Parent-Child and Sibling-Sibling Correlations of Height and Weight in a Rural Guatemalan Population of Preschool Children

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ABSTRACT

An investigation of parental height and weight and the height (supine length) and weight of their offspring at age three years shows that familial correlations of height and weight in 337 rural Mayan families living in the highlands of Guatemala are low compared with those reported in families living in technologically more developed countries. It is suggested that low familial correlation coefficients in the Guatemalan data are related to increased variability in height and weight caused by environmental factors which retard the growth of Mayan preschool children.

Familial correlation coefficients for height and weight have provided estimates of the contribution to growth made by genetic factors. Parent-child height and weight correlations have been reported in growth studies carried out in several industrialized countries, Britain (Thomson, 1955; Hewitt, 1957; and Tanner and Israelsohn, 1963), the United States (Bayley, 1954; Kagan and Moss, 1959; Livson, et al. 1962; and Garn and Rohmann, 1966), and Poland (Wolański, 1970; Welon and Bielicki, 1971). Sibling-sibling correlations of height (Hewitt, 1957; Garn and Rohmann, 1966) and weight (Karn, 1957; Garn and Rohmann, 1966) in industrialized countries are also available. Data on familial height and weight correlations in populations living in technologically less developed countries have also been reported for New Guinea (Malcolm, 1970).

The present study reports correlation coefficients of parent-child and sibling-sibling height and weight in a rural Guatemalan population of pre-school children, and compares them with parent-child and sibling-sibling correlations of height and weight reported in populations of industrialized countries. Guatemalan preschool children have higher mortality rates (Gordon, Wyon and Ascoli, 1967) and lower growth rates (Guzmán, et al. 1968; Mata, et al. 1972) than preschool children in industrialized countries. Excess mortality and poor growth in children of rural

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Guatemala and other less technologically developed countries are associated with synergism between malnutrition and infection (Scrimshaw, Taylor and Gordon, 1968), the effect of which is especially marked in the second year of life (Gordon, Chitkara and Wyon, 1963). The object of this study was to investigate the influence of adverse environmental conditions for growth on familial correlations of height and weight.

Hewitt (1957) set forth the principles governing the theoretical values of the correlations between relatives as follows:

1. When inheritance is autosomal and there is no dominance, all sib-sib and parent-offspring correlations have the expected value of +0.50.
2. These expected correlations will be raised by assortative mating.
3. The effect of dominance is to reduce the correlations, expecially those between parent and offspring.
4. Sex-linkage will not affect the average values of the coefficients, but the correlation between sibs of like sex will exceed that between sibs of unlike sex, and the correlation with the parent of unlike sex will exceed that with the parent of like sex (pp. 26-27).

Adult height is determined by the combined influence of genetic and environmental factors on both skeletal maturation rate and the growth rate, whereas child size at age three years is determined by the influence of genetic and environmental factors on prenatal and postnatal growth rates. Parent-child height and weight correlations will approach theoretical values if environmental conditions are the same for both generations, and if they have the same relative effect on adult height that they have on height in childhood.

The absence of intergenerational changes in environment does not guarantee that the growth and maturation of parents and child will be conditioned by the same environmental factors, though the likelihood that environmental factors will be the same seems higher in industrialized countries than in less technologically developed countries. There is little variability in the Mayan diet, which tends to be substandard for all preschool children; however, the number, severity, duration, and age of experiencing infectious diseases varies greatly from child to child, and the synergic effect of infection and malnutrition on development is profound (Mata, et al. 1972). There is little reason to suppose that infectious diseases experienced by a child during his preschool years will correspond to those of his parents over their lifetimes, though siblings may be exposed to the same diseases and resemble each other more in this respect than parent-child pairs.

