INCAP Publication C-273

Consequences of stunting in early childhood for adult body size in rural Guatemala

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Introduction

Stunting, or markedly reduced stature, is widely recognized as one of the most visible and widespread manifestations of malnutrition in developing countries [1]. Stunting occurs within a context of extreme poverty, deficient diets, poor environmental sanitation, high rates of infection, and low access to health care. It is now certain that growth retardation is most pronounced during early childhood [2]. The period of weaning, defined in traditional societies as the transition between breast-feeding and sole dependency on the adult diet, is when the growth of children is most seriously affected. A common observation in studies of children from developing countries is that average body length is near the 50th percentile of Western reference standards at 3 to 6 months of age but below the 5th percentile at 2 to 3 years of age. This is remarkable in two ways. First, it represents a pronounced departure in the growth trajectory. Second, the shift downwards occurs within a very short span of time.

It is of great importance whether children who are stunted in early childhood are necessarily destined to become stunted adults. In other words, can children who are retarded in their growth at an early age make up the losses in later childhood and adolescence?

Tanner [3] has described human growth as a target-seeking function. Using an elegant metaphor, he tells us the following: "Children, no less than rockets, have their trajectories, governed by the control systems of their genetic constitution and powered by the energy absorbed from the environment. Deflect the child from its natural growth trajectory by acute malnutrition or a sudden lack of hormone, and a restoring force develops, so that as soon as the missing food or the absent hormone is supplied again, the child hastens to catch up towards its original growth curve. When it gets there, the child slows down again, to adjust its path onto the trajectory once more" (page 167).

Clinical experience, particularly the restoration of hormonal balance in children with hypothyroidism, Cushing's syndrome and isolated growth hormone deficiency, has yielded striking examples of catch-up growth [3]. However, the extent to which growth retardation will be compensated by catch-up growth will depend on the age at which treatment is begun. Also, the effects of growth hormone therapy on growth velocity appear to diminish after a year of the initiation of treatment [4]. The fact that common illnesses, such as respiratory and gastrointestinal infections, have only a transitory effect on child growth in children from industrialized nations also supports Tanner's thesis. But, the fact that common illnesses have an enduring

and retarding effect on growth in developing countries suggests that there are limits to growth as a self-stabilizing phenomenon. Infections in developing countries are generally more severe and occur more frequently than in industrialized nations. Diets may be deficient at all times and catch-up growth during the convalescent period may be limited by a poor nutrient supply. Tanner [3] himself has noted that "the more severe the growth-retarding influence, the longer it acts, and the earlier in life it occurs, the worse the ultimate outcome" (page 167).

Thus, there are reasons to expect that stunted children may not be able to catch-up later in life. It may simply be a matter of lost opportunity. Malnutrition affects the biological clock but its effects are less than those on growth velocity. It is unlikely that children, say at the age of 5 years, can ever make up for losses incurred in infancy, even under vastly improved environmental conditions.

This is not the first investigation to assess the implications of early growth retardation for adult body size. A study in Indian boys found that stunting at 5 years of age largely determined small adult stature [5]. The gain in height from 5 to approximately 18 years was independent of the degree of stunting at 5 years of age and in fact, was of similar magnitude as the gain observed for well-to-do Indians and only 2 to 3 cm less than that found in samples of European origin.

A later report by the same authors found that the situation in Indian girls was somewhat different [6]. Indian girls grew from 5 to 18 years of age by an amount equal or greater than recorded for girls of European origin. However, those who were shortest at 5 years of age gained more than those who were tallest at 5 years of age. Clearly, there was catch-up growth but it did not totally eliminate the deficit. For example, the tallest and shortest groups of girls differed by 14.2 cm at 5 years but only by 7.7 cm at 18 years.

A study from Nigeria found that boys and girls classified into groups according to stature at 5 years of age maintained parallel growth curves to 17 years of age [7]. This implies that increments were independent of stature at 5 years. A Gambian study showed that the gain in height from 3 years to adult size was the same in local boys and girls as in British subjects [8]. The authors of that study concluded that the losses caused by growth faltering in early life in developing countries are never regained. Finally, a study of a middle-class Indian group showed that adult deficits in height were almost entirely a product of prepubertal growth [9].

Specific hypotheses were formulated in light of these investigations. The principal hypothesis of the present study is that stunting in early life, specifically at 5 years of age, leads to short adult body size. Two related sub-hypotheses are that growth in height from 5 years of age to adulthood is: *a*) independent of height at 5 years of age, and *b*) equal to values observed for healthy, ethnically similar populations.

