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Long-term consequences of growth retardation during early childhood*

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Introduction

Almost all of the growth retardation documented in studies carried out in developing countries has its origins in the first 2 or 3 yr of life, the 'age of growth failure' [1].

The causes of growth failure are deeply rooted in poverty and ultimately operate through the interaction of inadequate dietary intakes and high rates of infection. Growth failure is only one manifestation of a general syndrome of developmental impairment which also includes effects on motor and mental development. Growth failure is, however, the best nonspecific marker of deprivation and should be a strong predictor of subsequent functional impairment [1].

The purpose of this study is to test the hypothesis that growth failure in early childhood predicts functional impairment in young adults. The study uses data from rural Guatemala and includes measures of adult biological status and intellectual achievement. The study represents the most comprehensive assessment to date of these relationships.

Methods

The data are from studies carried out over the past two decades by the Institute of Nutrition of Central America and Panama (INCAP) in four villages located in the department of El Progreso in Guatemala. Data collection was in two phases. First, from 1969 to 1977, INCAP carried out a longitudinal study of the effects of improved nutrition on growth and physical development in children 7 yr or younger. Later, in 1988, INCAP and collaborating universities conducted a cross-sectional assessment of former participants of the longitudinal study. Details of the methods used in the follow-up study are given in Rivera [2].

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Subjects who were measured at 3 yr of age and who were 18 yr or older at the time of the follow-up assessment were selected for these analyses. A total of 249 subjects, 120 males and 129 females, met these criteria.

The analyses were also limited to specific outcome variables. The biological variables selected included adult height (HT88), growth from 3 yr to adulthood (HTINC), fat-free mass (FFM), percent body fat (PERFAT) and right-grip strength (Strength). Recumbent length at 3 yr of age and stature in adults were measured using recommended techniques [3]. Fat-free mass was estimated using a battery of anthropometric variables; the predictive equations used came from a study carried out in Guatemalan subjects [4]. Percent body fat was estimated from weight and fat-free mass (WT-FFM/WT). Right-grip strength was measured using a dynamometer.

The measures of intellectual achievement selected were non-verbal intelligence which was measured with scales A, B, and C of Raven's Standard Progressive Matrices (Raven; highest possible score is 36), the maximum number of grades attained as reported by the subject (School), literacy as determined by a test which used letters, syllables, words and short phrases (Literate: 0 = No, 1 = Yes), numeric ability using a test which measured the ability to read numbers and prices and to perform simple arithmetic calculations (Numeracy; highest possible score is 41), and general knowledge using a test about common experiences in regards to schooling, work, transportation, legal-political structures and health (Know; highest possible score is 22). These tests are described at length by Pollitt et al. [5].

The degree to which length at 3 yr of age predicts subsequent outcomes was assessed by means of multivariate analyses carried out separately for males and females. These analyses used length at 3 yr as a continuous variable and included a different set of covariates for biological outcomes than for intellectual achievement. For the former, age at the time of the follow-up assessment, which ranged from 18 to 26 yr, was used as a control variable. For intellectual achievement, additional control variables were included. Village idiots were used to control for unmeasured village characteristics. Two variables measured in the first phase of the study (i.e. 1970's) were used as indicators of the home environment in which children grew. These are maternal education as proxied by the highest grade passed by the mother and household wealth as proxied by an index of the characteristics of the home. Thus, the analyses involving measures of intellectual achievement are conservative in that the predictive power of growth retardation is examined after controlling for characteristics of the home environment.

Functional performance was examined as well by categories of degree of retardation in length at 3 yr of age. While less powerful, these analyses convey a better sense of the magnitude of relationships. Using the WHO reference population, children were allocated to any of three categories; 1 cm was subtracted from length at 3 yr of age to adjust for the fact that reference values at this age are provided for stature but not for length. Severe stunting was defined as adjusted length for age values which were ≥ 3 SD below the reference median. Moderate stunting was defined as values between 2.9 and 2.0 SD below the reference median and the absence of stunting was defined as values within 2 SD of the reference median. Means per category of stunting were adjusted for the same covariates used in the multivariate analyses.

