Anthropometric Changes Associated with Episodes of Linear Growth Retardation in Rural Guatemalan Children

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ANTHROPOMETRIC CHANGES ASSOCIATED WITH EPISODES OF LINEAR GROWTH RETARDATION IN RURAL GUATEMALAN CHILDREN.

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Summary

Stunting is endemic to poor communities throughout the world. However, its health significance and implications are the subject of much debate. This study sought to further develop our understanding of the natural history of stunting in children up to 3 years. The growth patterns of a sample of rural Guatemalan children were examined to determine the nature and extent of anthropometric changes associated with episodes of linear growth retardation.

Subgroups with different rates of linear growth during the age intervals 9 to 12 (N = 582), 18 to 21 (N = 574), and 30 to 36 mo (N = 541) were contrasted. Small but statistically significant differences were seen in the patterns of changes in body weight. Weight-for-length at the beginning of each interval was consistently associated with the subsequent rate of linear growth. Upper arm muscle and fat areas were uniformly low and not strongly related to linear growth.

It was concluded:

1. The pattern of growth retardation seen was consistent with a model of stunting where the fall in rate of linear growth occurs several months after the periods of lowest weight gain. However, this was only clearly evident during the age range when linear growth retardation was severe (up to 2 years of age), and thus it was an age related phenomenon.
2. Severe episodes of stunting were an outcome of exposure to some insult(s) for a prolonged period preceding and concurrent with the episode.
3. Anthropometric indicators of current nutrition were not good predictors of subsequent rate of linear growth.

Introduction

Stunting (linear growth retardation, low height-for-age) is endemic to poor communities throughout the world. Assessment of the degree of stunting in children has gained widespread use as an indicator of the wellbeing of communities. It is interpreted as a reflection and measure of the long term health and nutritional status of children (Jelliffe, 1966). However, there is some disagreement concerning the extent to which stunting should be regarded as an indicator of malnutrition, as opposed to a successful adaptation to unfavorable circumstances (ACC Sub-committee on Nutrition, 1989).

One approach to addressing this issue is to examine the relationship between stunting and other measures of current undernutrition. Studies of this type have had mixed results. Bagenholm, Nasher & Kristiansson (1990) report that, in Yemini children 0-7 years of age, those stunted had slightly more fat and muscle depletion (and thus current undernutrition) than non-stunted children. In contrast, other workers describe populations where stunting is unrelated to low weight-for-height, suggesting no current undernutrition (Waterlow, 1978), or even where stunting is associated with relatively high weight-for-height (Trowbridge et al, 1987). Some of these inconsistencies may be explained by temporal differences in the response of soft tissues (fat and muscle) to undernutrition and illness relative to that of bone growth.

Brown, Black & Becker (1982) report on seasonal changes in nutritional status of young children in rural Bangladesh in which the fall in expected length-for-age occurred several months after the periods of greatest malnutrition identified by other measurements (weight, arm circumference, skinfolds). Nabarro et al (1988) report that the maximum length gain in a group of Nepalese children occurred 3 months after the period of maximum weight gain. This implies that in cross-sectional studies one could see quite different relationships between stunting and other anthropometric indices of undernutrition, depending on when the measurements were taken. The general applicability of the above results is perhaps limited by the marked seasonality of growth observed.

The study reported here sought to further develop our understanding of the natural history of stunting, the process of becoming stunted. The growth patterns of rural Guatemalan children were examined, a population where stunting is endemic but where seasonality of growth is not marked. The objective was to determine the nature and extent of anthropometric changes associated with episodes of linear growth retardation across the age range when the onset of stunting is most evident, up to 3 years.

Study population and methods

Data were from a longitudinal study of the effects of mild and moderate malnutrition on child growth and development conducted by the Institute of Nutrition of Central America and Panama during the period 1969 to 1977. The study was conducted in four, rural Ladino villages in eastern Guatemala. The population was very poor and children were severely retarded in growth at 7 years of age. A more detailed description of the population and study is given elsewhere (Lechtig et al, 1975; Martorell et al, 1975a).

Anthropometry

Anthropometry was collected at specific ages by well trained and standardized observers. Total body length was measured on a standard measuring table; weight was measured on a beam balance; arm circumference was measured with a flexible steel tape; triceps skinfolds were measured with a Harpenden skinfold caliper. All measurements were made following standard procedures that did not vary during the course of the study (Martorell, Klein & Delgado, 1980). Weight was measured to the nearest 10 gram, supine length, and arm circumference to the nearest millimeter, and skinfolds to the nearest tenth of a millimeter.

The measures used in this analysis were taken every three months (mo) from 3 to 24 mo, at 30 and at 36 mo of age. The anthropometric examinations were performed within set time limits: within 5 days of due date from 3 to 24 mo, and within 7 days of due date for the other two examinations. Measures beyond five standard deviations from the mean were regarded as probably in error and excluded from the analysis (< 0.05% of observations).