Control of infectious disease and malnutrition has greatly reduced variability in development due to these factors in industrialized countries. Improved nutrition may produce variability in the development of individuals, particularly in weight, but the magnitude of the height response to overnutrition in industrialized countries is unlikely to be as great as the height response is to malnutrition and infection in developing countries. Indeed, there is some evidence to indicate that the maximum response to environmental factors which stimulate linear growth may have been reached in privileged U. S. population groups (Bakwin and McLaughlin, 1964). Therefore, it is expected that relatively greater variability in height attributable to environmental factors will produce correspondingly lower familial correlation coefficients for height in the Guatemalan population compared to populations of industrialized countries.

There may be a difference between the sexes in the effect of environment on development. In the terminology of Waddington (1957), the development of females is thought to be more "canalized" than that of males, i.e., tending to be less affected by environmental factors than that of males, whether such factors might stimulate development (Acheson, Fowler, and Janes, 1962; Acheson and Fowler, 1964; Welon and Bielicki, 1971) or retard development (Greulich et al. 1953; Acheson and Hewitt, 1954).

There is still some question regarding inter-sex differences in the developmental response of children to chronic malnutrition. Frisancho, Garn and Ascoli (1970) reported that the conception-corrected percent delay in the skeletal maturation of Guatemalan boys and girls is of the same magnitude during infancy, childhood, and adolescence; growth rates are comparable to USA standards during the first year of life and are slower thereafter in both sexes. In this case, there should be no sex-related differences in familial height and weight correlation coefficients. However, Blanco et al. (1972) found the skeletal maturation of Guatemalan boys to be more variable than that of girls, and reported a greater delay in boys' maturation than in girls'. The delay is of marginal statistical significance, but is consistent with the theory of more canalized female development.

In summary, it is expected that: 1. familial height and weight correlation coefficients will be lower for the Guatemalan population than for populations of industrialized countries, 2. that parent-child height and weight correlations will be lower than sibling-sibling correlation coefficients, and 3. that mother-daughter and sister-sister correlation coefficients may be higher than those of father-son and brother-brother pairs.

Materials and Methods

Anthropometric data used in the present analysis were gathered in the course of two longitudinal studies on the health of preschool children carried out by members of the Institute of Nutrition for Central America and Panama. The first, "The Nutrition and Infection Field Study in Guatemalan Villages," was conducted from 1959 to 1964 and included all children under age five years in two rural villages, Santa Mariá Cauqué and Santa Cruz Balanyá (Schrimshaw, et al. 1967a). The villages had been matched with respect to ethnic background and general life styles of their populations (Scrimshaw, et al. 1967b), and subsequent study revealed no significant differences in mean growth rates of children from the two villages (Guzmán, et al. 1968). The second, "The Longitudinal Study of Infection and Nutrition," begun in 1964 in Santa Mariá Cauqué, was still in progress at the close of the observation period for the present study, September, 1971 (Mata, et al. 1967). In this study children were enrolled at birth and followed to age five years.

The study population consisted of 337 families with preschool children living in two predominantly Mayan Indian villages in the highlands of Guatemala. All possible sibling-sibling pairs were formed, matching earlier-born with later-born siblings, in families where the growth of two or more children had been studied during their preschool years. One child had been studied in 154 families, two in 99, three in 55, four in 20, and five siblings in nine families.

Duplicate measurements of height and weight were made of children at three-month intervals from birth to age five years. From 1959 to 1964, weight was measured on a frequently calibrated platform scale. Because of a cultural prejudice against undressing children, the children were weighed barefoot with minimal clothing for which no allowance was made in recorded weights. By actual test of selected children, representing both sexes and ages ranging from newborns to five years, the mean weight of clothing was 624 grams for infants less than three months old and 25 or 50 grams less for children over age three months. Variations among children were small (Scrimshaw, et al. 1967b). Height was measured with the child in a prone position, using a steel tape.

From 1964 to 1971 weight was measured on a Seca baby scale with an approximation of seven grams. Height was measured with the child in a prone position, using a wooden "infantometer." Children weighing over 14.5 kg were weighed in the clinic on a balance scale (Trademark, Alvo), and a correction factor was applied to bring the weights into agreement with those measured on the Seca scale. However, very few children in this population under age five years weigh more than 14.5 kg.