Results

The population exhibited a marked degree of growth retardation at 3 yr of age with greater prevalences of stunting occurring among girls. Of 120 males, 31 showed severe stunting (25.8%), 51 moderate stunting (42.5%) and 38 were not stunted (31.7%). The corresponding numbers for 129 females were 54 (41.9%), 45 (38.0%) and 26 (20.2%) respectively.

Descriptive statistics for biological and intellectual outcomes are shown in Table 1.

Because of space limitations, full presentation of the multivariate regression models is not possible. Two statistics were selected as general measures of the strenght of relationships. The first is the standardized regression coefficient (also known as beta weight) which is obtained after setting the variance of independent and dependent variables to unity. The standardized regression coefficient is equivalent to the simple correlation between predictor and outcome and as such, is independent of the units of measurement. The second is the probability value (two-tailed test) associated with the standardized regression coefficient. The results, given in Table 2, indicate that length at 3 yr of age is independent of linear growth from 3 yr of age to adulthood. The growth retardation incurred in early childhood, therefore, is not recuperated later (e.g. catch-up growth would

Table 1. Descriptive statistics for biological and intellectual outcomes in subjects 18 yr of age or older

Variable	Males			Females		
	n	$\bar{x}$	SD	*n*	$\bar{x}$	SD
Age88 (yr)	120	20.1	1.3	129	20.2	1.4
Length3 (cm)	120	86.6	3.5	129	84.2	42.2
HT88 (cm)	120	162.9	5.2	129	149.7	6.1
HTINC (cm)	120	76.3	2.6	129	65.5	4.7
FFM (kg)	119	49.1	4.7	129	36.5	4.4
PERFAT (%)	119	13.9	2.6	129	25.5	3.8
Strength (kg)	120	37.0	6.0	127	22.5	6.9
Raven	118	12.8	5.0	124	11.1	4.6
School (yr)	118	5.6	3.1	125	4.8	3.0
Literate (0/1)	118	0.79	0.41	124	0.76	0.43
Numeracy	118	35.2	6.3	124	32.7	7.8
Know	118	15.1	3.4	125	14.7	3.1

result in a significant, negative relationship).

Length at 3 yr, as expected, is highly related to adult height. Also, size at 3 yr predicts strength and fat-free mass but not percent body fat. Weaker, but nonetheless striking relationships are evident with measures of intellectual achievement. Only in the case of the RAVEN test in females is the relationship with length at 3 yr of age not statistically significant. Except for the Raven test, relationships are of similar magnitude in males and females.

Alternative measures of the magnitude of relationships are presented in Figs. 1-4. In these, categories of the degree of stunting are used as defined earlier. Sample sizes for males are a maximum of 31, 51, and 38 for severe, moderate, and no stunting, respectively. For females, the corresponding sample sizes are 54, 49, and 26.

Short stature in mothers is a predictor of obstetric risk. A commonly used cut-off point for obstetric risk is 149 cm. In Fig. 1, the percentage of women with short stature is shown to vary strikingly according to the degree of stunting at 3 yr of age.

Differences between cell means and sex-specific population means are shown in Fig. 2 for fat-free mass, a key determinant of work capacity. For example, males who were severely stunted as young children are 3.9 kg below the FFM mean for all males 18 yr or older. Differences between extreme categories of stunting in early childhood are 6.4 kg in males and 5.4 kg in females. These values are significant in statistical as well as biological terms.

Two examples in the area of intellectual achievement are also included: highest grade completed (Fig. 3) and literacy (Fig. 4). For years of school completed, differences between extreme categories are 1.8 yr in boys and 1.0 yr in girls.

Table 2. Standardized regression coefficients (*b*) and probability values (*P*) for length at 3 yr of age on biological outcomes[a] and intellectual achievement[b] at 18 yr or older

Variable	Males		Females	
	b	*P*	*b*	*P*
HTINC	0.066	0.4726	0.077	0.3877
HT88	0.721	0.0001	0.637	0.0001
FFM	0.562	0.0001	0.514	0.0001
PERFAT	0.143	0.1203	0.162	0.0522
Strength	0.401	0.0001	0.382	0.0001
Raven	0.305	0.0007	0.154	0.1221
School	0.191	0.0205	0.187	0.0287
Numeracy	0.198	0.0238	0.191	0.0441
Know	0.228	0.0097	0.271	0.0054
Literacy	0.326	0.0214	0.354	0.0212

[a] Model for biological variables includes age in years as a covariate.
[b] Model for intellectual achievement includes age, village idiots, maternal education, and household wealth. Logistic regressions were carried out in the case of the variable 'Lit'.