Subsamples for this research

Three subsamples of the population were used for this analysis: those with complete serial length measurements in the age intervals 3 to 15 mo, 9 to 24 mo and 18 to 36 mo, referred to as the "9 mo" (N = 582), "18 mo" (N = 574) and "30 mo" (N = 541) subsamples respectively. Three hundred and nineteen children had complete serial length data for the three year age range and were in all three subsamples.

Definition of derived variables.

The rate of linear growth was calculated as the difference in length between two measurements, divided by the length of the interval (in mo) and is expressed in centimeters per month.

WHO reference values were used for calculating Z-scores for weight-for-length (WL):

$$\text{Z-score} = (\text{actual weight} - \text{expected weight}) / SD,$$

where the expected weight and standard deviation (SD) are functions of the length of the child (WHO, 1979).

Body composition was inferred from upper arm anthropometry, as recommended by several authors (Gurney and Jelliffe, 1973; Frisancho, 1981; Heymsfield et al, 1982a,b). Upper arm muscle area (UAMA) and upper arm fat area (UAFA) were derived from measures of mid upper arm circumference (MUAC) and triceps skinfold (TSF) using the following formulae (Frisancho, 1981):

$$UAMA = (MUAC - TSF \times 3.1416) / (4 \times 3.1416)$$

$$UAFA = [(MUAC^2) / (4 \times 3.1416)] - UAMA.$$

Analytic methods

Children were divided into quartiles based on their rates of linear growth (sexes separate). This was done for the age intervals 9 to 12, 18 to 21, and 30 to 36 mo. The quartiles for the age intervals were independent of each other such that an individual child could be in the lowest growth quartile at one age, but in the highest at another age. The analysis was based on comparisons of other anthropometric measures across these quartiles. Differences were tested using analysis of variance (ANOVA). Because of the large number of comparisons made, differences between individual means are reported as statistically significant only if the overall ANOVA was also significant at $p < 0.05$ (Protected Least Significant Difference; Snedecor & Cochran, 1980). Correlation and regression analysis were used to assess the validity of the results. Correlation analysis was based on Pearson's correlation coefficient (r). Regression analysis used Ordinary Least Squares regression.

Measurement reliability (R) was estimated as follows:

$$R = 1 - (S^2_r/s^2)$$

where s^2 is the sample or interindividual variance, and S^2_r is the intrasubject (unreliability) variance based on replicate observations taken on the same individuals at two different times (Marks, Habicht & Mueller, 1989). The estimates of S^2_r used were from previous work in this population (Martorell et al, 1975b; Martorell et al, 1976); s^2 were for the subsamples used in this analyis.

Measurement reliabilities (R_x, R_y) were used to "correct" observed correlations ($r_{x'y}$) for random measurement error. The "corrected" correlation (r_{xy}) was obtained as follows (Habicht, Yarbrough & Martorell, 1979):

$$r_{xy} = r_{x'y} / (R_x \cdot R_y)^{1/2}.$$

The distributions of all variables used as a dependent variable were checked to see how well they approximated a Gaussian distribution. All of the variables were considered to be approximately Gaussian and to meet the assumptions of the statistical methods used.

Results

Characteristics of the study sample

Table 1 describes the mean rate of linear growth in the Guatemalan children by age and sex. If one uses the increments of the WHO reference median (WHO, 1979) as the basis for comparison, linear growth retardation is most marked in the interval 6 to 18 mo (70 - 80% of that implied by the WHO reference). By 36 mo the rate is more similar to that implied by the WHO reference (90 - 95%), but the children are significantly stunted in length with a mean length-for-age that is 88% of the reference median (-2.9 Z).

[TABLE 1]

Anthropometry for the subsamples at 9, 18 and 30 mo is described in Table 2. These values are consistent with, though not identical to those published in previous studies of this population (Yarbrough et al, 1975; Martorell et al, 1976). The notable differences are in the standard deviations for TSF and UAFA, which are about 80% of the earlier values. The differences are due primarily to changes in the characteristics of the population over the course of the study (Marks, 1989). The earlier studies cited describe the project children 1969-73, while the present research also includes data from a project extension (1973-77).

[TABLE 2]

Comparison of upper arm anthropometry with reference values (Frisancho, 1981) shows that the mean MUAC values are very low at each of the three ages (< 5th percentile). Mean UAFA values are well below the 5th percentiles, and mean UAMA values are consistently between the 10th and 25th percentiles, indicating that most of the MUAC differences are in the amount of fat tissue. The standard deviations for the measures are similarly affected. Those for TSF and UAFA are less than half of the values inferred from the reference data (Frisancho, 1981), while UAMA standard deviations are 65% to 85%.

