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Effects of Hb types and G-6-PD deficiency on height, weight and skinfolds: a study on Indian population*

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With 13 tables in the text

Summary: In this paper the effect of age, Hb types and G-6-PD deficiency on height, weight and skinfold thickness among 1720 subjects belonging to Nava-Budha, Maratha and a mixed Scheduled caste of Maharashtra, India, have been examined using two models of analysis of variance. In the first model the factors used for explaining the variation are communities, age, sex, Hb types based on the total sample. In the second model another factor, G-6-PD deficiency, was introduced and only the male sample (n = 852) was considered. The age groups (assessed), sex and communities contribute highly significantly to the variation in weight. Variation in communities, age and sex is highly significant for variations in height and the three skinfold measurements. The effect of variation in Hb types is more than random for height and significant for biceps and triceps thicknesses. G-6-PD deficiency causes significant variation in height and the three skinfold measurements.

Zusammenfassung: An 1720 Individuen der Nava-Budha, Maratha sowie einer gemischten scheduled caste-Gruppe aus Maharashtra, Indien, wurden die Effekte von Alter, Hb-Typen und G-6-PD-Mangel auf Körperhöhe, Körpergewicht und Hautfaltendicke untersucht. Dabei wurden zwei Modelle zur Varianzanalyse verwendet. Im ersten Modell wurden die Faktoren Communities (Sozialgruppen), Alter, Geschlecht und Hb-Typen zur Erklärung der beobachteten Merkmalsvariabilitäten (im Gesamtmaterial) berücksichtigt. Im zweiten Modell, welches nur die männliche Stichprobe (n = 852) umfaßt, wurde auch der G-6-PD-Mangel einbezogen. Für die Variabilität des Körpergewichts spielen Alter, Geschlecht und Communities (Sozialgruppen) eine entscheidende Rolle, desgleichen für die von Körperhöhe und Hautfaltendicken. Die Hb-Typen haben einen nur geringen Einfluß auf die Körperhöhe, dagegen einen statistisch signifikanten für die Dicke von Bizeps- und Trizepshautfalten. G-6-PD-Mangel bewirkt signifikante Variationen sowohl bezüglich der Körperhöhe als auch der drei Hautfalten (Bizeps, Trizeps und Subscapularfalte).

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Introduction

The effects of various components of environment viz., climate, nutrition, disease etc. on human growth and development continue to receive considerable attention, and the effects of several of the environmental components are fairly well understood (Ito 1942; Whitacare & Grimes 1959; Levine 1953; Wilson & Sutherland 1953; Greulich 1957; Ranocha 1972; Raghavan et al. 1971; Roberts 1960; Rothhammer et al. 1972; Stini 1969; Prokopec 1977; Mueller & Titcomb 1977; Rao & Sastry 1977; Pachauri et al. 1971). In contrast, the effects of biochemical genetic markers, in particular sickle-cell anaemia (Hb SS), sickle-cell trait (Hb AS) and G-6-PD deficiency on the physique of an individual through the relative immunity to malaria that has been postulated are yet to be fully explored and understood.

A few attempts have, however, been made to examine the effects of abnormal haemoglobins on the growth and development of children. Of the available studies, a majority of them deal with sickle-cell anaemia. The results of the previous studies are briefly given below:

(1) Children with SS have been found to be shorter, of lighter weight, and generally thinner body build than normal (AA) children (Ashcroft et al. 1972; Gross 1971; Jimenz et al. 1966; McCormack et al. 1975; Scott et al. 1966; Whitten 1961).

(2) Studies of adults with SS have yielded somewhat different results: they were found to be of average or above average height, longer legged, shorter in sitting height, and thinner than the comparable controls (Ashcroft et al. 1969; Ashcroft & Serjeant 1972; Serjeant et al. 1968). Whitten (1961) observed a delay in skeletal maturation in early adolescence in SS. Ashcroft et al. (1972) showed further that the average height of younger SS subjects was relatively shorter than controls, but notably this was not observed in more aged subjects.