Differences of this magnitude would be considered significant by education specialists. Similarly, literacy in adults is related to the degree of stunting at 3 yr of age but only in males (Fig. 4). Differences between extreme categories are 31.6% in males and 9.7% in females.

Discussion

The present study is the most comprehensive and clearest demonstration that growth retardation in early childhood is associated with significant functional impairment in the adult.

The Guatemalan subjects of this study suffered a marked degree of linear growth retardation in early childhood. By 3 yr of age, nearly three-quarters of the

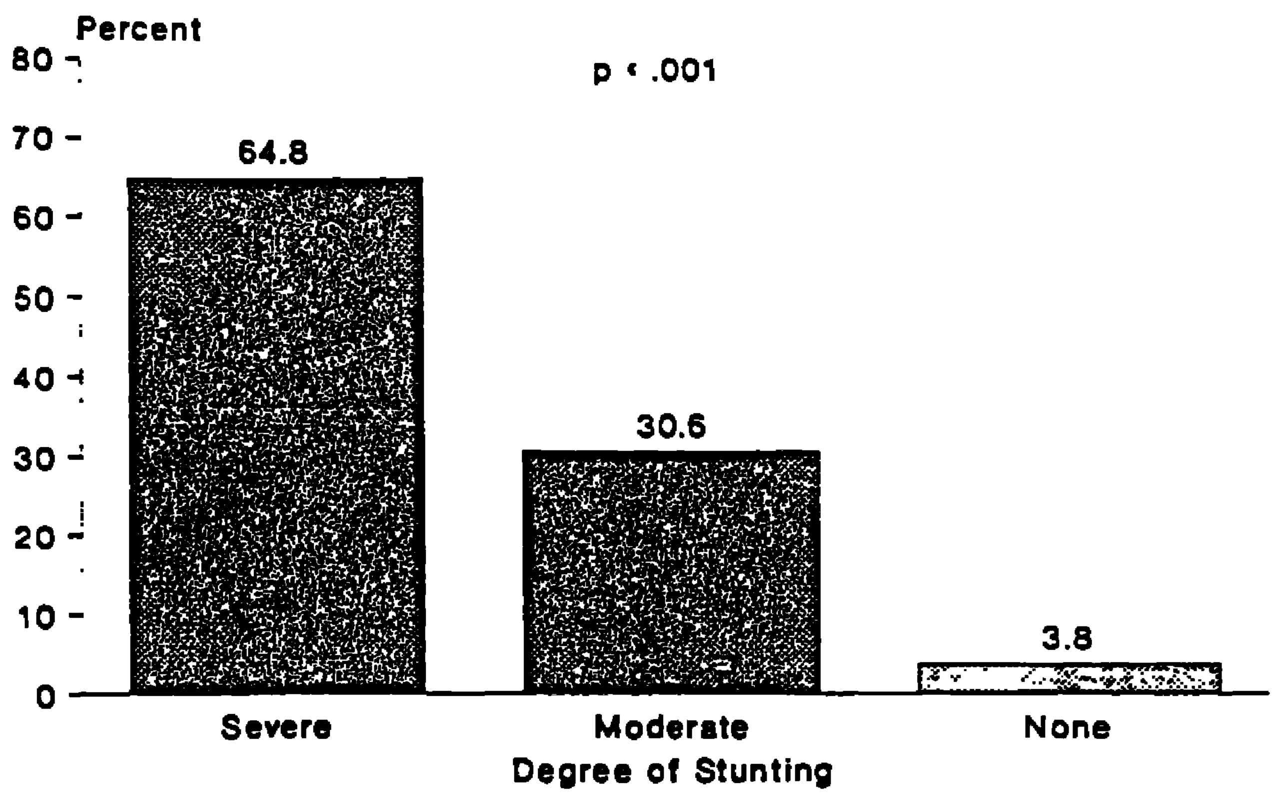

Fig. 1. Prevalence of short stature (< 149 cm) in Guatemalan Women (≥ 18 yr) by degree of stunting at 3 yr of age.