Anthropometry by rate of linear growth

Table 3 describes the anthropometric status of the children at 9 mo, by quartile of linear growth from 9 to 12 mo. In each of the Tables and Figures that follow quartile 1 has the slowest rate of linear growth, and quartile 4 the fastest. The cut-offs for defining the quartiles for 9 to 12 mo growth were at 57%, 76% and 93% percent of the reference rate of growth (as defined above) for males, and at 54%, 72% and 87% for females. For both sexes, mean weight and WL is significantly different across the quartiles, showing a clear trend of higher absolute and relative weight being associated with greater subsequent linear growth. In males, mean UAMA is also significantly different across quartiles with a similar trend of higher values being associated with greater subsequent linear growth.

[TABLE 3]

Anthropometric status at 18 mo, by quartile of linear growth 18 to 21 mo, is given in Table 4. The cut-offs for defining the quartiles were at 55%, 81% and 107% percent of the reference rate for males, and at 54%, 79% and 103% for females. For both sexes, WL is significantly different across quartiles, with a clear trend of higher WL being associated with greater subsequent linear growth. The other significant differences are length and weight in males. The trend in these variables is similar to that above for the lowest three quartiles, but the children of the highest linear growth quartile are shortest and lightest. The apparent contradiction is resolved when one considers weight in terms of the childrens' lengths. Despite their low mean weight, the high growth quartile have the highest mean WL. This is indicative of catch-up growth in this quartile.

[TABLE 4]

Table 5 gives the anthropometric status of the children at 30 mo, by quartile of linear growth 30 to 36 mo. The cutoffs for defining the quartiles were at 81%, 98% and 112% percent of the reference rate of growth for males, and at 79%, 93% and 107% for females. As with both younger age groups there is a trend for greater WL to be associated with greater linear growth, but this is not significantly different across the quartiles. Again the greatest linear growth tends to be in short, light children, but the quartile means are not significantly different.

[TABLE 5]

Individual measures of fatness are not statistically different across quartiles for either sex. A similar result was found using the sum of skinfolds.

Time course of the changes

In Figure 1 the attained length and weight of the children is given over the age range 3 - 15 mo by quartile of linear growth for the interval 9 - 12 mo. Results are presented for males but the patterns in females are very similar. While the plots of attained length diverge only from 9 mo onward, differences in the mean weights of the quartiles are seen before 9 mo. If one compares the mean weight gain for the interval 6 to 9 mo across the quartiles, there are significant differences for the males; and for the interval 9 to 12 mo weight gain is significantly different across quartiles for both sexes.

[FIGURE 1]

Figure 2 gives the growth patterns for males, by quartile of linear growth 18-21 mo. Similar patterns are seen in the females. The changes in attained length of the top growth quartile suggests that this group is undergoing catch-up growth in length. A similar pattern in the attained weights shows that it is not just an artifact of measurement errors in the extreme groups. As with the younger age group, the Figure shows that changes in weight both precede and accompany linear growth changes. The weight increment for the intervals 15 to 18 mo, and 18 to 21 mo are significantly different across quartiles for both sexes.

[FIGURE 2]

Figure 3 gives the growth patterns for males, by quartile of linear growth 30 - 36 mo. In males the mean weight increment from 24 to 30 mo is significantly different across quartiles, while the mean increments from 30 to 36 mo are different in both sexes.

[FIGURE 3]

A similar analysis was conducted for the other anthropometry. Trends in UAMA for males suggest a weak relationship at all ages, but it is non significant. It is significant in females at 9 and 30 mo. UAFA shows a weak, non significant, relationship in both sexes at 9 and 18 mo.

Validity of the results

TSF and MUAC are subject to fairly high levels of random measurement error which could attenuate the observed relationship of linear growth with UAMA and UAFA. This issue was addressed using correlation analysis. Table 6 presents correlations between length increment and other variables across the complete subsamples (that is, not stratified into quartiles of growth). It is noteworthy that none of the correlations are very strong -- the largest being r = .34, and about half of the significant correlations are less than r = .20. The pattern is similar to the results already reported. The magnitude of random measurement error is reflected by measurement reliability. Reliability was estimated to be 0.94-0.98 for linear growth, 0.85 for UAMA and 0.72 for UAFA. Accounting for measurement reliability increased the correlations of linear growth with UAFA by about 20%, and with UAMA by about 10%. These values are not sufficiently different from those reported above to change any conclusions.

[TABLE 6]

The most consistent result of the analysis was the association of linear growth with WL. However, because both are a functions of length (t_o) there is potential for "building-in" a relationship. This was assessed by modelling the relationships using regression analysis with: i) initial length as a covariate; and ii) the residual of weight (t_o) regressed on height (t_o) in place of WL. The regression results were very similar to those obtained with the correlation analysis (Marks, 1989), suggesting that the results are not an artifact.