(3) Studies of growth of children with AS genotype have been rather few. Ashcroft et al. (1969) suggest that the Jamaican adults with AS had both normal heights and weights compared with the controls. Katz et al. (1974) indicated significant differences in the regression equations for log 10 weights vs. height relationships between normal and AS male adolescents. McCormack et al. (1975) observed statistically significant differences in several anthropometric measures on American Black children with AS. McCormack et al. (1976) further observed that the AS male children showed decreased biacromial breadth and the female children (AS) showed decreased values on all measures except sitting height and triceps skinfold thickness.

(4) Roberts (1960) studied male and female Yoruba and Yaba children from Africa and observed no effect of haemoglobin type on mean log weight or mean height, nor on the regression of log weight on height, height on age, and log weight on age.

(5) Hiernaux (1979) examined 1079 male adult Zairians (212 sicklers and 867 nonsicklers) and found that the two groups did not differ in their variances, and that the sicklers had a higher mean for seven measures, but significantly so for head breadth only.

Thus, while at least a few studies are available on the growth status of sicklers and nonsicklers, to our knowledge the effect of G-6-PD on the physique is yet to be explored.

Surveying literature on this subject it is evident that no attempt has as yet been made to examine the effect of haemoglobin types and G-6-PD deficiency among the Indian populations despite the fact that a very high incidence of HbS and G-6-PD deficiency has been reported among several tribal groups and some scheduled castes of Central, Western and Southern India: the incidence of HbS among some tribal populations are as follows: 15.53 % in Bhils, 30.43 % in Gamits, 16.10 % in Naikas (Vyas et al. 1962); in Pawras 22.15 %, Katkaris 6.10 % (Kate et al. 1978), etc., while the incidence of G-6-PD is in Gonds 11 % (Kher et al. 1967), in Bhils 7.44 %, in Pawra 3.45 % (Kate et al. 1978).

The purpose of this paper is, therefore, primarily to examine the effect of haemoglobin types mostly AS and G-6-PD deficiency on weight, height and skin-fold thickness at three sites – biceps, triceps and sub-scapular among the three social groups of the state of Maharashtra in Western India. In addition the effects of age, sex and social group on physique have also been examined.

Methods and materials

The data which form the subject matter of this paper are the products of a multidisciplinary research project. A total of 1720 persons (887 males and 833 females) belonging to two endogamous castes – Nava-Budha (total 732 persons: 368 males and 364 females) and Maratha (total 656 persons: 361 males and 295 females) – and a mixed social group of Scheduled castes (total 332 persons: 158 males and 174 females) were sampled from a number of villages of three tahsil, one each, of three districts: Murbad tahsil in Thana district, Washim tahsil in Akola district and Nagpur tahsil in Nagpur district (Table 1). A multi-stage stratified sampling design was used to generate the data (Mukherjee et al. 1980). The ages (mostly assessed) of the surveyed persons have been classified in 5 age-group classes.

Subjects were measured wearing light clothing, but shoes were removed. Stature was measured using an anthropometer with the subject standing erect with heels together. Weight was measured on a portable weighing machine. Skinfolds were measured using Lange skinfold caliper; the land marks used were those recommended by Weiner & Lourie (1969). The red cell G-6-PD deficiency was determined by Brilliant crysel blue dye decolourization test of Motulsky & Kraut (1961). The haemoglobin variants were detected using electrophoresis on cellulose acetate membrane after Kate et al. (1976). All those samples with electrophoretic bands additional to normal ones were further subjected to electrophoresis with known control haemoglobin sample, in addition to alkaline denaturation and sickling tests.

The analysis is aimed at explaining variations of each of the five measures, viz. height, log weight, log skinfold thickness at biceps, triceps and sub-scapular by social

Table 1. The sample and its distribution in various age groups.