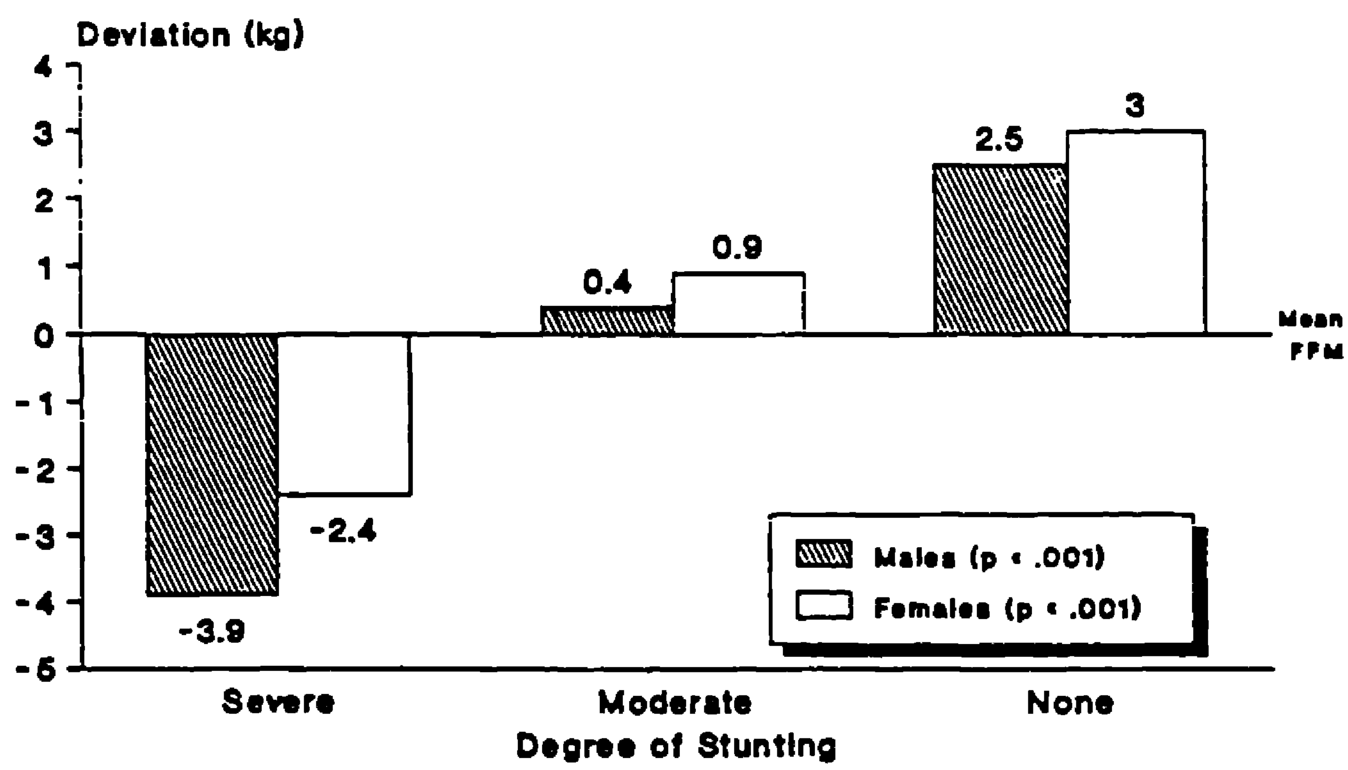

Fig. 2. Deviations from the sex-specific FFM mean (49.1 ± 4.7 kg in males; 36.5 ± 4.4 in females).