The reason for specifying "ethnically similar populations" in this study is that healthy populations of Spanish-Indian admixture appear to have similar growth patterns as Europeans prior to adolescence but not during the adolescent years [10-13]. Use of norms derived from studies of European samples in this study may, therefore, lead us to conclude that there was growth retardation from 5 years to adulthood when there might have been none.

Methods

The study used data from rural Guatemalan children of Spanish-Indian ancestry. Children's growth was measured from birth to 7 years of age from 1969-1977 in a longitudinal study carried out by the Institute of Nutrition of Central America and Panama (INCAP) [14]. The children were participants in a nutrition supplementation study which was designed to assess effects on growth and development. There were small but important effects on growth [14] but, in this preliminary paper, these have not been taken into account. It is unlikely that the effects of dietary supplementation on growth will alter the results of this study or the conclusions derived from them. Beginning in 1988, a follow-up

study of these children was begun and residents and migrants are being located and remeasured. The anticipated sample coverage rate is around 76%. The sample selected for the present analysis includes children measured at 5 years of age and at 18 years or older which is defined as the adult stage. The data reported here are preliminary because the final, clean and edited tapes are not yet (August 1989) available.

This report also makes detailed references to four populations. The key population is the Guatemalan rural sample. Analyses reported for the Guatemalan population are also presented for a middle class population from Berkeley, CA, USA [15]. This allows us to compare growth from 5 years to adulthood in both populations and also enables us to test whether size at 5 years of age is independent of subsequent growth in industrialized nations. Although the Berkeley data were reported 35 years ago, the children in that sample are taller at all ages and as adults than the general US population. Other data included for comparison are the US NCHS* reference data [16] which the World Health Organization (WHO) has adopted for use in developing countries [17]. Finally, data are also considered for Mexican-Americans, a group of similar ancestry as our rural Guatemalan population. These data are from large representative samples of Mexican-Americans living in the USA and were obtained by NCHS from 1982-1984 as part of HHANES* [13]. Mexican-Americans, although poor by US standards, have similar growth patterns as elite samples of children from Guatemala and Mexico and have heights that are very near the NCHS 50th percentile during early and middle childhood but which deviate more during adolescence. As adults, the average height of Mexican-Americans is near the 25th percentile of the NCHS reference data. The extent to which this difference is genetic or environmental in origin is unclear [13].

In order to study the relationship between stature at 5 years of age and subsequent growth, the distribution of height at 5 years for both the Berkeley and Guatemalan samples was divided into tertiles for males and females (Table I). Both the Berkeley and Guatemala samples were measured at exactly 5 years of age. The Berkeley sample continued to be measured at exact ages till adulthood and for this study, the data at 18 years of age were selected for analysis. As noted earlier, Guatemalan subjects 18 years or older with data at 5 years of age were selected for this study; age at measurement did not differ by tertile group (Table II).

*US NCHS – US National Center Health Statistics.

*HHANES – Hispanic Health and Nutrition Examination Survey.

Table I: Definition of groups according to height (cm) at 5 years of age in the Berkeley and Guatemalan samples.*

tertile	n	range	$\bar{x}$	SD	n	range	$\bar{x}$	SD
a) males								
		Berkeley (n=66)				Guatemala (n=175)		
1	21	100.6-109.0	107.0	2.3	60	85.4- 97.1	94.5	2.8
2	22	109.2-112.3	110.6	1.1	57	97.2-100.7	99.2	1.1
3	23	112.4-118.5	115.2	2.1	58	100.8-110.8	103.4	2.0
b) females								
		Berkeley (n=70)				Guatemala (n=168)		
1	23	100.1-109.0	105.3	2.7	56	85.7- 95.9	92.8	2.5
2	23	109.2-111.8	110.5	0.8	56	96.0- 99.0	97.5	0.9
3	24	112.0-123.5	114.4	2.6	56	99.2-109.6	102.3	2.3

* 1 cm has been subtracted from the Guatamalan range and mean values to correct for the fact that supine length, rather than height, was measured.

Table II: Ages at anthropometric assessment in adulthood for the Guatemalan sample.*

tertile	range	$\bar{x}$	SD	range	$\bar{x}$	SD
	males (n=175)			females (n=168)		
1	18.09-25.10	20.61	1.87	18.21-24.74	20.94	1.81
2	18.05-24.22	20.91	1.80	18.01-24.88	21.09	1.92
3	18.01-23.86	20.72	1.68	18.18-24.74	20.79	1.94

*No statistically significant difference in age among tertiles.

