Secular trends in adult and child anthropometry in four Guatemalan villages

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Abstract

Secular trends in the stature and head circumference of adults born between 1905 and 1959 and in the length of three-year-old children born between 1965 and 1985 from four villages of eastern Guatemala are analysed. Data were collected before (1968), during (1969–1977), and after (1988) a longitudinal protein-energy supplementation trial conducted in the four villages. No secular trends are observed in the age-adjusted height or the head circumference of the adults studied; similar results are obtained whether a longitudinal or a cross-sectional method is used to correct height for the effects of ageing. A positive and significant linear trend is observed in the length of the three-year-olds. The estimated increase of 2.5–3.3 cm seen over this 20-year period represents only approximately 27% of the total deficit in length seen in these children in 1968 (11 cm).

Introduction

A secular trend of increasing stature in adults has been observed in developed countries over the last century [1, 2]. This increase in height has been attributed to general improvements in socio-economic conditions, environmental sanitation, and health care associated with industrialization which have led to improved nutrition and decreased morbidity. Very little is known, however, about trends in the stature of adults in the developing world, where poverty and insalubrious conditions remain highly prevalent. Studies in poor populations of Colombia [3], Mexico [4, 5], and Brazil [6] have documented the absence of a secular trend in adults' height. As noted by the authors, this result could be expected since these populations have experienced little change in sanitary facilities, dietary patterns, and the availability of health care over the last century [4].

The present study examines whether there is a secular trend in the height and head circumference of adults from four rural villages of Guatemala born between 1905 and 1959. The availability of anthropometric data on the same individuals measured on two occasions, with an interval of approximately 14 years, allowed us to estimate the height loss associated with ageing in this population and to correct for it in the analysis of secular trends. Various methods and correcting factors have been proposed to adjust for this well-documented phenomenon [3, 7–10], but the general consensus is that population-specific correction factors should be used when possible because of large variability between populations both in the importance of the shrinkage and in its timing. In this study, therefore, we used a longitudinal method to partition the effects of age-associated height reduction from those of secular trends. We also compared this method with a commonly used cross-sectional method based on the association between stature and subischial height [3]. Finally, we assessed the existence of a secular trend in the length of three-year-old children born between 1965 and 1985.

Methods

The data were collected by the Institute of Nutrition of Central America and Panama (INCAP) before, during, and after a longitudinal supplementation trial conducted in the four villages. During the intervention, two villages were randomly assigned to receive a high-energy, high-protein drink (*atole*) and the other two were assigned to a low-energy, non-protein drink (*fresco*). The supplements were made available at a central location for all pregnant and lactating women and all children younger than seven years. Health services were provided in all four villages throughout the supplementation period (1969–

1977). In 1988–1989 INCAP carried out a follow-up study of the participants.

Two cross-sectional surveys were also conducted in the same villages. One took place in 1968, before the intervention trial, and the second in 1988–1989 (referred to, for simplicity, as the 1988 survey), 11 years after the intervention was terminated. Data from the two surveys and from the longitudinal trial were used for the present analysis. Only relevant information about these data sets and about the analytical methodology used are presented here. The reader is referred to other publications for a detailed description of the design of the original study and data-collection procedures [11, 12].

Secular trends in adults

Height

Two methods were used to assess the existence of a secular trend in the height of adults (specifically, parents of participants of the longitudinal study, 1969–1977) born between 1905 and 1959, controlling for the effect of ageing (age-associated shrinkage). The first method took advantage of the availability of two measurements at approximately a 14-year interval on 498 adults, the first of which was taken during the supplementation trial (in 1974 ±1 year) and the second during the 1988 survey. The second method, commonly used in cross-sectional studies, is based on the high correlation between subischial height (the difference between stature and sitting height) and stature [3]. The rationale behind this method is that the length of certain long bones is highly correlated with stature and is influenced by secular trends but not by age-associated-shrinkage. For instance, stature and sitting height are assumed to reflect the effects of both ageing and secular trend, whereas subischial height reflects only the effects of secular trends [13]. This second method was used to compare the results obtained using longitudinal information with those derived from a cross-sectional data set. The availability of longitudinal information on the sitting height of women also allowed us to test whether the assumption of stability in subischial height throughout ageing was verified in this sample.