Though children were measured at three-month intervals, not all were measured at the same age. Advantage was taken of the repeated measurements to fit a linear regression equation, based on at least four measurements between the ages of one and four years, for each child. Height and weight at age three years were then estimated from the individual growth curves. Growth rates decelerate during the first year of life, but they are nearly linear between the ages of one and four years (Guzmán, et al. 1968). Children were included in the study only if the linear repression accounted for over 80% of the variability in their height or weight measurements.

Linear regression equations accounted for over 95% of the variability in the height measurements of 80% of the children and failed to account for a minimum of 80% of the variability in height in only 3% of the children. The regression equations accounted for over 90% of the variability in weight measurements for 79% of the children and failed to account for a minimum of 80% of the variability in weight for 9% of the children. Departures from linearity may have occurred because of errors in measurement, because of errors in the recording of measurements, in response to environmental factors, or in response to genetically determined changes in growth rates. Since some of the children excluded were those whose growth was most severely affected by environmental factors, the present study provides conservative estimates of the influence of environmental factors on familial correlation coefficients for height and weight.

This method of estimating height and weight summarized the information available on the growth of each child for the entire preschool period and precluded estimation of familial height and weight correlation coefficients at more than one age. However, it maximized the number of children for whom height and weight at a given age could be estimated.

The children's parents were weighed and measured for height barefoot, but fully clothed. From 1959 to 1964 weight was measured on a frequently calibrated platform scale, and height was measured using a steel tape. After 1964, weight was measured on a balance scale (trademark Alvo); height was measured using a steel tape affixed to a wooden frame having a movable wooden block attached at right angles to the tape, the block resting on the subject's head. Women let down their hair, which is customarily wound into an elaborate pile on top of the head. It is unlikely that clothing introduced a large variable error in weight since standard native dress was worn by all the subjects, and there was little seasonal variation in apparel.

Approximately 30% of the parents in Santa Mariá Cauqué were weighed and measured in the course of both longitudinal studies. The correlations between measurements reported in the two studies are .80 for maternal weight, .99 for maternal height, .84 for paternal weight, and .95 for paternal height. In cases where the two measurements differed, the following guidelines were followed in recording the usual adult height and weight. All weights of women recorded during pregnancy were eliminated. The age of parents when measured was taken into consideration and in cases where the height and weight of a young parent increased between the first and second study periods in a manner suggesting that the increase was due to growth, the latter measurements were taken as the usual adult height and weight. When there were three measurements, and only two were the same, the mode was recorded; when there were two different values reported for height and weight, and no additional information to indicate which was more usual, the mean of the two values was recorded.

Fifteen per cent (95) of the study children were born to mothers younger than age 20 years. However, since the present study was limited to children at age three years and since families were followed for five years in one village and twelve years in the other, mothers' height was measured at least once after age 20 years in all but five cases. One mother was weighed and measured at age 17 years, two at 18, and two at 19. Information on fathers' age at measurement was not recorded.

Not all the parents consented to be weighed and measured for height. However, there were no significant differences in children's height or weight related to whether or not parental height and weight had been measured, which suggests that incomplete parental participation did not bias the study sample.

RESULTS:

Correlation coefficients between the parents' adult height and children's height at age three years for the rural Guatemalan population presently under investigation are given in Table 2 together with coefficients previously reported for British, U. S., and New Guinea populations.

The Guatemalan parent-child correlation coefficients for height tend to be lower than coefficients previously reported for British and U.S. populations. For example, the correlation coefficient for Guatemalan

Table 1

Average Height (cm) and Weight (kg) of Mayan Parents and their Children at Age three Years old

	Fathers			Mothers			Boys			Girls		
	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
Height	158	154.8	4.9	279	142.6	4.6	266	80.4	3.5	310	79.4	4.0
Weight	158	115.9	9.4	238	103.0	12.7	279	24.0	2.6	317	23.3	2.6

Table 2

Correlation Coefficients between the Height (supine Length) of Children at the Age of three Years and the Adult Height of their Parents (N in Parentheses)