Results

A comparison of the heights of each of the groups of interest is given in figure 1 for both males and females. Berkeley, Guatemalan and Mexican-American samples are identified by the letters "B", "G" and "M", respectively and selected NCHS percentile values are shown for comparison. The means for the Berkeley and Guatemalan groups are shown to the right of the percentile values to illustrate their relative positions. The tallest group in the Berkeley sample, for example, is above the 75th percentile while the shortest is near the 25th percentile. All of the Guatemalan groups are very short: the tallest tertile is barely above the 5th percentile while the lower two tertiles are substantially below this level. To a paediatrician in France or the USA, these children would appear to be markedly retarded in height. It should be stressed that small stature at 5 years of age is not a genetic or racial trait of Guatemalans. For example, the means for Mexican-Americans are less than 2 cm below the 50th percentile of NCHS. These small differences in growth have been shown to be due to the greater poverty of the Mexican-American population compared to the rest of US society [13].

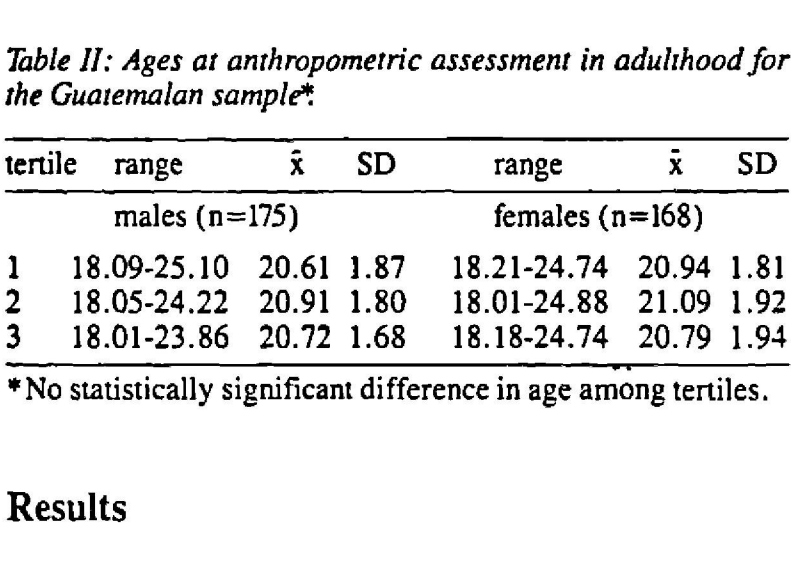

Fig. 1: Comparison of group means to US NCHS percentiles at 5 years of age (B=Berkeley, G=Guatemalan, M=Mexican-American; subscripts refer to tertile number.)

Table III: Height increments (cm) from 5 years to adulthood in the Berkeley and Guatemalan samples.*

	males (n=175)				females (n=168)			
ter-tile	Berkeley $\bar{x}$	SD	Guatemala $\bar{x}$	SD	Berkeley $\bar{x}$	SD	Guatemala $\bar{x}$	SD
1	65.8	3.3	63.8	4.0	56.3	3.5	52.9	5.2
2	68.9	3.2	64.1	3.6	57.1	5.1	52.5	3.1
3	68.9	5.1	63.7	3.9	56.0	3.9	52.8	4.6
	$p = 0.019$		$p = 0.824$		$p = 0.634$		$p = 0.840$	

* 1 cm has been added to mean values for Guatemalan values to correct for the fact that supine length, rather than height, was measured.

The gain in height from 5 years to adulthood for each of the groups of interest is shown in Table III for males and females. For males in the Berkeley sample, there was an association between tertile level and growth in height; this was due entirely to the fact that the shortest group grew 3 cm less than the two taller groups. In Guatemalan males, no relationship was observed between tertile level and gain in height. With one exception, the data for females are similar to those for males. The exception is that there is no relationship between tertile level and increments in height from 5 years to adulthood in the Berkeley sample. The data in Table III also indicate that increments in Guatemala were smaller than in Berkeley ($p \ll 0.001$) and that Guatemalans and Mexican-Americans had similar gains in height ($p \gg 0.05$) in spite of living under very different environments.