Social groups	Sex	Sample size	Age groups				
			1	2	3	4	5
1. Nava-Budha	M	368	13	77	97	94	87
	F	364	37	107	115	66	39
	T	732	50	184	212	160	126
2. Marathas	M	361	9	61	109	86	96
	F	295	22	97	82	63	31
	T	656	31	158	191	149	127
3. Scheduled castes (mixed)	M	158	7	39	51	37	24
	F	174	22	63	50	20	19
	T	332	29	102	101	57	43
All social groups	M	887	29	177	257	217	207
	F	833	81	267	247	149	89
	T	1720	110	444	504	366	296

M = male; F = female; and T = males plus females.
1 = upto 21, 2 = 22 to 31, 3 = 32 to 41, 4 = 42 to 51, 5 = above 51.

groups, age groups, sex, haemoglobin types and G-6-PD status. In the analysis of variance models the total variation is divided into components explained by the individual factors (main effects) or combination of factors (interactions), whereas the unexplained part of the total variation attributed to sampling error.

In the present study, however, due to unequal number of observations within cells, which is expected in this type of studies, the variation explained by the factors or their interactions are overlapping. In view of this, we have adopted a conservative approach and looked into each factor individually. For each factor, the total variation is divided into two components, one explained by the factor and the remaining treated as error (actual error is, of course, smaller). Then it is examined whether the explained variation is significant compared to the error. If a factor is observed to affect variation significantly, then its effect will remain significant even when adjustments, as stated earlier, are made. However, if a factor does not affect variation significantly, it may turn out to be significant after adjustments; our approach is thus conservative in this sense.

Results

Out of 1720 sample screened for abnormal haemoglobin a total of 132 (7.68 %) individuals (65 males and 67 females) were found to be sicklers. Except 2 individuals with SS genotype and 2 with AD genotype, the rest all were of AS genotype. Wide variation with respect to sicklers is noticed between the social groups: Percentages of males having Hb A+S in Nava-Budha, Maratha and Scheduled castes (mixed) are 15.76, 0.83 and 2.53, respectively, whereas the corresponding figures for the females

Table 2. Analysis of variance (variable) log (weight).

Sources of variations	d.f.	Sum of squares	Mean sum of squares	Mean error sum of squares	F ratio
Social groups	2	.1174	.0587	.0193	3.34 (.95–.99)
Age group	4	.3489	.0872	.0191	4.57 (>.995)
Hb-type	1	.0066	.0066	.0194	–
G-6-PD	1	.0234	.0234	.0194	–
Total	851	16.5117			

Table 3. Analysis of variance (variable) log (weight).

Sources of variations	d.f.	Sum of squares	Mean sum of squares	Mean error sum of squares	F ratio
Social groups	2	.1406	.0703	.0331	2.12 (.75–.9)
Age group	4	.0977	.0244	.0331	–
Sex	1	10.2422	10.2422	.0272	376.6 (>.995)
Hb-type	1	.0244	.0244	.0331	–
Total	1719	56.9250			

are 15.11, 2.03 and 3.45. For the three social groups combined figures are respectively 15.44, 1.37 and 30.01, whereas, for all males it is 7.33 and for all females 8.04 giving 7.68 for overall populations. A total of 852 males were tested for G-6-PD deficiency, and 46 of them (5.40 %) were found to be deficient. Nava-Budha, Maratha and Scheduled caste (mixed) show 5.35 %, 6.43 % and 2.23 % G-6-PD deficiency, respectively. It is noteworthy that there were 5 males who were both sicklers and deficient for G-6-PD. For want of space we have not presented here the mean values and variances of the 5 measures.

We shall now consider each of the 5 measures separately and examine the effect, if any, separately for social groups, age, sex, haemoglobin types and G-6-PD status.

Log weight

It is observed from Tables 2 and 3 that the effect of social groups on weight is highly significant for males whereas it is marginal when both the sexes are included. It seems that social groups do not influence the weight of the females.

The effect of both haemoglobin types and G-6-PD status on log weight is non-significant.