Source of Data Subjects' Date of Birth	Boys		Girls	
	Father	Mother	Father	Mother
Berkeley Growth Study, 1928-1929 Bayley, 1954)	0.45 (25)	0.25 (25)	0.38 (24)	0.67 (24)
Edinburgh, 1950's (Thomson, 1955)		0.44 (109)		0.69 (101)
Oxford Child Health Survey, 1944-1948[1] (Hewitt, 1957)	0.245 (133)	0.294 (133)	0.395 (143)	0.383 (143)
Fels Research Institute, 1949-1952[2] (Kagan and Moss, 1959)	0.45 (91)	0.20 (84)	0.53 (69)	0.46 (76)
Child Health Center, London, 1949 (Tanner and Israelsohn, 1963)	0.40 (30)	0.43 (60)	0.17 (27)	0.61 (57)
Fels Research Institute, 1948-1962[2] (Garn and Rohmann, 1966)	0.37 (167)	0.32 (182)	0.20 (153)	0.13 (172)
Pooled data, above study[3]	0.35	0.32	0.36	0.27
Guatemala, 1955-1960; 1964-1968 (Present study)	0.320 (151)	0.222 (244)	0.228 (166)	0.256 (263)
Bundi of New Guinea, 1962-1966[4] (Malcolm, 1970)	0.16 (154)	0.32 (154)	0.17 (156)	0.23 (156)

[1]Stature rather than supine length measured and expressed in standard deviation units (Acheson, Kemp and Parfit, 1955)

[2]The latter year was estimated by subtracting four years from the publication date.

[3]A series of parent-child correlation coefficients was reported for a cohort of children who were measured at regular age intervals from birth to age 7 years. The pooled data are based on those correlation coefficients calculated at six-month intervals between the ages of 1.5 and 4.5 years.

[4]Partial correlations between parental height and child height measured between the ages of one and four years, controlling for child age.

fathers and sons is lower than in all studies shown in the table except that for Oxford fathers and sons (Hewitt, 1957). Guatemalan mother-son correlation coefficients are lower than all but the earlier Fels Institute data (Kagan and Moss, 1959). Likewise, father-daugher and mother-daughter coefficients were lower than all but the London father-daughter height coefficient, based on only 27 paired observations (Tanner and Israelsohn, 1963), and the later Fels Institute observations (Garn and Rohmann, 1966), which themselves are much lower than the pooled values from the same series.

None of the differences between Guatemalan and other father-son height correlations reported in Table 2 are statistically significant. The mother-son correlation coefficients for height reported in Edinburgh (Thomson, 1955) are significantly higher (p = .015*) than those in Guatemalans, as are the father-daughter height correlations reported in Oxford (Hewitt, 1957; p = .054) and the earlier Fels Institute Study (Kagan and Moss, 1959; p = .010). In the series of mother-daughter height correlation coefficients, all are significantly higher than the Guatemalan coefficients except those in Oxford (Hewitt, 1957) and the later Fels Institute Study (Garn and Rohmann, 1966); probability levels for the differences are as follows: Kagan and Moss, 1959 (p = .038); Tanner and Israelsohn, 1963 p = .001); Bayley, 1954 (p = .008); and Thomson, 1955 (p = .0001).

Livson, McNeill and Thomas (1962) have pooled correlations from the Berkeley (Bayley, 1954), Oxford (Hewitt, 1957), and Fels Institute (Kagan and Moss, 1959) studies together with data of their own. Reading from their graph, the correlation coefficients were approximately 0.32 for father-son pairs, 0.27 for mother-son pairs, 0.36 for father-daughter, and 0.40 for mother-daughter pairs (N = 297). The Guatemalan mother-daughter correlation for height is significantly lower than the pooled value (p = .029).