Estimates of the gain in height from 5 years to adulthood are given in Table IV for the four populations of interest. Several points are clear. First, the two US, non-Hispanic samples, that is Berkeley and NCHS, have similar increments. For example,

Table IV: Height increments (cm) from 5 years to adulthood in US and Guatemalan populations.

	males		females	
	$\bar{x}$	SD	$\bar{x}$	SD
Berkeley	67.9	4.2	56.5	4.2
NCHS[1]	66.9	—	55.3	—
Mexican-Americans [2]	62.8	—	51.5	—
Guatemala [3]	63.9	3.8	52.7	4.2

[1] Estimated from Hamill *et al.* [16] by subtracting 50th percentile values given at 5 years from those given at 18 years.
[2] Mexican-Americans are from HHANES. Estimate of increment derived by subtracting the mean height at 5 years (i.e. 4.5 to 5.5 year range) from the average height at adulthood (18 to 26 years).
[3] 1 cm added to Guatemalan values to correct for the fact that supine length, rather than height, was measured.

the estimated gain for males is 67.9 cm for Berkeley and 66.9 cm for NCHS. Second, Mexican-Americans and rural Guatemalans have similar increments. For example, the estimated gain for males is 62.8 cm for Mexican-Americans and 63.9 for Guatemalans. Clearly, increments for non-Hispanic US samples appear to be 4 to 5 cm greater than those for the samples of Mexican or Guatemalan origin.

Another interesting question is how the original tertile groups are situated relative to each other as adults. The mean adult stature for each of the groups is compared to the NCHS percentiles in figure 2 as was done at 5 years of age in figure 1. Itis most interesting that the relative position of the groups is very similar to that observed at 5 years of age.

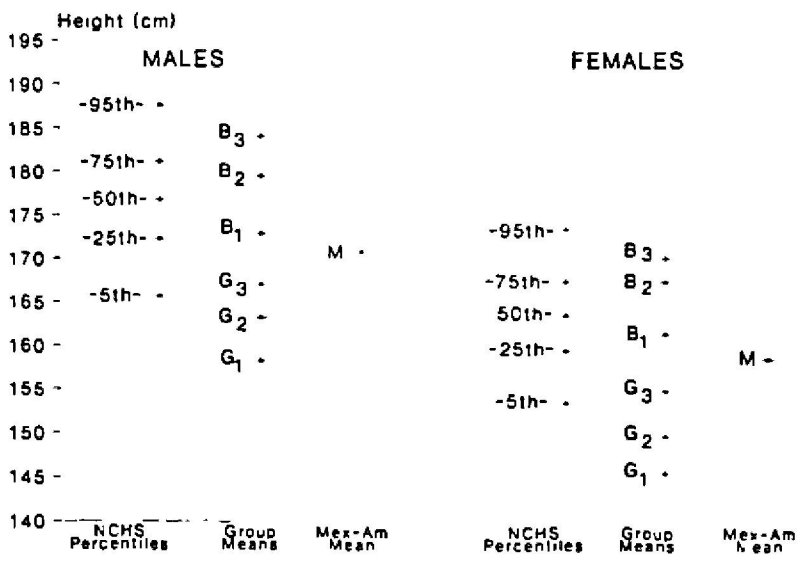

Fig. 2: Comparison of adult stature to US NCHS percentiles (B=Berkeley, G=Guatemala, M=Mexican-American; subscripts refer to tertile number.)

Differences in body composition among the Guatemalan groups were also examined. A study was carried out to generate predictive equations of body composition in a sample of 210 Guatemalan subjects of similar ethnic and socio-economic background as the study sample. Body density by underwater weighing was used to derive the dependent variable, fat-free mass. Anthropometric characteristics were then used to predict fat-free mass*. The predictive equations were then applied to the rural Guatemalan sample to estimate fat-free mass and the results are given in table V.

Table V: Fat-free mass (kg) at adulthood for Guatemalan males and females by tertiles of height at 5 years.

tertile	males (n=175)		females (n=168)	
	$\bar{x}$	SD	$\bar{x}$	SD
1	45.8	4.2	35.4	4.9
2	48.6	4.1	37.0	4.4
3	52.5	3.8	39.2	3.6
	$p < 0.001$		$p < 0.001$	

These data suggest marked differences in adult fat-free mass by tertile of height at 5 years of age. For example, for males, the tallest group had 52.5 kg compared to 45.8 kg for the shortest group. This is a difference of 6.7 kg of fat-free mass. For females, a similar comparison yields a difference of 3.8 kg. Differences in total body fat or in percent body fat were also assessed, but these were not as clear or as marked as differences in fat-free mass.