Height

From Tables 4 and 5 it is evident that the effect of social groups and age groups is highly significant both for the male sample as well as for the whole sample. The sex effect is also statistically significant. The effect of G-6-PD status on height is significant, whereas the effect of haemoglobin types is little more than random.

Table 4. Analysis of variance (variable) height.

Sources of variations	d.f.	Sum of squares	Mean sum of squares	Mean error sum of squares	F ratio
Social groups	2	57856	28928	3861	7.49 (>.995)
Age group	4	34560	8640	3902	2.21 (.9–.95)
Hb-type	1	7376	7376	3920	1.88 (.5–.75)
G-6-PD	1	8144	8144	3920	2.08 (.9–.95)
Total	851	3340032			

Table 5. Analysis of variance (variable) height.

Sources of variations	d.f.	Sum of squares	Mean sum of squares	Mean error sum of squares	F ratio
Social groups	2	137216	68608	9789	7.01 (>.995)
Age group	4	98048	24512	9823	2.50 (.95–.975)
Sex	1	5687040	5687040	6553	868 (>.995)
Hb-type	1	11776	11776	9856	1.19 (.5–.75)
Total	1719	16944640			

Biceps skinfold thickness

From Tables 6 and 7 it seems that all factors viz., social groups, age groups, sex, and haemoglobin types, affect significantly biceps skinfold thickness. The effect of social groups and G-6-PD on this measure among the males is also evident; the effect of haemoglobin types is marginal for males.

Table 6. Analysis of variance (variable) log (skinfold 1).

Sources of variations	d.f.	Sum of squares	Mean sum of squares	Mean error sum of squares	F ratio
Social groups	2	2.0201	1.0100	.1463	6.90 (>.995)
Age group	4	.0444	.0111	.1490	–
Hb-type	1	.3169	.3169	.1481	2.14 (.75–.9)
G-6-PD	1	1.2381	1.2381	.1470	8.42 (>.995)
Total	851	126.2234			

Table 7. Analysis of variance (variable) log (skinfold 1).

Sources of variations	d.f.	Sum of squares	Mean sum of squares	Mean error sum of squares	F ratio
Social groups	2	6.0652	3.0326	.2178	13.9 (>.995)
Age group	4	11.1189	2.7797	.2151	12.9 (>.995)
Sex	1	36.5439	36.5439	.2000	183 (>.995)
Hb-type	1	1.0728	1.0728	.2206	4.86 (>.995)
Total	1719	380.0612			

Triceps skinfold thickness

It appears from Tables 8 and 9 that the effect of social groups, age groups, sex and haemoglobin types on this measure, for the whole sample, is highly significant. The effect of social groups and G-6-PD for the male sample is also highly significant, while age groups and haemoglobin types indicate marginal effects.

Table 8. Analysis of variance (variable) log (skinfold 2).

Sources of variations	d.f.	Sum of squares	Mean sum of squares	Mean error sum of squares	F ratio
Social groups	2	.7085	.3542	.1452	2.44 (.9–.95)
Age group	4	.8508	.2127	.1454	1.46 (.75–.9)
Hb-type	1	.3295	.3295	.1455	2.26 (.75–.9)
G-6-PD	1	.4385	.4385	.1454	3.02 (.9–.95)
Total	851	124.0323			

Table 9. Analysis of variance (variable) log (skinfold 2).

Sources of variations	d.f.	Sum of squares	Mean sum of squares	Mean error sum of squares	F ratio
Social groups	2	1.6375	.8187	.2343	3.49 (.9–.95)
Age group	4	13.7778	3.4444	.2275	15.1 (>.995)
Sex	1	83.2786	83.2786	.1866	446 (>.995)
Hb-type	1	.7236	.7236	.2347	3.08 (.9–.95)
Total	1719	403.9414			

Table 10. Analysis of variance (variable) log (skinfold 3).