Discussion

The average rate of linear growth in these children was clearly reduced relative to that seen in developed countries, and is comparable to that of many other developing countries where stunting is endemic (see Waterlow, 1988). But within the population there was a wide range in the rates of linear growth. Across the quartiles the average rates ranged from about 55 to 110 percent of those needed to maintain growth along the WHO reference median. One would expect comparisons across this range and with the sample sizes involved to be capable of identifying important relationships of linear growth with the other variables assessed. Indeed the analyses had a power exceeding 0.90 of detecting differences as small as 1/5 SD on any variable, if they existed (Fleiss, 1986).

Patterns of growth

Comparisons across subgroups with different rates of linear growth showed clear patterns for changes in body weight. Weight-for-length at the beginning of each interval was consistently associated with the subsequent rate of linear growth. Weight gain in the previous 3 mo was also related, showing that weight gain was affected before linear growth, leading to differences in weight-for-length at the start of the interval. This pattern was most evident at 9 and 18 months of age (Figures 1 and 2) when the rates of linear growth are most rapid, and growth retardation most marked. Consequently, for these ages the children's rates of linear growth at any time appear to be affected by factors operating in the previous several months, as well as concurrently. While the pattern is similar at 30 months, the differences across the quartiles are smaller and non-significant. This may be an artifact of the longer time interval used for this subsample, 30-36 months, with weight at 30 months being related to linear growth early in the interval, but becoming more irrelevant to linear growth after a couple of months. However, the extent of linear growth retardation is also less at this age.

The pattern of growth retardation seen in these Guatemalan children is consistent with that seen in Bangladesh (Brown et al, 1982) and Nepal (Nabarro et al, 1988) where the fall in linear growth occurred several months after the periods of lowest weight gain. However, this study goes further and suggests that it is an age related phenomenon, being most evident in the first 2 years of life when the retardation of linear growth is most marked. It is also significant that the pattern is seen in a population that does not have a strong seasonality to their growth.

It is important to note that, even though the patterns relating weight changes to linear growth are fairly clear, the magnitude of the differences between the fastest and slowest growing quartiles is relatively small -- in the order of 0.3 to 0.6 kg of weight, and 0.4 to 0.5 Z weight-for-length. Thus weight and weight gain are not strongly predictive of subsequent linear growth, reflected also in the weak correlations (Table 6).

Changes in body composition

Upper arm indicators of body composition were not strongly related to rate of linear growth in this sample. There was no association between indicators of body fatness and rate of linear growth; and only weak associations of rate of linear growth with UAMA. These changes were most evident in 9 and 18 month old children. Even after correcting for random measurement error, the upper arm anthropometry was not predictive of rate of linear growth. This may be attributable to the limitations of the indicators, as well as the condition of the children.

Heysmfield et al (1979) have pointed out the limitations of these indicators, particularly with malnourished subjects where the measures are biased and changes in body composition difficult to detect. UAFA values for the population were extremely low (well below the 5th percentile of the reference values), and had little variation in the study sample, or across the subgroups. Mean UAMA values were slightly higher relative to reference values, being between the 10th and 25th percentiles, with standard deviations that were only moderately reduced relative to US children. Thus, according to the upper arm anthropometry the children were already severely compromised and from both an analytical (reduced variance) and biological perspective it would be difficult to find major differences between groups. Given this, the results of no association of rate of linear growth with UAFA and the weak association with UAMA are perhaps not surprising. In other populations, where UAFA and UAMA values are more variable, they may be more predictive of rate of linear growth.

Stunting, undernutrition and adaptation

Animal research shows that as one lowers the plane of nutrition (total intake of a mixed diet), the growth of a young animal responds in a predictable way with fat and muscle growth being retarded to a greater extent than bone growth (Palsson, 1955; Kerr et al, 1970; Fleagle, Samonds & Hegsted, 1975). This progression is consistent with what is observed with acute malnutrition in children (Dean, 1965; Garrow, Fletcher & Halliday, 1965) and contributes to the expectation that mild and moderate undernutrition in children may be indicated first by a reduction in weight velocity and altered body composition, followed by reduced length velocity. The results presented support this general model of stunting but with some significant limitations.

The sequence of changes is most evident when the episodes of stunting are most severe, in the range of 50 to 80 percent of expected growth rates, up to about two years of age in this population. However, having low values for mid-upper-arm circumference, muscle or fat areas does not necessarily predict poor linear growth (for example, 30 month children), and having weight-for-length values close to "normal" does not necessarily predict good linear growth (for example, 9 month children). Thus, while we can conclude that there is evidence of current undernutrition preceding and accompanying severe episodes of stunting, one cannot generalise these results to infer that the usual anthropometric indicators of current nutrition (weight-for-age, weight-for-height, upper-arm measures) can successfully be used to distinguish between those who will or will not have an episode of stunting. The sensitivity and specificity of the indicators is likely to be quite low and to vary with age, even across the range 9 to 30 months.

