Relationship of Skinfolds and Muscle Size to Growth of Children

I. COSTA RICA

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ABSTRACT The relationships between triceps skinfolds and stature and between upper arm muscle size and stature were studied on 874 pairs matched for age derived from a cross-sectional sample of 2,445 Costa Rican rural subjects, aged 0 to 20 years. The results indicate that fatter children for their age, on the average, are not taller than their leaner counterparts. On the other hand, more muscular children, on the average, are taller than their less muscular counterparts of the same age.

Studies on human growth and nutrition have, in recent years, utilized anthropometric measurements to determine fatness and muscularity of children. Although the general development of both subcutaneous fat and muscle is well known, remarkably little information is available concerning the relationship of fatness and muscularity to growth of children, especially children of underdeveloped countries. Clearly, such information is crucial in evaluating the effectiveness of measurements of skinfold thickness and muscularity in the assessments of growth and nutritional status of children in underdeveloped countries. Therefore, the purpose of this investigation is to determine whether increased fatness and muscularity are associated with stature differences during the growing period of Costa Rican rural children.

MATERIAL AND METHODS

Sample and statistical analyses

This study is based upon a cross-sectional sample of 2,445 subjects, aged 0 to 20 years, from the rural areas of Costa Rica. These subjects were participants in a 1966 nutritional survey of Costa Rica that originally included both rural and urban subjects (Evaluacion Nutritional de la Poblacion de Centro America y Panama, Costa Rica, INCAP, '69). However, the present study is limited to subjects only from the rural communities of Costa Rica.

The following hypotheses were considered: (1) Fatter children are taller for their age than their leaner counterparts, (2) more muscular children are taller for their age than their less muscular counterparts, and (3) taller children are not necessarily more muscular than their shorter counterparts. The statistical analyses consisted of four steps. First, using the total cross-sectional sample of 2,445 subjects from Costa Rica sex and age-specific percentiles for triceps skinfolds, upper arm muscle diameter and stature were established at three-month intervals from 0.0 to 1.9 years (i.e., 0.0–0.24; 0.25–0.49, etc.), six-month intervals from 2.0–4.9 years (i.e., 2.0–2.49, etc.), and one-year intervals from 5 to 20 years (i.e., 5.0–5.9; 6.0–6.9, etc.). Second, those individuals who were above the eighty-fifth and below the fifteenth percentile limits for triceps skinfolds, upper arm muscle diameter, and stature were separated. Third, the fattest (above 85th percentile) and leanest (below 15th percentile) subjects were matched for age to the nearest 0.08 year for children under five years and 0.50 year thereafter. In the same manner, the more muscular (above the 85th percentile) and less muscular (below the 15th percentile) were matched for age. In addition,

the taller (above the 85th percentile) and shorter (below 15th percentile) were matched for age. In this way, a total of 874 age-matched pairs were selected. Of these, 329 pairs consisted of the fatter and leaner children, 317 pairs consisted of the more muscular and less muscular children, and 228 pairs consisted of the taller and shorter children. Fourth, these individual matched pairs were then grouped into seven three-year age groups (i.e., 0.0–2.9; 3.0–5.9; 6.0–8.9) covering the entire range of 0 to 20 years (see tables 1 and 2). The significance of differences in stature between the more fat and less fat, more muscular and less muscular groups and the significance of the difference in muscle size between the taller and shorter children were tested by "t" tests for matched pairs (Snedecor and Cochran, '67:98).

Furthermore, for each individual matched pair, Z-scores involving differences in stature between more muscular and less muscular children, and differences in muscle size between the taller and shorter children were calculated. In this manner, absolute differences between the parameters of size (stature) and muscle diameter were reduced to equivalent values. The Z-scores were calculated using the previously developed sex and age-specific percentile limits of muscle diameter and stature of Costa Rican rural children.