Sources of variations	d.f.	Sum of squares	Mean sum of squares	Mean error sum of squares	F ratio
Social groups	2	.7405	.3702	.1196	3.10 (.95–.975)
Age group	4	.6238	.1560	.1200	1.30 (.5–.75)
Hb-type	1	.0896	.0896	.1202	–
G-6-PD	1	.3606	.3606	.1199	3.01 (.9–.95)
Total	851	102.2385			

Table 11. Analysis of variance (variable) log (skinfold 3).

Sources of variations	d.f.	Sum of squares	Mean sum of squares	Mean error sum of squares	F ratio
Social groups	2	2.3743	1.1871	.1595	7.44 (>.995)
Age group	4	10.1335	2.5333	.1551	16.33 (>.995)
Sex	1	13.5254	13.5254	.1529	88.45 (>.995)
Hb-type	1	.1082	.1082	.1609	–
Total	1719	276.2109			

Subscapular skinfold thickness

The effects of social groups, age groups and sex are highly significant on this measure for the whole sample (Table 10 and 11). The social groups and G-6-PD status also reveal highly significant effect on the male sample; the effect of age groups is little more than random.

Discussion

The results of analyses presented in the preceding section have been summarized in Table 12. From this table the following three main points emerge which will be discussed in this section: (1) the social groups, sex and age groups contribute highly significantly to the variation in all the five measures considered here; (2) the effect of haemoglobin genotype AS is highly significant on height and skinfold thickness at biceps and triceps; effect on log weight and sub-scapular skinfold thickness are

Table 12. Effect of variables on five anthropometric measures.

Variables	Log weight	Height	Skinfold thickness at		
			biceps	triceps	sub-scapular
1. Social groups	+	+	+	+	+
2. Age group	+	+	+	+	+
3. Sex	+	+	+	+	+
4. Haemoglobin type	–	+	+	+	–
5. G-6-PD	–	+	+	+	+

Note: + indicates significant effect; – does not indicate significant effect.

nonsignificant; and (3) the effect of G-6-PD deficiency is highly significant on all the measures considered except log weight.

The obtained results in (1) above were expected. It is well established that sex and age affect all the five measures considered here. In view of the differential economic status of the three social groups it is also expected that they will depict varying effect on the physique as observed in the present data.

The observations in (2) above disclose that the haemoglobin AS genotype affects height and biceps and triceps skinfold thickness and do not influence log weight and subscapular skinfold thickness and this agrees with some of the previous studies but is at variance with some other studies.

Roberts (1960) found no effect of haemoglobin genotypes (mostly AS and some SS) on the mean log weight or mean height among the male and female Yoruba and Yaba children aged between 6–20 years. McCormack et al. (1976) observed that the AS male children did not differ in body weight, height and triceps skinfold thickness from the normal, while the female AS children differed significantly in body weight and height but not in triceps skinfold thickness. Katz et al. (1974) observed that the male AS adolescent Black American children differed significantly from the normal in height and body weight, while the female AS did not differ in both these measures from the control.

While, as noted above, at least in some of the studies on AS children and adolescents significant differences have been observed in a few anthropometric measures, studies on AS adults, in general, have shown that such individuals have normal height and weight compared with controls (Ashcroft et al. 1969; Hiernaux 1979).

We are not aware of any previous study in which skinfold thickness at biceps and sub-scapular region were considered, and therefore our observations cannot be subjected to any comparative examinations.

Though the children, adolescents and adults with AS genotype show different growth trend compared to corresponding normal subjects of our data, but strictly speaking, they are not comparable with most of the previous studies. In the present study the ages of the subject vary considerably. The distribution of 132 individuals with abnormal haemoglobin types in various age-classes is indicated in Table 13.

Our sample, therefore, does not only differ from earlier studies in terms of age variations of the individuals but also with 128 sicklers (AS) and 2 individuals each with SS and AD genotypes. Some of the differences in this study and previous studies could be because of these differences. Nonetheless the present study clearly brings home that the abnormal haemoglobins do effect growth status.

Table 13. Distribution of abnormal Hb in various age groups.