The longitudinal method involved four steps. First, the difference in height per decade was calculated for each subject using the following formula:

$$\frac{\text{height in cm}}{\text{decade}} = \frac{(\text{height in 1974} - \text{height in 1988}) \cdot 10}{\text{years between measurements}} \qquad (1)$$

Second, the mean change in height (cm/decade) was computed for each 10-year age group, based on the age of the subjects in 1988. Third, the mean changes per decade were used cumulatively to adjust each adult's height for the effects of ageing. For instance, if an adult was 51 years of age in 1988, the height was adjusted for the measured mean change per decade observed in this sample for adults between 30 and 40 years plus the mean change per decade observed between 40 and 50 years. (It was assumed that height reduction did not occur before age 30 [3].) Finally, age-adjusted heights were regressed on the year of birth, to assess the existence of a secular trend. All analyses were done separately for each sex. (Data for subjects born before 1930 are presented for men but not for women, because only parents of preschool children were measured in 1969–1977 and few mothers were born before 1930 whereas the age range for fathers was much broader.)

The 1988 data were used for the cross-sectional method, which consists of computing the partial regression coefficient of stature on age, controlling for subischial length [3]. The equation is as follows:

$$\text{height} = b_0 + b_1(\text{age}) + b_2(\text{subischial length}) \qquad (2)$$

The coefficient for age (b_1) is interpreted as being the rate of shrinkage per year (ageing effect), and is used in the following step to compute the age-adjusted height for each individual, using the following equation:

$$\text{age-adjusted height} = \text{observed height} + b_1(\text{age} - 30) \qquad (3)$$

where b_1 is the coefficient for age obtained in equation 2. Since shrinkage is assumed not to occur before the age of 30 [3], the age used in the equation is the difference between the actual age and 30 years. As in the case of the previous method, the age-adjusted height was regressed against the year of birth to test for the secular trend effect.

Head circumference

Measurements of head circumference from the 1988 survey were regressed on the year of birth, by sex, to assess the existence of a secular trend in adults born between 1905 and 1959.

Secular trend in the length of three-year-olds

Information from the three data sets was used for this analysis. The two cross-sectional surveys were used to estimate length at three years of age in 1969 and 1988 respectively, using regression analysis. Longitudinal data collected throughout the supplementation period (1969–1977) were used to compute the mean length of three-year-olds (± 7 days) for each two-year period (from 1969 to 1976) and for 1977.

The method used to estimate length at three years of age from the cross-sectional data consisted of regressing the length of all children 9–60 months old against age and age squared, and using the regression coefficients obtained to estimate length at 36 months. Separate regressions were done for each year (1968 and 1988) and treatment group (atole and fresco). The interaction between sex and treatment was not statistically significant and therefore the analyses were done with both sexes combined.

The analysis of a secular trend in the children was complicated by two aspects related to the nature of the data available. First, because of the use of both estimated and observed length values, the assumption of equal variance could not be made. Second, because of unequal spacing between measurements, coefficients commonly used to estimate linear and quadratic trends could not be used [14].

The first problem was addressed by calculating separate estimates of variance for the longitudinal and cross-sectional data. For the longitudinal data, analysis of variance was used to estimate the variance of a model that included treatment (fresco, atole) and cohort (data collection years), and the two-way interaction term between these variables. The variance estimate obtained was 15.50. For the cross-sectional data, separate regressions of length on age were done for each treatment and data-collection period (1968, 1988). The variance estimates obtained ranged between 13.97 (fresco, 1968) and 19.78 (atole, 1988).