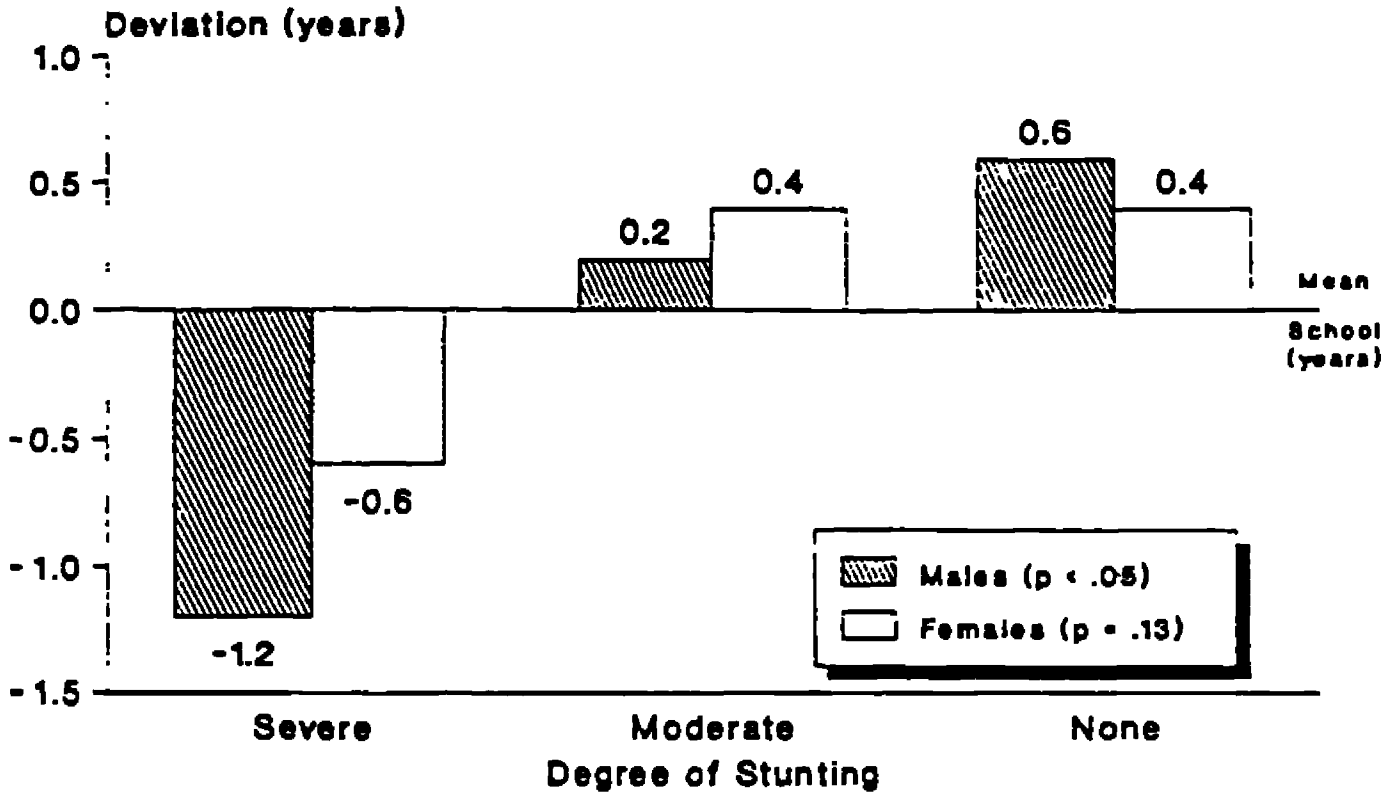

Fig. 3. Deviations from the sex-specific mean for years of school (5.6 ± 3.1 yr in males; 4.8 ± 3.0 yr in females).