Sex	Age groups					Total
	below 22	(22–31)	(32–41)	(42–51)	over 51	
Males	4	13	19	15	14	65
Females	7	20	26	10	4	67
Total	11	33	45	25	18	132
%	8.33	25.0	34.09	18.94	13.64	100.00

The results obtained in (3) above show that G-6-PD deficiency has pronounced and significant effect on all the five measures except log weight which is highly noteworthy. Since no previous study is available on this aspect we are unable to confirm our findings. It would be of considerable interest to examine if, like haemoglobin AS persons, G-6-PD also influences the physique of children, adolescents and adults differently.

It may be noted that in the present study we have used a "conservative" analysis of variance model. Thus, irrespective of use of other models the significant effects of different variables on the 5 measures will remain invariably significant, but where nonsignificant effects have been observed they may or may not turn out to be significant.

In conclusion, it may be said that abnormal growth patterning, as indicated by a few measures considered in this study, is associated more strongly with G-6-PD deficiency than haemoglobin type AS. The present findings, therefore, call for a detailed investigation incorporating many more growth indicators of these two genetic markers which are prevalent in a large number of tribal and other groups in India, on various aspects of growth and development.

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References

Ashcroft, M. T., Miall, W. E. & Milner, P., 1969: A comparison between the characteristics of Jamaican adults with normal haemoglobin and those with sickle cell trait. – A. J. Epidemiol. 90, 236–243.

Ashcroft, M. T. & Sergeant, G. R., 1972: Body habitus of Jamaican adults with sickle cell anemia. – South. Med. J. 65, 579–582.

Ashcroft, M. T., Sergeant, G. R. & Desai, P., 1972: Heights, weights, and skeletal age of Jamaican adolescents with sickle cell anemia. – Arch. Dis. Child. 47, 519–524.

Eveleth, P. B. & Tanner, J. M., 1976: World wide variation in Human Growth. – Cambridge Univ. Press, Cambridge.