The problem of unequal spacing between measurements was addressed by using the method proposed by Robson [15] to construct special polynomials for unequally spaced data. The formulae used for the estimation of contrasts (L) and their variance (V) are presented in the appendix (p. 252), which also shows an example of the methodology used. Two sets of confidence intervals were calculated for all contrasts, one using the smallest variance obtained (13.97) and one using the largest one (19.78). Since the results were similar in terms of the statistical significance of the various contrasts, only those using the largest variance estimate are presented. All analyses were done using the micro-computer version of SAS, release 6.03. Probability values smaller than or equal to .05 were considered statistically significant.

Results

Secular trends in adults

Height

The comparison of adults' heights measured at two different times (1974 ±1 year and 1988) shows a decrease in height during this interval, beginning between the ages of 41 and 50 years in men and between 31 and 40 years for women (table 1). As seen in figure 1, the mean reduction over 10 years increased with age but in a non-linear fashion: in men, for instance, the reduction was approximately 0.5 cm per decade between the ages of 41 and 60 but was about three times larger during the next two decades (−1.38 between 51 and 60 years and −1.60 between 61 and 70). As expected, linear regression analysis of height change on age provided a poor fit of the data, and the usual linearizing transformations (logarithmic and exponential) did not improve the fit.

The age-specific estimates of height changes per decade were used cumulatively to correct the 1988 heights for the effects of ageing. The correction factors used for each age group and sex are presented in table 2. The age-adjusted heights were then regressed against year of birth to examine the presence

TABLE 1. Unadjusted and age-adjusted heights of adults (centimetres) by age group and sex

Age in 1988 (years)	N	Height		Change per decade	Age-adjusted height	
		1974 ± 1 yr	1988–89		Method 1[a]	Method 2[b]
Males						
<41	26	160.71 (5.23)	160.76 (5.42)	+0.05 (0.69)	160.76 (5.42)	161.60 (5.42)
41–50	79	160.75 (5.79)	160.04 (5.48)	−0.49 (0.81)	160.48 (5.48)	161.68 (5.49)
51–60	71	159.32 (5.51)	158.53 (5.47)	−0.55 (0.90)	159.52 (5.47)	161.10 (5.42)
61–70	37	161.43 (5.27)	159.44 (5.31)	−1.38 (0.89)	161.81 (5.31)	162.93 (5.29)
≥71	11	159.00 (6.31)	156.71 (5.58)	−1.60 (1.29)	160.68 (5.58)	161.31 (5.59)
Females						
<41	110	149.49 (5.11)	148.27 (5.21)	−0.85 (0.86)	149.12 (5.21)	149.00 (5.32)
41–50	102	148.78 (5.34)	147.28 (5.33)	−1.04 (0.90)	149.17 (5.33)	149.02 (5.40)
≥51	62	148.55 (5.14)	146.30 (5.34)	−1.55 (1.19)	149.74 (5.34)	149.06 (5.34)

a. Longitudinal method. b. Cross-sectional method.

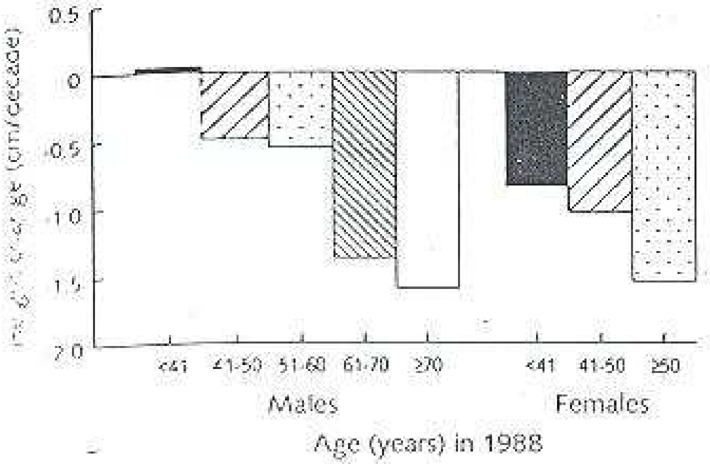

FIG. 1. Mean change in the stature of adults between measurements in 1974 and 1988, by sex and age group