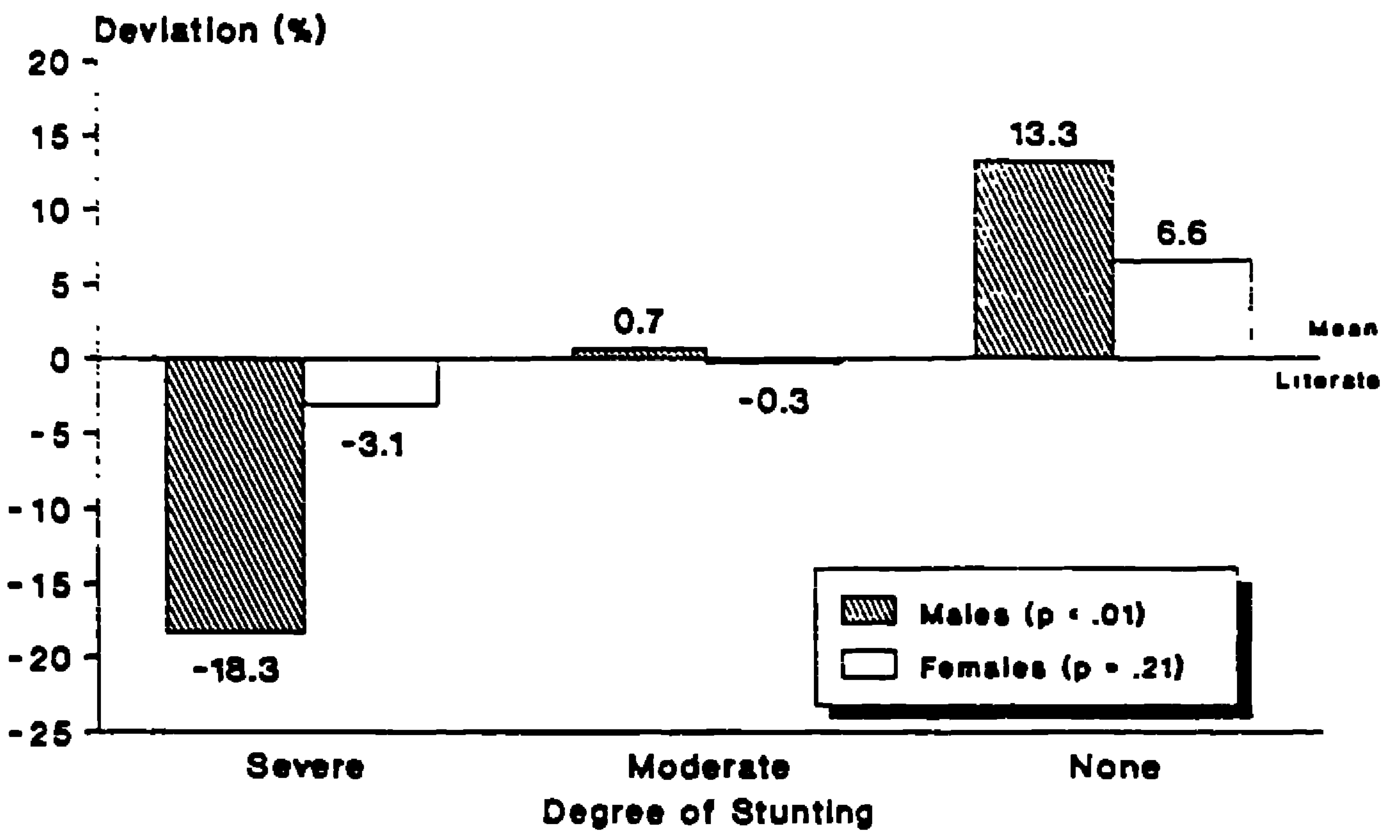

Fig. 4. Deviations from the sex-specific mean for passing rate for the literacy test (73.8% in males and 76.4% in females).

sample were stunted using conventional criteria (i.e. lengths below 2 SD of the reference distribution). Growth was similar after 3 yr of age for stunted and non-stunted subjects. There was no evidence, therefore, of catch-up growth. Surprisingly, growth from early childhood to adulthood was only about 4 to 5 cm less than observed for U.S. populations [6].

Children affected by marked growth retardation grew up to be adults with limited biological and intellectual capital. Stunted children had reduced strength and fat-free mass as adults and therefore, diminished work capacities. Short stature in women was another outcome of stunting in early childhood; this is a matter of great concern in terms of obstetric risk.

Intellectual achievement was also constrained in subjects who were stunted as young children. Intelligence, numeracy, literacy and school attainment were all lower in children who were stunted. It should be stressed that these analyses controlled for unmeasured village characteristics and for characteristics of the home environment. One interpretation of these results is that the conditions which gave rise to marked growth retardation also affected cognitive development adversely. Growth failure becomes, in this view, not a cause, but a marker of the syndrome of developmental impairment of early childhood.

The policy implications seem clear. The first few years of life are critical in shaping physical and mental development. To allow the malnutrition-infection complex and unstimulating environments to depress human development leads to reduced human capital and to the perpetuation of poverty. Therefore, conscientious governments seeking to accelerate economic development should consider investing heavily in the promotion of optimal growth and development in childhood.

Acknowledgements

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