Greulich, W. W., 1957: A comparison of the physical growth and development of American born and native Japanese children. – Amer. J. Phys. Anthrop. **15**, 489.
Gross, S. & Godel, J., 1971: Comparative studies of height and weight as a blood volume reference standard in normal children and children with sickle cell anemia. – Amer. J. Clin. Path. **55**, 662–670.
Hiernaux, J., 1979: Anthropometric differences between sicklers and nonsicklers in Zairian adults. – Hum. Hered. **29**, 95–99.
Ito, P. K., 1942: Comparative biometrical study of physique of Japanese Women born and reared under different environments. – Hum. Biol. **14**, 279–351.
Jimenz, C., Scott, R., Henry, W., Sampson, C. & Ferguson, A., 1966: Studies in sickle cell anemia. XXVI. The effects of homozygous sickle cell disease on the onset of menarche, pregnancy, fertility, pubescent changes and body growth in Negro subjects. – Amer. J. Dis. Child. **111**, 497–504.
Kate, S. L., Mukherjee, B. N., Malhotra, K. C., Phadke, M. A., Sainani, G. S. & Mutalik, G. S., 1978: Red cell glucose-6-phosphate dehydrogenase deficiency and haemoglobin variants among ten endogamous groups of Maharashtra and West Bengal. – Hum. Genet. **44**, 339–343.
Kate, S. S., Khedkar, V. A. & Mukherjee, B. N., 1976: Cellulose Acetate Membrane Electrophoresis: Simple rapid and inexpensive method for detection of haemoglobin variants. – Indian J. Phys. Anthrop. Hum. Genet. **2**, 123–124.
Katz, S. H., Lubin, B. & Armstrong, D., 1974: Growth of adolescents with sickle cell trait. – Lancet **1**, 814–815.
Kher, M. M., Solanki, B. R., Parande, C. M. & Junnarkar, R. V., 1967: Glucose-6-phosphate dehydrogenase deficiency at Nagpur and in surrounding areas, a survey. – Indian Med. Gaz. **7**, 34–39.
Levine, V. E., 1953: Studies in physiological anthropology. III. The age of onset of menstruation of the Alaska Eskimos. – Amer. J. Phys. Anthrop. **11**, 252.
Manocha, S. L., 1972: Malnutrition and retarded human development. – Charles C. Thomas, Springfield, Illinois.
McCormack, M. K., Dicker, L., Katz, S. H., Cleb, M., McDaniels, J., Humphery, A., Buchert, E. & Lubin, B., 1976: Growth pattern of children with sickle-cell disease. – Hum. Biol. **48**, 429–437.
McCormack, M. K., Scarr-Salapatek, S., Polesky, H., Thompson, W., Katz, S. & Barker, W., 1975: A comparison of the physical and intellectual development of black children with and without sickle cell trait. – Pediatrics **56**, 1021–1025.
Motulsky, A. G. & Campbell Kraut, J. M., 1961: Standardization of Procedure for study of Glucose-6-phosphate dehydrogenase. – WHO, Techn. Series No. 366, p. 35–36, Geneva.
Mueller, W. H. & Titcomb, M., 1977: Genetic and environmental determinants of growth of school-aged children in a rural Colombian population. – Ann. Hum. Biol. **4**, 1–15.
Mukherjee, B. N., Malhotra, K. C., Pakrasi, K. & Kate, S. L., 1980: Inbreeding, village endogamy and marriage distance: spatial, temporal and social variation. – Homo **31**, 21–38.
Pachauri, S., Marwah, S. M. & Rao, N. S. N., 1971: A Multifactorial Approach to the study of the factors influencing birth weight in the urban community of New Delhi. – Ind. J. Med. Res. **59**, 1318–1341.
Prokopec, M., 1977: An anthropometric study of the Rembarranga: Comparison with other populations. – J. Hum. Evol. **6**, 371–391.
Raghavan, K. V., Singh, D. & Swaminathan, M. C., 1971: Heights and weights of well nourished Indian Children. – Ind. J. Med. Res. **59**, 648–654.
Rao, D. H. & Sastry, J. G., 1977: Growth Pattern of well to do Indian Adolescents and young adults. – Ind. J. Med. Res. **66**, 950–956.
Roberts, D. F., 1960: Effects of race and climate on human growth as examplified by studies on African children. – In: Tanner, J. M. (ed.), Human Growth, p. 59–72. Oxford Univ. Press, Oxford.
Rothhammer, F. & Spielman, R. S., 1972: Anthropometric variation in the Aymara: genetic, geographic and topographic contributions. – Amer. J. Hum. Genet. **24**, 371–380.
Scott, R. B. & Ferguson, A., 1966: Studies in sickle cell anemia. XXVII. Complications in infants and children in the United States. – Clin. Ped. **5**, 403–409.
Sergeant, G. R., Richards, R., Barbor, P. P. H. & Milner, P. F., 1968: Relatively benign sickle cell anemia in 60 patients aged over 30 in the West Indies. – Brit. Med. J. **3**, 86–91.

Stini, W. A., 1969: Nutritional stress and growth: sex difference in adaptive response. – Amer. J. Phys. Anthrop. **31**, 417–426.

Vyas, G. N., Bhatia, H. M., Sukumaran, P. K., Balakrishnan, V. & Sanghvi, L. D., 1962: Study of blood groups, abnormal haemoglobins and other genetical characters in some tribes of Gujarat. – Amer. J. Phys. Anthrop. **20**, 255–260.

Weiner, J. S. & Lourie, J. A., 1969: Human biology – A guide to field methods. – IBP Handbook No. 9. Blackwell Scient. Publ., Oxford.

Whitten, C. F., 1961: Growth status of children with sickle cell anaemia. – Amer. J. Dis. Child. **102**, 101–110.

Wilson, D. C. & Sutherland, I., 1953: The age of the menarche in the tropics. – Brit. Med. J. **2**, 607–608.

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