TABLE 2. Correction factors used to adjust the 1988–1989 height of adults by the longitudinal method

Age group (years)	Age-corrected height
Males	
31–40	no adjustment
41–50	observed height + (−0.05 + 0.49) = 0.44
51–60	observed height + (−0.05 + 0.49 + 0.55) = 0.99
61–70	observed height + (−0.05 + 0.49 + 0.55 + 1.38) = 2.37
≥71	observed height + (−0.05 + 0.49 + 0.55 + 1.38 + 1.60) = 3.97
Females	
31–40	observed height + (0.85)
41–50	observed height + (0.85 + 1.04) = 1.89
≥51	observed height + (0.85 + 1.04 + 1.55) = 3.44

secular trends in the heights of men and women respectively. Figure 2 presents the age-adjusted heights by birth cohort and clearly shows the absence of change over time for both sexes. The regression analysis confirmed that birth year was not a significant determinant of age-adjusted height in adults.

The cross-sectional method using subischial height provided age-adjusted heights very similar to those obtained by the longitudinal method. The regression of age-adjusted heights on birth year also demonstrated the absence of secular trends between ... and 1959. The coefficients obtained for the ageing effect (b_1 in equation 2) were −0.10 cm per year for men and −0.11 cm per year for women, and the coefficients for subischial height were 1.254 and ... for men and women respectively.

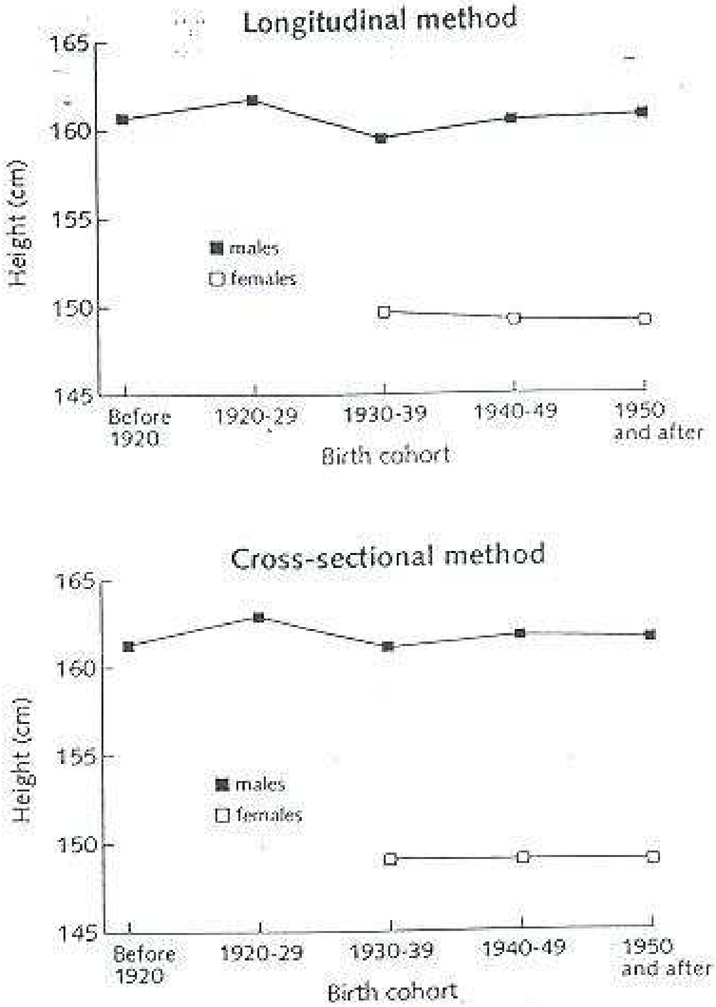

FIG. 2. Secular trends in the stature of adults, corrected for age-associated shrinkage by longitudinal and cross-sectional methods

Analysis of the change in women's subischial height over time revealed a constant and minimal decrease of approximately 0.05 cm per decade. The assumption that the shrinkage associated with ageing originated mainly from the upper portion of the body was thus verified in this sample.