There are no significant differences between the Mayan and the Bundi parent-child height correlation coefficients, and differences between Bundi parent-daughter height correlations and those reported for industrialized countries follow the same pattern as the Mayan parent-daughter correlations. However, unlike the Guatemalans, the Bundi correlation coefficient for father-son pairs is significantly lower than those for the Ohio population (Kagan and Moss, 1959, p = .006; Garn and Rohman,

*All tests of significance pertaining to stated hypotheses are one-tailed.

Table 3

Correlation Coefficients between the Weight of Children at Age three Years and the Adult Weight of their Parents (N in Parentheses)

Source of Data Subjects' Date of Birth	Boys		Girls	
	Father	Mother	Father	Mother
Child Health Center, London, 1949 (Tanner and Israelsohn, 1963)	0.07 (30)	0.36 (60)	0.24 (27)	0.57 (57)
Guatemala, 1955-1960; 1964-1968 (Present Study)	0.336 (160)	0.296 (214)	0.229 (282)	0.192 (242)
Bundi of New Guinea, 1962-1966 (Malcolm, 1970)[1]	0.22 (133)	0.27 (133)	.05 (135)	.22 (135)

[1]Partial correlations between parental weight and child weight measured between the ages of one and four years, controlling for child age.

1966, p = .023), and the Bundi mother-son height correlation does not differ significantly from the Edinburgh or Oxford data.

Parent-child correlation coefficients for weight (Table 3) have been less frequently studied than those for height, perhaps because of the greater inherent variability in weight. Measurement errors in weight may also be greater than those for height when circumstances dictate that measurements must be made with the subjects clothed, as they were in the present study.

Despite the greater potential for variability and measurement error, there are no significant differences between Guatemalan parent-child weight correlation coefficients and those for height. As with the height correlations, mother-daughter weight correlations are significantly lower in the Guatemalan and New Guinea populations than in London (Tanner and Israelsohn, 1963), p = .001 and .004, respectively. In the London series the father-son weight correlation coefficient is smaller than that for mother-daughter pairs (p = .007), whereas in the Guatemalan series the relationship is in the opposite direction, though the difference is not statistically significant.

Sibling correlations in height and weight at age three years are summarized in Table 4.

Correlations are higher in the Oxford series (Hewitt, 1957) than in the Guatemalan for brother-sister height (p = .029), sister-sister height (p =

Table 4

Sibling-Sibling Correlation Coefficients for Height and Weight at age three Years (N in Parentheses)

	Brother-Brother	Brother-Sister	Sister-Sister
HEIGHT			
Oxford Child Health Survey (Hewitt, 1957)[1]	0.372 (23)	0.695 (33)	0.719 (27)
Fels Research Institute (Garn and Rohmann, 1966)	0.68 (70)	0.47 (137)	0.62 (93)
Guatemala, Present Study	0.530 (88)	0.448 (177)	0.438 (93)
WEIGHT			
Oxford Child Health Survey (Karn, 1957)	0.493 (79)	Sex not specified	
Oxford Child Health Survey (Hewitt, 1957)[1]	0.537 (25)	0.671 (36)	0.627 (30)
Guatemala, Present Study	0.441 (97)	0.380 (190)	0.347 (107)

[1]Height and weight were expressed in "standard deviation units" (Acheson, Kemp, and Parfit, 1955), and averaged over at least four measurements taken at six-month intervals between the ages of six months and five years.

.029), brother-sister weight (p = .015), and sister-sister weight (p = .041). The difference between the sister-sister height correlation reported by Garn and Rohmann (1966) and that for Guatemalan sister pairs approaches significance (p = .063). There are no significant differences between Guatemalan correlation coefficients and those of populations of industrialized countries for brother-brother height or weight.

A correlation in body size between parents of r would change the parent-child or sibling-sibling correlation coefficient of 0.5 to an expected value of $(1 + r)/2$ (Hewitt, 1957). Father-mother correlations for height and weight for the Guatemalan population are 0.065 (N = 152) and −0.105 (N = 124) respectively; therefore, the theoretical value of familial correlation coefficients expected in the present study would be .53 for height and .45 for weight. The 95% confidence intervals for parent-child correlation coefficients for height and weight do not include the theoretical value, whereas confidence intervals for sibling-sibling correlation coefficients do encompass the theoretical value.