Measurements

Standard anthropometric measurements included stature, upper arm circumference and triceps skinfold. Stature was recorded to the 0.1 cm. Upper arm circumference in centimeters was measured with a flexible tape midway between the acromion and olecranon processes with the arm hanging freely. Skinfold thickness in millimeters at the triceps was measured with a Lange skinfold caliper having a pressure of 10 gm per square millimeter of contact surface area. The upper arm muscle diameter (UAMD) was derived from upper arm circumference and triceps skinfolds by computation (Brožek, '61; McFie and Welbourn, '62) as follows:

$$\text{UAMD} = \frac{C}{\pi} - S$$

where: UAMD, upper arm muscle diameter in millimeters; C, circumference of the upper arm; S, triceps skinfolds.

TABLE 1

Evidence that fatter Costa Rican children are not significantly taller than their leaner counterparts

Age group	No. pairs	Stature of children		t
		High in Fat [1]	Low in Fat [2]	
		cm	*cm*	
		Males		
0.0– 2.9	29	78.7	80.1	0.66
3.0– 5.9	32	90.0	99.8	0.92
6.0– 8.9	26	114.2	115.8	0.86
9.0–11.9	28	133.3	131.2	1.00
12.0–14.9	26	143.9	142.2	0.66
15.0–17.9	12	160.5	161.7	0.39
18.0–20.9	8	166.2	162.8	1.16
		Females		
0.0– 2.9	26	78.1	75.9	0.92
3.0– 5.9	30	97.7	97.8	0.08
6.0– 8.9	27	117.7	114.8	1.57
9.0–11.9	29	133.5	128.8	2.35 [3]
12.0–14.9	26	147.1	144.5	1.04
15.0–17.9	16	152.1	151.4	0.30
18.0–20.9	14	154.9	153.3	0.75

[1] High in fat, children whose triceps skinfold is above the eighty-fifth percentile of Costa Rican skinfolds.

[2] Low in fat, children whose triceps skinfold is below the fifteenth percentile of Costa Rican skinfolds.

[3] $p < 0.05$.

TABLE 2

Evidence that more muscular children are significantly taller than their less muscular counterparts

Age group	No. pairs	Stature of children		Difference (Z-score)	t	No. pairs	Muscle of children		Difference (Z-score)	t
		High in muscle [1]	Low in muscle [2]				Taller [3]	Shorter [4]		
		cm	*cm*				*mm*	*mm*		
					Males					
0.0– 2.9	24	80.8	76.6	1.14	2.68 [5]	8	38.5	36.6	0.64	0.81
3.0– 5.9	29	102.4	95.1	1.35	3.78 [5]	13	43.5	38.2	0.84	5.55 [5]
6.0– 8.9	30	118.8	109.9	1.62	5.75 [5]	24	47.7	41.4	0.85	7.65 [5]
9.0–11.9	28	135.2	124.1	1.66	6.54 [5]	22	55.9	46.7	1.11	6.90 [5]
12.0–14.9	25	152.8	134.1	2.20	8.07 [5]	25	61.0	50.6	1.84	6.47 [5]
15.0–17.9	13	166.7	148.9	2.25	5.85 [5]	10	73.3	60.3	1.93	4.21 [5]
18.0–20.9	8	162.9	159.0	0.56	1.01	8	72.6	69.6	0.44	0.71
					Females					
0.0– 2.9	24	79.7	72.6	1.70	2.83 [5]	11	40.0	37.0	2.25	2.05
3.0– 5.9	30	102.4	92.1	1.84	5.01 [5]	10	44.6	37.4	2.01	4.56 [5]
6.0– 8.9	30	119.3	112.9	1.32	3.13 [5]	20	47.5	43.1	1.24	3.51 [5]
9.0–11.9	30	135.3	124.2	1.64	4.83 [5]	33	51.8	45.6	1.52	6.08 [5]
12.0–14.9	21	151.4	138.1	1.88	5.16 [5]	21	58.2	49.4	1.79	5.50 [5]
15.0–17.9	13	153.8	151.4	0.40	1.04	11	61.3	56.5	0.92	2.31 [6]
18.0–20.9	12	157.3	153.1	0.72	1.65	12	66.2	60.0	1.00	2.48 [6]