Head circumference

Figure 3 shows the absence of any secular trend in adults' head circumference (confirmed by the regres-

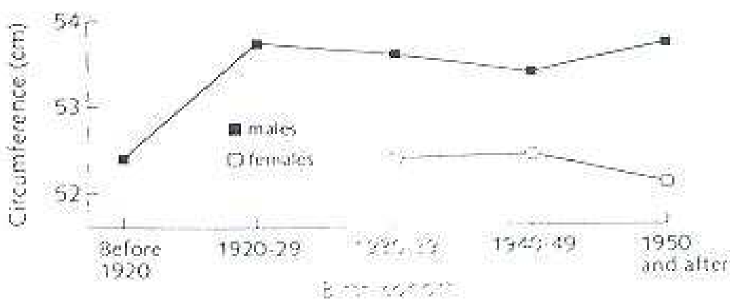

FIG. 3. Secular trends in the head circumference of adults

TABLE 3. Length of three-year-old Guatemalan children (centimetres) by treatment and year of data collection

	Atole			Fresco		
	N	Mean	SD	*N*	Mean	SD
1968[a]	196	85.14		179	84.70	
1969–70	82	85.53	3.69	78	84.82	4.50
1971–72	100	86.58	4.17	101	84.63	4.02*
1973–74	117	86.09	3.56	110	84.46	3.94*
1975–76	117	86.86	3.83	101	84.69	4.11*
1977	35	86.55	3.54	39	85.23	3.66
1988[a]	344	87.62		363	87.99	

a. The means in 1968 and 1988 were estimated by regressing the length of children 9–60 months old on age and age squared, using ordinary least squares. Separate regressions were done for each year (1968 and 1988) and treatment group (atole and fresco).

*Differences between the atole and fresco groups statistically significant at the $p < .05$ level.

FIG. 4. Secular trends in the length of three-year-old children, by supplement type (The estimates and confidence-interval limits of the linear and quadratic contrasts used to test secular trends were as follows. Atole: linear, 1.85 ± 0.61 [1.24, 2.46]; quadratic, −0.54 ± 0.98 [−1.52, 0.44]. Fresco: linear, 2.71 ± 0.61 [2.10, 3.32]; quadratic, 1.33 ± 0.99 [0.34, 2.32].)

sion analysis of head circumference on birth year). This corroborates the absence of a secular trend in height found in this population.

Secular trend in the length of three-year-olds

A positive and statistically significant linear trend in the length of three-year-olds between 1968 and 1988 was observed for both treatment groups (table 3 and fig. 4). In the fresco group, the quadratic term was also statistically significant, which corresponds to the slight decrease in length observed between 1969 and 1974, followed by a positive linear trend thereafter. In addition, during the supplementation years (1969–1977) the length of children from the atole villages was consistently greater than that of children from the fresco villages, and this trend disappeared after the supplementation period. In fact, the differences were seen only during the supplementation years, and they were not statistically significant at baseline (1968) and in 1988. (The difference between treatments was tested by including treatment in a regression model of length on age and age squared. Treatment was not statistically significant in either 1968 or 1988.)

Overall, the length of three-year-olds increased by 2.5 cm (atole) and 3.3 cm (fresco) in the 20-year period.

Discussion

The present analysis of secular trends covers two different populations and time periods: adults born between 1905 and 1959 and three-year-old children born between 1965 and 1985. In the adults, no secular trend was observed for either age-adjusted height or head circumference, whereas for children's length a significant positive trend was seen in the four villages studied. There were no reasons to expect similar trends for adults and children, not only because the time periods covered were different but also because the children were measured during an intervention trial that was intended to affect their growth. Therefore, the remainder of the discussion proceeds separately for adults and children.