Does this represent successful adaptation to unfavorable circumstances? Successful adaptation implies compromised growth without any cost. This is not addressed directly in the present study as causes and outcomes were not examined. However, the results suggest that severe episodes of stunting are an outcome of prolonged exposure to some insult(s). Thus, the marked linear growth retardation seen in the first two years of life is associated with exposure to undernutrition and/or illness over several months before the episode of stunting. Martorell (1989) has argued that this process of stunting is in itself unhealthy and cannot represent a benign adaptation. Previous studies have largely studied the influence of diet and illness during a particular time interval. The present study extends previous findings to show the time course of these events in stunting and the results demonstrate prolonged exposure to the insult(s) leading to stunting.

Conclusions

1. The pattern of growth retardation seen in these Guatemalan children is consistent with a model of stunting where the fall in rate of linear growth occurs several months after the periods of lowest weight gain. However, this is only clearly evident during the age range when linear growth retardation is severe (up to 2 years of age), and thus it is an age related phenomenon.

2. Severe episodes of stunting are an outcome of exposure to some insult(s) for a prolonged period preceding and concurrent with the episode.

3. Anthropometric indicators of current nutrition are not good predictors of subsequent rate of linear growth.

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Table 1. Rate of linear growth for the study subsamples, by age and sex.

Age Period (mo)	Mean (cm/mo)	Standard Deviation	N
Males			
3-6	1.77	0.47	317
6-9	1.09	0.38	318
9-12	0.94	0.35	317
12-15	0.76	0.37	312
15-18	0.72	0.41	312
18-21	0.74	0.38	311
21-24	0.68	0.35	275
24-30	0.71	0.24	277
30-36	0.67	0.21	277
Females			
3-6	1.75	0.44	262
6-9	1.12	0.41	262
9-12	0.92	0.35	259
12-15	0.79	0.42	257
15-18	0.77	0.43	257
18-21	0.75	0.41	258
21-24	0.69	0.37	218
24-30	0.69	0.23	217
30-36	0.67	0.19	216

Table 2. Anthropometric description of the study subsamples (mean ± standard deviation).

Measures	Subsample 1 at 9 mo. Males	Subsample 1 at 9 mo. Females	Subsample 2 at 18 mo. Males	Subsample 2 at 18 mo. Females	Subsample 3 at 30 mo. Males	Subsample 3 at 30 mo. Females
Length (cm)	66.6 ± 2.7	65.1 ± 2.4	74.0 ± 3.5	72.5 ± 3.1	82.3 ± 3.7	80.9 ± 3.6
Weight kg)	7.62 ± 1.09	7.11 ± 0.90	8.95 ± 1.15	8.46 ± 1.01	11.08 ± 1.19	10.55 ± 1.18
Weight-for-Length (Z scores)	0.02 ± 0.98	0.15 ± 0.78	-0.74 ± 0.88	-0.63 ± 0.81	-0.45 ± 0.68	-0.47 ± 0.71
Arm Circumference (cm)	12.9 ± 1.2	12.7 ± 1.1	13.1 ± 1.1	12.8 ± 0.9	13.9 ± 0.9	13.6 ± 0.9
Triceps Skinfold (mm)	6.2 ± 1.2	6.2 ± 1.2	6.0 ± 1.2	6.1 ± 1.1	6.6 ± 1.2	6.5 ± 1.1
Subscapular Skinfold (mm)	5.9 ± 1.3	6.1 ± 1.3	5.1 ± 1.0	5.2 ± 1.0	5.3 ± 1.0	5.3 ± 1.1
UAMA (cm^2)	9.74 ± 1.83	9.21 ± 1.65	10.03 ± 1.68	9.57 ± 1.48	11.17 ± 1.66	10.71 ± 1.56
UAFA (cm^2)	3.77 ± 0.90	3.67 ± 0.83	3.65 ± 0.87	3.61 ± 0.75	4.24 ± 0.88	4.14 ± 0.83
N	319	263	315	259	297	244

Table 3. Physical growth at 9 months of age for subgroups based on quartiles of rate of linear growth 9-12 months.[a,b]