[1] High in muscle, children whose upper arm muscle diameter is above the eighty-fifth percentile for muscle.
[2] Low in muscle, children whose upper arm muscle diameter is below the fifteenth percentile for muscle.
[3] Taller, children whose stature is above the eighty-fifth percentile for stature of Costa Rica.
[4] Shorter, children whose stature is below the fifteenth percentile for stature of Costa Rica.
[5] $p < 0.01$. [6] $p < 0.05$.

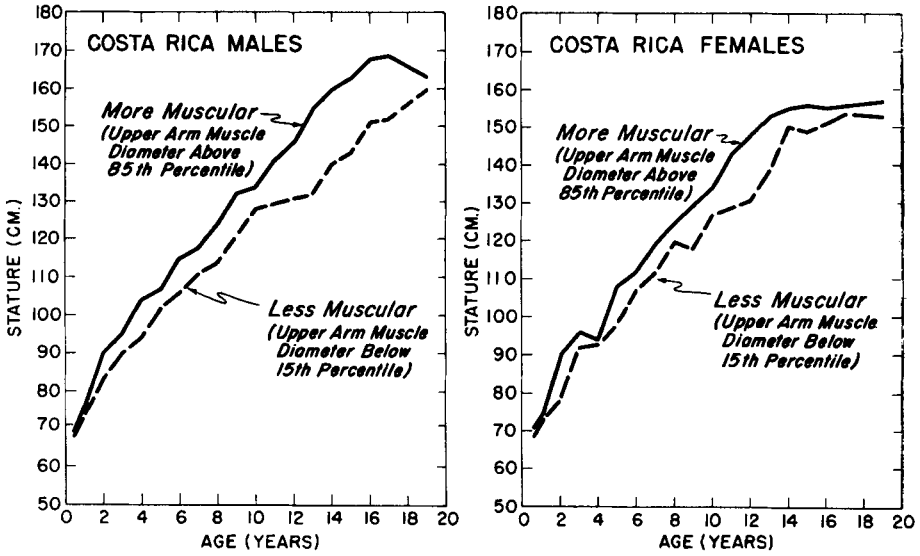

Fig. 1 Growth in stature of more muscular and less muscular Costa Rican rural children. In both sexes, more muscular children, especially during adolescence, are systematically taller than their counterparts with less muscle (see text and table 2).

RESULTS

As shown in table 1, where the statures of Costa Rican rural children with triceps skinfolds above the eighty-fifth percentile and below the fifteenth percentile are compared, increased fatness is not significantly associated with greater stature. Of the 14 "t" valves involving differences in stature, 13 are not significant.

Table 2 gives the statures of the children whose upper arm muscle diameter is above the eighty-fifth percentile matched for age to their counterparts whose upper arm muscle diameter is below the fifteenth percentile. This table also compares the mean muscle diameter of taller children (stature above the 85th percentile) and shorter children (stature below the 15th percentile). From this information and as shown by the "t" valves, it can be seen that between 0 to 18 years in males and 0 to 14 years in females, increased muscularity is significantly associated with greater stature. More muscular children are systematically taller than their less muscular counterparts in both sexes as illustrated in figure 1. Although taller children also exhibit greater muscle size than their counterparts, the Z-scores in males indicate that during infancy (0.0–2.9 years) and adolescence (12.0–20.9 years), the difference in stature between the more muscular and less muscular is relatively greater than the difference in muscle size between the taller and shorter children. In females, the Z-scores for the difference in stature are greater than the Z-scores for muscle size during childhood and adolescence (6.0–14.9). During the sex and age intervals indicated, stature is more dependent upon muscle size than muscle size is dependent upon stature.