Discussion

The tendency for parent-child and sibling-sibling height and weight correlation coefficients to be lower for Guatemalan and New Guinean than for British and U. S. populations is consistent with the hypothesis that familial correlations in body size are lower in rural populations of technologically less developed countries than they are in industrialized countries. The variability in parent-child correlation coefficients for height and weight in the U. S. and British studies is less easily accounted for. In smaller series, such as the Berkeley Growth Study (Bayley, 1954), a few unusual parent-child pairs might be enough to bias the results. However, there are sizable differences even in relatively large samples, drawn from the same study population, and sharing some of the same data (Kagan and Moss, 1959; Garn and Rohmann, 1966). Measurement errors may account for some of the variability, although in the Oxford Child Health Survey, the fact that fathers' heights are less accurately known than mothers (Hewitt and Stewart, 1952) has no significant effect on the parent-child height correlation coefficients, father-child coefficients differing very little from mother-child coefficients (Hewitt, 1957).

Improved nutrition and the application of modern principles of public sanitation in industrialized countries are associated with secular trends toward taller children at age three years (Meredith, 1963), greater adult body size (Tanner, 1962; Meredith, 1963) and earlier menarche (Tanner, 1965). Since menarche is closely related to skeletal age (Dreizen, et al. 1967), this would suggest that an environment which stimulates growth rates, stimulates both sexual and skeletal maturation as well, but that growth is stimulated more than maturation, for a net gain in adult height. Thus, variability in the heights of both child and parent due to secular change in the environment may partly account for the low parent-child correlation coefficients in some of the U. S. and British populations.

It might be argued that intergenerational changes in environment should not affect parent-child correlation coefficients for height and weight if the environment for each generation is homogeneous. This argument presupposes that all genotypes would respond in the same way to a changed environment, whereas there is some evidence which suggests that individuals with a genetic potential for rapid growth will suffer more on a restricted diet than those with genetically slow growth rates (Garrow and Pike, 1967; Widdowson, 1968). Thus, parent-child correlations in height and weight may be reduced when the development of children is conditioned by a changed environment, even when the change in environment is the same for all children.

The observation that sibling-sibling height and weight correlation coefficients are higher than parent-child correlations in industrialized countries, as well as in Guatemala, is consistent with the hypothesis that there were significant differences between the environment of parent and children in these populations. Between-generation shifts in social class may also have contributed to differences in the environment of parent and child.

Within industrialized countries the mother-daughter and sister-sister height correlations are relatively high in several of the studies cited, and this tendency has been attributed to greater stability of development in females. Though differences are not statistically significant, father-son and brother-brother height and weight correlations are higher among the Guatemalans than correlations including female family members. Below average weight and height correlations between female family members in the Guatemalan population, coupled with the above average correlations in some of the populations studied in industrialized countries, account for most of the significant differences between Guatemalan familial height and weight correlation coefficients and those of industrialized countries reported here.

Several explanations for this discrepancy suggest themselves. It may be that the severity of the environmental stress on the growth of Guatemalan preschool children is too great for the female canalization effect to be seen, with the result that the growth of girls is delayed as much as that of boys. This possibility is supported by the findings of Frisancho, Garn and Ascoli (1970) and of Malcolm (1970). Alternatively, boys' development may be more severely affected than that of girls', but the most severely retarded boys may fail to survive. The male/female toddler mortality rate in the highland areas of New Guinea is significantly higher than expected (Malcolm, 1970). A third possibility is that boys receive more favorable treatment than girls. It has often been observed that men in developing countries eat before the women and children and consume proportionately more of the scarce animal proteins in the diet. Even if male dominance does not consciously extend to the male children, it is reasonable to suppose that if boys develop less well than girls, mothers might attempt to compensate for their poorer growth by providing them with better food and care. A less speculative possibility is that early childbearing in women who have not completed their own growth may stunt the growth of Mayan mothers.

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