	Quartile of Linear Growth 9-12 mo.							
(Low)	1		2		3		4	
Males								
Length (cm)	66.2	(0.3)	66.7	(0.3)	66.6	(.3)	67.0	(.3)
Weight (kg)	7.31	(.16)[de]	7.47	(.11)[f]	7.78	(.12)[d]	7.93	(.12)[ef]
Weight-for-Length (Z scores)	-0.21	(.10)[de]	-0.21	(.10)[fg]	0.22	(.11)[ef]	0.26	(.12)[dg]
Arm Circumference (cm)	12.8	(.1)[d]	12.8	(.1)[e]	13.1	(.1)	13.2	(.1)[de]
UAMA (cm^2)	9.41	(.22)[d]	9.44	(.19)[e]	9.86	(.18)	10.25	(.22)[de]
UAFA (cm^2)	3.69	(.10)	3.69	(.10)	3.83	(.11)	3.87	(.11)
Females								
Length (cm)	64.9	(.3)	65.2	(.3)	65.4	(.3)	64.8	(.3)
Weight (kg)	6.85	(.11)[def]	7.17	(.11)[d]	7.18	(.11)[e]	7.28	(.12)[f]
Weight-for-Length (Z scores)	-0.14	(.09)[def]	0.19	(.09)[dg]	0.12	(.10)[eh]	0.49	(.09)[fgh]
Arm Circumference (cm)	12.5	(.1)	12.8	(.1)	12.7	(.1)	12.8	(.1)
UAMA (cm^2)	8.90	(.19)	9.39	(.23)	9.25	(.19)	9.29	(.21)
UAFA (cm^2)	3.51	(.10)	3.79	(.11)	3.60	(.09)	3.81	(.10)

a. Mean and standard deviation (in brackets) for subgroups as defined by quartiles.

b. Quartile means were tested for differences using the protected LSD procedure: individual differences are reported only if an ANOVA across all quartiles was significant at $p < 0.05$; quartile means in a row that are significantly different are denoted by a common superscript ($p < 0.05$).

Table 4. Physical growth at 18 months of age for subgroups based on quartiles of rate of linear growth 18-21 months.[a,b]

	Quartile of Linear Growth 18-21 mo.							
(Low)	1		2		3		4	
Males								
Length (cm)	73.0	(.4)[d]	74.1	(.4)	74.9	(.3)[de]	73.3	(.4)[e]
Weight (kg)	8.66	(.14)[d]	8.95	(.11)	9.28	(.11)[de]	8.91	(.15)[e]
Weight-for-Length (Z scores)	-0.99	(.10)[de]	-0.77	(.10)	-0.61	(.09)[d]	-0.60	(.09)[e]
Arm Circumference (cm)	12.9	(.1)	13.1	(.1)	13.3	(.1)	13.0	(.1)
UAMA (cm^2)	9.74	(.20)	10.11	(.19)	10.32	(.17)	9.96	(.20)
UAFA (cm^2)	3.54	(.10)	3.73	(.10)	3.81	(.10)	3.52	(.09)
Females								
Length (cm)	72.6	(.4)	72.5	(.4)	72.6	(.4)	72.3	(.4)
Weight (kg)	8.29	(.13)	8.42	(.12)	8.51	(.13)	8.61	(.12)
Weight-for-Length (Z scores)	-0.87	(.10)[d]	-0.69	(.09)[e]	-0.60	(.09)	-0.38	(.11)[de]
Arm Circumference (cm)	12.6	(.1)	12.8	(.1)	12.9	(.1)	13.0	(.1)
UAMA (cm^2)	9.21	(.19)	9.64	(.19)	9.57	(.19)	9.87	(.16)
UAFA (cm^2)	3.46	(.09)	3.62	(.09)	3.67	(.10)	3.70	(.10)

a. Mean and standard deviation (in brackets) for subgroups as defined by quartiles.

b. Quartile means were tested for differences using the protected LSD procedure: individual differences are reported only if an ANOVA across all quartiles was significant at $p < 0.05$; quartile means in a row that are significantly different are denoted by a common superscript ($p < 0.05$).

Table 5. Physical growth at 30 months of age for subgroups based on quartiles of rate of linear growth 30-36 months.[a,b]

	Quartile of Linear Growth 30-36 mo.			
(Low)	1	2	3	4
Males				
Length (cm)	82.5 (.5)	82.9 (.4)	82.3 (.4)	81.4 (.5)
Weight (kg)	11.06 (.16)	11.15 (.13)	11.12 (.13)	10.99 (.14)
Weight-for-Length (Z scores)	-0.52 (.09)	-0.49 (.08)	-0.41 (.07)	-0.35 (.07)
Arm Circumference (cm)	13.8 (.1)	13.8 (.1)	13.9 (.1)	13.9 (.1)
UAMA (cm^2)	10.99 (.19)	11.20 (.19)	11.38 (.19)	11.11 (.20)
UAFA (cm^2)	4.29 (.12)	4.18 (.10)	4.12 (.09)	4.37 (.10)
Females				
Length (cm)	80.9 (.5)	81.3 (.5)	81.6 (.3)	80.4 (.5)
Weight (kg)	10.40 (.17)	10.53 (.17)	10.62 (.13)	10.58 (.15)
Weight-for-Length (Z scores)	-0.57 (.10)	-0.54 (.10)	-0.51 (.09)	-0.32 (.07)
Arm Circumference (cm)	13.5 (.1)	13.7 (.1)	13.7 (.1)	13.7 (.1)
UAMA (cm^2)	10.43 (.20)	10.88 (.26)	10.85 (.18)	10.71 (.19)
UAFA (cm^2)	4.07 (.11)	4.12 (.13)	4.07 (.09)	4.28 (.10)

a. Mean and standard deviation (in brackets) for subgroups as defined by quartiles.

b. Quartile means were tested for differences using the protected LSD procedure: individual differences are reported only if an ANOVA across all quartiles was significant at $p < 0.05$; quartile means in a row that are significantly different are denoted by a common superscript ($p < 0.05$).