Secular trends in adult height and head circumference

The availability of two measurements of adults' height with an approximate interval of 14 years allowed us to estimate the age- and population-specific effect of ageing on height reduction. The importance of using an age-specific correction factor was highlighted by the fact that reduction in stature was not linearly associated with age, particularly in men. Previous studies have documented a similar non-linear relationship [7, 10]. Despite this, in the absence of longitudinal information, most studies of secular trends use cross-sectional data and a correction factor that assumes a linear relationship between shrinkage and ageing.

Our study also illustrates the importance of using a population-specific correction factor, since both the magnitude and the timing of the age-associated shrinkage in our population differed from previous reports. In men, the magnitude of the cumulative ageing effect on height reduction was higher than that in previous longitudinal studies. We estimated a cumulative reduction of approximately 4 cm between 30 and 70 years of age, which was slightly higher than previously documented levels of 3.6 cm [7], 3 cm [10], and 2.8 cm [16]. In our sample of women, the height reduction occurred earlier (before the age of 40) and was of larger magnitude (3.44 cm between 20 and 50 years) than previously reported. Other studies have found the reduction starting only in the early fifties [10] and being approximately 1 cm by 50 years of age [7]. Differences in the timing and magnitude of the height reduction have been related to population differences in initial height, socio-economic factors, bone mineralization, and osteoporosis and vertebral fractures [8, 17, 18]. Low socio-economic status, poor bone mineral status, and a high frequency of osteoporosis and fractures and deformities caused by hard physical work are potential explanations for the higher and earlier stature reduction in our Guatemalan sample, particularly in women.

The comparison of our longitudinal method with the cross-sectional method commonly used to correct for age-associated height reduction provided surprisingly similar results: the age-adjusted means were very comparable, and both methods agreed in showing the absence of a secular trend in the four villages. These results are encouraging, suggesting that little or no bias is introduced by using the cross-sectional method based on the assumption of a linear relationship between stature loss and ageing, even though the assumption is incorrect. Considering the scarcity of available longitudinal data sets for the analysis of secular trends, it is useful to know that cross-sectional data sets can be used with some confidence.

Another assumption of the cross-sectional method that could be tested in the women of the present study was the absence of reduction in subischial height associated with ageing (absence of shrinkage of the lower portion of the body). Only a minimal decrease was observed, on the order of approximately 0.05 cm per decade, and it was independent of age. This difference could be attributable to a systematic measurement bias in the 1988 data collection, since a single anthropometrist took all the measurements then, whereas a team was used for the 1974 measurements. If this was the case, systematic bias could cause an overestimation of the shrinkage effect on total height of approximately 0.05 cm per decade for each age group, which would cumulate to an overestimate of 0.15 cm for the older subjects (51 years old or over). The magnitude of this effect is small and represents only about 4% of the estimated cumulative shrinkage experienced by women in this age group.

This analysis could not be done for men because of the unavailability of sitting height information for 1974. However, the slight increase in height (0.05 cm per decade) observed between 20 and 30 years of age suggests that systematic underestimation of height in 1988 did not occur. In this survey, men and women were measured by a different anthropometrist. It is thus possible that the individual assigned to women systematically underestimated height, whereas the one assigned to men did not. If such a bias existed, however, its overall impact would be negligible, as discussed above. Nevertheless, it would have been interesting to examine shrinkage of the lower part of the body in our sample of men since a previous study (of men only) did document that some shrinkage occurred between the ages of 25 and 82 years, and that the amount increased with age until the age of 75 [16].

The absence of secular trends in adult stature between 1905 and 1959 was as documented for other developing countries [4-6]. Although some improvements in global health and nutrition indicators occurred in Guatemala during this period, improvements in environmental sanitation, health care, and food security at the household level appear to have been insufficient to produce an increase in adult stature over time.

In summary, our results suggest that all of the apparent increase in adults' height between 1905 and 1959 was due to an ageing effect rather than a secular trend. The findings were similar whether a longitudinal or a cross-sectional approach was used to correct height for the effects of ageing. The absence of a secular trend in head circumference corroborates the results obtained for height.