DISCUSSION

Because increased fat content (or skinfold thickness) resulting from either high calorie intake or low energy expenditures, reflects a greater calorie reserve, one would expect that fatter children, for their age, are both taller and developmentally more advanced than average children. Indeed, clinical studies indicate that obese children are taller and more advanced in maturity (Talbot, '45; Fry, '53; Peckos, '53; Quaade, '55; Wolff, '55; Lloyd, Wolff and Whelen, '61). Similarly, investigations of skinfold thickness demonstrated conclusively that increased fat storage is associated with advanced somatic development during childhood and adolescence (Rey-

nolds, '46, '50; Garn and Haskell, '59, '60). These generalizations are also supported by numerous animal experiments indicating that over-nutrition speeds maturation and dimensional growth (Hammond, '54). Yet, in Costa Rican rural children, triceps skinfolds thickness and stature are not significantly associated, either during infancy, childhood, or adolescence. At all ages, fatter children on the average are only slightly, but not significantly, taller than their less fat counterparts. The same results were found when using the subscapular skinfolds. Thus, the lack of relationship between fat and growth is not due to differences in fat distribution.

In evaluating these findings, it must be noted that Costa Rican children do not reach the degree of fatness seen in American or British children (Evaluacion Nutricional de la Poblacion de Centro America y Panama, INCAP, '69). Thus, it is quite possible that the degree of fatness of Costa Rican children is not large enough to be reflected in growth differences. In order to test this hypothesis, we have selected the children with triceps skinfolds above the ninety-fifth percentile and matched them for age with their counterparts below the fifth percentile. As shown in table 3, children with triceps skinfolds above the ninety-fifth percentile are significantly taller than their counterparts with triceps skinfolds below the 5th percentile. Thus, among Costa Rican rural children, fat folds are significantly associated with size (stature) at the extremes of the distribution. In other words, the relationship between fat thickness and growth in Costa Rican rural children is not necessarily linear.

It is evident from these extensive findings on cross-sectional samples of boys and girls from Costa Rica that muscle size and stature are significantly related during childhood and adolescence. More muscular children (through the 18th year in boys and 15th year in girls) proved to be taller as well. Various studies have demonstrated that mesomorphic children, during childhood and adolescence, are more advanced in growth and maturation than ectomorphic or endomorphic ones (Dupertuis and Michael, '53; Acheson and Dupertuis, '57; Tanner, '62). Since the major component of mesomorphy, as usually conceived, is muscle size, it is quite possible the greater stature of the more muscular children is due to nutritional factors.

Experimental and clinical studies have shown that the decrease in muscle mass, determined either through creatinine output or limb measurements, during malnutrition exhibit a greater reduction than body weight (Waterlow and Mendes, '57; Standard, Wills and Waterlow, '59). This reduction in muscle size occurs as a compensatory mechanism to provide amino acids for gluconeogenesis and protein synthesis in the liver (Arroyave and Castellanos, '61). These indications would suggest that the relationship between greater muscularity and size superiority during growth of Costa Rican rural children is

TABLE 3

Evidence that fatter Costa Rican children are significantly taller than their leaner counterparts

Age group	No. pairs	Stature of children		t
		High in fat [1]	Low in fat [2]	
		cm	*cm*	
		Males		
1.0– 9.9	17	105.1	100.5	2.31 [3]
10.0–18.9	22	147.1	138.7	5.86 [4]
		Females		
1.0– 9.9	21	109.1	104.2	2.98 [4]
10.0–18.9	14	146.4	132.5	7.82 [4]

[1] High in fat, children whose triceps skinfolds is above the ninety-fifth percentile for skinfolds of Costa Rican children.
[2] Low in fat, children whose triceps skinfolds is below the fifth percentile for skinfolds of Costa Rican children.
[3] $p < 0.05$. [4] $p < 0.01$.

related to nutritional factors. The implication of these findings is that measurements of muscularity in children of underdeveloped countries can serve as a general index of nutritional status and growth in size.

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