Table 6. Correlation of rate of linear growth over three intervals, with other anthropometry at the beginning of the interval.

Variable	Males, Age Intervals (mo.) 9-12	18-21	30-36	Females, Age Intervals (mo.) 9-12	18-21	30-36
Length (t_0)[a]	.14[d]	-.02	-.13[d]	-.06	-.08	-.07
Weight (t_0)	.25[d]	.12[d]	-.01	.15[d]	.11	.02
Weight-for-Length (t_0)	.21[d]	.22[d]	.14[d]	.31[d]	.26[d]	.11
Arm Circumference (t_0)	.19[d]	.07	.03	.11	.18[d]	.07
Upper Arm Muscle Area (t_0)	.20[d]	.08	.02	.10	.16[d]	.05
Upper Arm Fat Area (t_0)	.11[d]	.03	.03	.09	.10	.06
Length Increment (t_{-1},[b] t_0[c])	-.09	-.15[d]	-.17[d]	-.19[d]	-.30[d]	-.13[d]
Weight Increment (t_{-1}, t_0)	.16[d]	.22[d]	.19[d]	.09	.22[d]	.07
Weight Increment (t_0, t_{+1})	.32[d]	.26[d]	.20[d]	.34[d]	.26[d]	.32[d]
N	317	311	277	259	258	216

a. t_0 = 9, 18, 30 months.

b. t_{-1} = 6, 15, 24 months.

c. t_{+1} = 12, 21, 36 months.

d. Correlation is significant at $p < 0.05$.

Figure 1: **Attained length and weight for males, by quartiles of linear growth from 9 to 12 months (Q1 = slowest, Q4 = fastest).**