Secular trend in the length of three-year-olds

For three-year-olds born between 1965 and 1985, a positive and significant linear trend in length was observed. Interestingly, no differences were seen between children from the atole and fresco villages before the intervention and 12 years after its termination, but clear differences in favour of the atole villages were found throughout the supplementation period. This suggests that the higher rate of length increase seen between 1969 and 1977 in the atole villages was caused by the intervention. Because of the absence of data between 1977 and 1988, however, it is impossible to quantify the rate at which the deceleration in the changes in length occurred in the atole villages after the supplementation ended.

Interpretation of the results on secular trends in children was complicated by the absence of data on control villages or on the region as a whole. Such information would be helpful to determine whether the trend seen in the fresco villages during the intervention period (specifically between 1973 and 1977) was due to the health services offered by INCAP in all villages or whether it reflected overall improvements in standards of living in the region. It would also facilitate the interpretation of the positive trend seen after the intervention trial. Although it is more likely that the trends observed during this period are attributable to overall improvements in schooling, infrastructure, and availability of services in the villages [19], a possible long-term effect of INCAP's presence cannot be ruled out. Quantification of this effect is impossible in the absence of information on other villages from the region.

Overall, the estimated increase in the length of three-year-olds over the 20-year period ranged between 2.5 and 3.3 cm. This improvement represents only approximately 27% of the total deficit in length (11 cm) seen in these children in 1968, compared with the fiftieth percentile of the reference standards [20]. Effects of this magnitude were obtained at the community level with a caloric supplementation of approximately 10% of the recommended daily intake [21] provided during the first three years of life.

Appendix: Calculation of linear and quadratic contrasts

The following formulae were used to calculate the contrasts (L) and their variance (V) and confidence intervals (CI) [22] used in estimating secular trends in the length of the three-year-old Guatemalan children studied:

$$L = \Sigma c_i X_i$$
$$V = [\Sigma c_i^2/n_i]s^2$$
$$CI = t\sqrt{(s^2 \Sigma c_i^2/n_i)}$$

where

c = coefficients (see below)
$\bar{X}$ = mean length at three years of age
n = sample size
i = time of measurement (= 7)
s^2 = estimated variance

The coefficients were obtained by the method proposed by Robson [15] for the construction of polynomials for unequally spaced data (table A1).

As an example of the use of the methodology, we show the calculation of the linear contrast and its confidence interval for the atole group. Table A2

TABLE A1. Coefficients for linear and quadratic contrasts

		Coefficients	
	Spacing	Linear	Quadratic
1968	0	−0.43	+0.56
1969–70	2	−0.31	+0.20
1971–72	4	−0.19	−0.07
1973–74	6	−0.06	−0.28
1975–76	8	+0.06	−0.41
1977	9	+0.12	−0.44
1988	20	+0.81	+0.44

TABLE A2. Calculation of $\Sigma c_i X_i$ and $\Sigma c_i^2/n_i$

	$c_i X_i$	c_i^2/n_i
1968	85.14 × −0.435801	$-0.4358^2/196$
1969–70	85.53 × −0.311286	$-0.3113^2/82$
1971–72	86.58 × −0.186772	$-0.1868^2/100$
1973–74	86.09 × −0.062257	$-0.0622^2/117$
1975–76	86.86 × +0.062257	$0.0622^2/117$
1977	86.55 × +0.124515	$0.1245^2/35$
1988–89	87.62 × +0.809345	$0.8093^2/344$
Σ	1.85	0.0049

gives the calculation of the summations $\Sigma c_i X_i$ and $\Sigma c_i^2/n_i$. From this:

$$L = \Sigma c_i X_i = 1.85$$

Then, using $s^2 = 19.78$,

$$V = [\Sigma c_i^2/n_i]s^2 = 0.097$$

and

$$CI = 0.61$$

Thus, the contrast = 1.85 ± 0.61 (1.24, 2.46).

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