percentages given in the appropriate prediction tables. The data from the larger sample were used in constructing the tables, and therefore the mean error for this group should be very small. The smaller Berkeley Growth Study group forms an independent validating sample. Through 12 years in the girls, and 14 years in the boys, the standard deviations are approximately one inch or a little larger. That is, about two-thirds of the children grew to a height which varied an inch or less from the prediction made on a

slightly accelerated in skeletal maturity before 11 years, and slightly retarded for a period after 13 years. The heights predicted at each age are shown in the almost horizontal line across the top. The early estimates for this boy are a little short, and there is some fluctuation between 9 and 14 years, but after 14 the predictions become very stable and accurate.

In practice the accuracy of estimates on a given child can be greatly increased by taking repeated x-rays over a period of time. The *trends* of the

child's growth can then be evaluated in the light of other knowledge about him.

In general, the accuracy of prediction from the new tables for Greulich-Pyle SA's compares favorably with the prediction tables for the Todd SA's published in 1946.¹

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