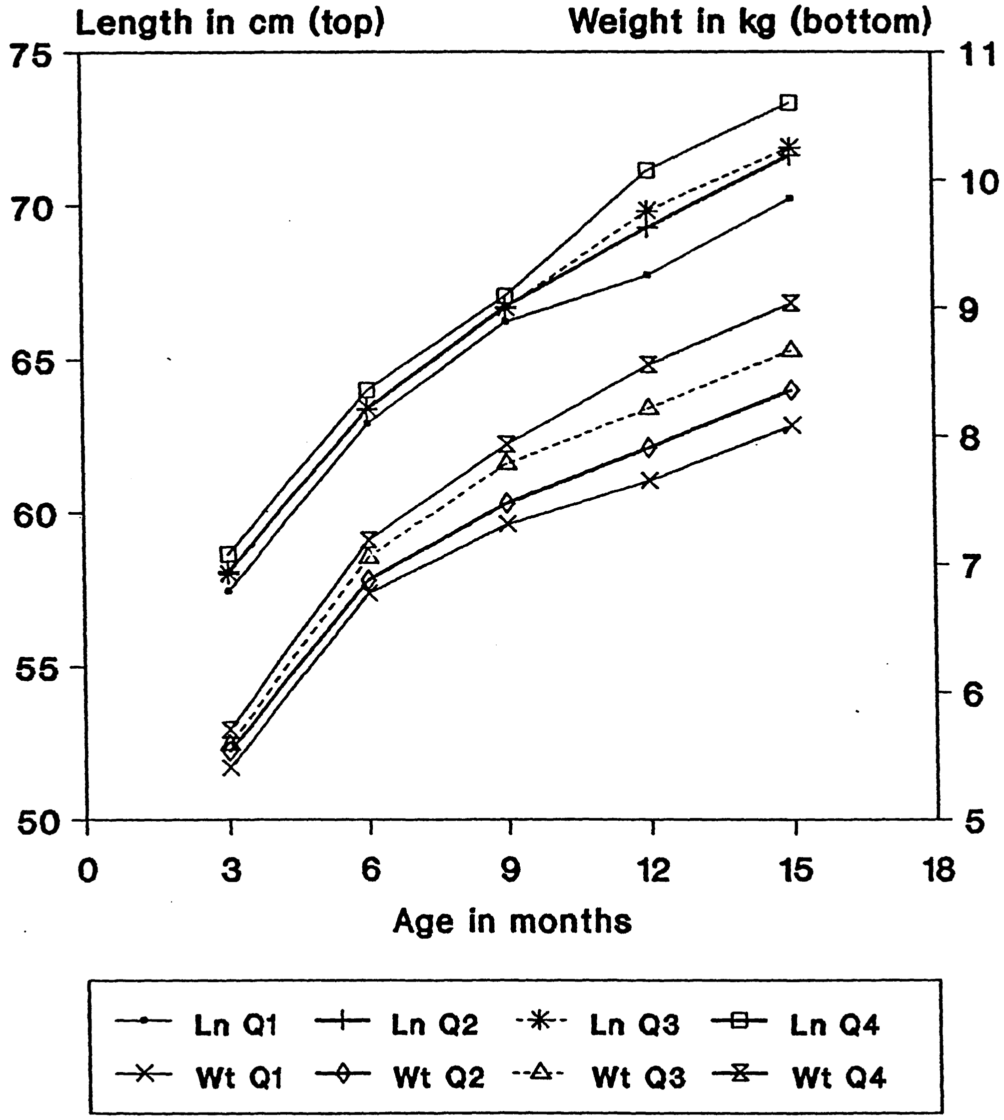

Figure 2: **Attained length and weight for males, by quartiles of linear growth from 18 to 21 months (Q1 = slowest, Q4 = fastest).**

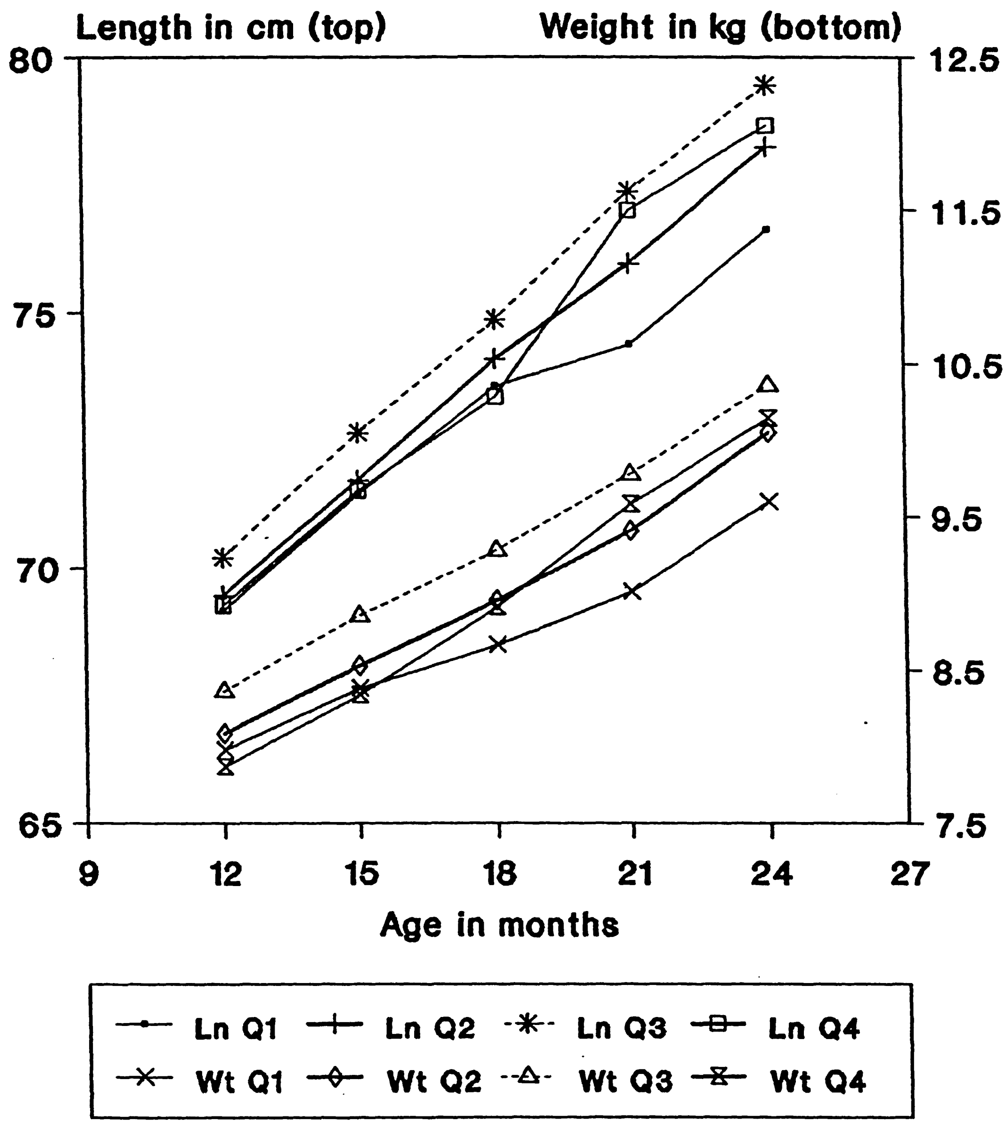

figure 3 : **Attained length and weight for males, by quartiles of linear growth from 30 to 36 months (Q1 = slowest, Q = fastest).**