Discussion

The results presented corroborate previous work and indicate that stunting is a condition resulting from events in early childhood and which, once

* The analyses of these data have yet to be completed and hence. the equations used in this study are preliminary. The final version of the equations will be available soon. More information may be obtained from the authors.

present, remains for life. All three of the hypotheses formulated are accepted. It was shown that growth from 5 years of age to adulthood is independent of the degree of stunting at 5 years of age. Also, the gain in height in the rural Guatemalan population examined appears to be similar to that observed in subjects of Mexican-American origin, suggesting that growth is normal after 5 years of age in Guatemala. There is no catch-up growth in later childhood and adolescence as some might have expected. If maturation were markedly delayed, one would have expected catch-up simply because the growth phase would have lasted longer. But this is not the case in the study sample. Preliminary analyses of skeletal age data indicate only a modest delay, perhaps around half a year. This minor delay may account for the slightly greater gain in height in the Guatemalan sample when compared to the Mexican-American sample (see Table IV). Whether Guatemalan children would have grown better after 5 years of age if they had been removed from their environment into a more favourable one, say by migration or adoption, is not clear. What is so remarkable is that they grew so well after 5 years of age in spite of remaining in the environment that caused them to be stunted earlier.

Should one be surprised to discover that growth rates are adequate after 5 years of age? Perhaps not. Once the stormy early years are passed, rates of some infections, such as diarrhoeal diseases, decline to very low levels. Subsequent nutritional requirements, per unit of body mass, are lower than during infancy and early childhood and rise only moderately during adolescence. Older children are also more in control of their feeding patterns and may express and satisfy their needs more effectively. It has been known for a long time that clinical signs of malnutrition are rare in older children but very common in young children. Therefore, it should not be surprising that growth is deficient in younger but not in older children.

It is interesting that growth in early childhood is as independent of subsequent growth in Guatemala as it is in Berkeley. By 5 years of age, children in Berkeley are probably already travelling along their "rocket trajectory" using Tanner's metaphor. By this age, children in Guatemala are also already set in their ways. Their's, however, are not the trajectories they would have travelled on if they had not been exposed to poor diets and infection as infants and toddlers. Instead, they find themselves in lower trajectories. When it is that rural Guatemalans become "locked into" their lower trajectories is not clear. It probably occurs earlier than 5 years of age, possibly closer to 3 years of age judging by the adequacy of growth rates [2]. The selection of 5 years as the age of focus of study was arbitrary and related to prior use by other authors and to the fact that a larger sample is available at 5 than at 3 years of age.

From 5 years of age to adulthood, children in Guatemala possibly grow as well as children of similar ancestry can grow. Their growth trajectories, as well as those of children at Berkeley, are largely independent of initial size. Except for early infancy, when birth size is negatively related to growth, gains are generally not correlated with initial size. For example, a study of growth in adolescence shows that height at take-off is not correlated with peak height velocity [9].

The implication of these observations is that, for practical purposes, stunting remains once it is established. Since gains in height are independent of stunting at 5 years of age, there are shifts in the relative rank of individuals and some short children become taller adults than others who were once taller. But, the average growth is similar across groups and thus, the groups maintain the same relative standing as adults.

But what does it all mean? What is the significance of being a stunted adult? This has been a subject of some debate in recent years [18-20]. Clearly, the process of becoming small is what matters most. Growth retardation is a marker or indicator of problems which threaten health and life. But, having made it through early childhood, does small body size matter? Some would say it is helpful. Smaller people require less food to live and in this way small body size might be a benefit. But, other aspects come into play which may negate this benefit. Stunted adults, as one would expect and as we have shown, have markedly

reduced fat-free masses. Fat-free mass is intimately related to work capacity and thus to economic productivity [21, 22]. Also, short maternal stature is known to be a risk factor for poor outcomes during pregnancy.

In conclusion, the most significant contribution of this study is to highlight the importance of nutrition and growth during the early years for adult body size. It can be unequivocally stated that impairments in adult function derived from small body sizes, such as noted above, are directly traced to the adverse effects of poor diets and infection on growth during early childhood.

Conclusion

Height at 5 years of age was linked with anthropometry at 18 to 26 years of age in 175 Guatemalan males and 168 females. Subjects were stratified into tertiles of height at 5 years of age. All groups were markedly retarded in height; the tallest was situated near the 5th percentile of the NCHS reference curves and the two shortest tertiles were well below this level. The gain in height from 5 years to adulthood was independent of status at 5 years. This gain was 4 to 5 cm less than in US non-Hispanic populations (Berkeley Growth Study and NCHS reference data) but equal to values for healthy populations from Guatemala and Mexico and for Mexican-Americans. The tertile groups maintained their relative rank as adults, and occupied similar positions with respect to the NCHS reference curves as they did at 5 years of age. Thus, children who are stunted in early life have a high probability of being small adults. Finally, the groups showed marked differences in fat-free mass. As adults, the tallest 5 year old had 6.7 kg and 3.8 kg more fat-free mass than the shortest group in males and females, respectively.

Acknowledgement

Research funded by grant HD22440 from the National Institutes of Health.

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