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The Impact of Season and Climate on Growth during Early Childhood in Different Socio-economic Groups in Lahore, Pakistan.

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ABSTRACT

Aim. The aim of this study was to analyse the impact of season and climate on early child growth in four socio-economically different groups living in Lahore, Pakistan.

Methods. A prospective cohort study was conducted among children living in a village, periurban slum area, urban slum area and a group of children from the upper middle class. Monthly observations were made on 1476 infants from birth to 24 months. Growth in terms of length and weight were analysed in relation to age, socio-economical group, and season of the year and different climate variables such as rain, day temperature and humidity. The longitudinal data was analysed by the derived variable method and regression models.

Results. Season of birth did not have any important impact on the birth weight or length. There were differences in weight gain during the first six months as well as between 6-12 months, depending on which time of the year the child was born. This seasonal differences was most prominent in the poorer groups. The climate variable mean day temperature was negatively correlated to weight gain with a p-value<0001 for the regression coefficient in all groups except for the upper middle class. In the poorer groups the impact increased with age up to 14 months and decrease with higher ages. Growth velocity concerning length was not clearly related to season and climate. In the upper middle class neither season nor climate markedly affected weight or length velocity.

Conclusions. Season and climate are modifying growth. The socio-economic level and the age of the child influence the impact of climate on growth. Together with age, sex and length of gestation, season is an important factor when comparing growth of children living in poor environments.

INTRODUCTION

Growth during the first year of life is rapid and can easily be negatively affected by external factors. Studies in developing countries have shown a higher incidence of disturbed growth and development, as well as higher morbidity and mortality among children under

24-months of age compared to other age groups.^{1, 2, 3} Genetic predisposition and other intrinsic factors determine growth, but extrinsic factors are important in modelling attained growth. It has repeatedly been shown that the socio-economic situation, such as housing-standard, family income, educational status of the parents⁴ and feeding patterns,⁵ are of significance for early child growth in developing countries.⁶

Several studies have demonstrated that the pattern of growth of breast-fed infants differs from that of the WHO/CDC reference and of infants fed currently available formulas.^{7, 8} The most typical pattern for breastfed infants is to grow as rapidly or more rapidly than the WHO/CDC reference during the first 2-3 months, but thereafter they show a relative deceleration. Currently used growth charts throughout the world for monitoring growth of children are based on the US National Center for Health Statistics reference data. The adequacy of these data has been questioned. It does not take into account infant feeding practices in modelling the growth.⁹ Season of the year, which has been shown to influence early child growth,¹⁰ is neither adjusted for in growth charts. The implications of climatic seasonality have not so far been related to growth in length, weight or weight for height. Seasonal variations are not commonly adjusted for in models describing early child growth.

In a community-based prospective cohort study of young children in Lahore, Pakistan, we show that the climate variable temperature affects growth velocity and that the impact of the temperature on growth varies for groups at different socio-economic levels in a developing country.

MATERIAL

Study Population

Lahore, the second largest city in Pakistan, can be considered a typical expanding city in the third world with migration from villages to slumareas at the outskirts of the city and from there to more organised and steady living in the city slum areas. The study population was selected according to this and consisted of 1476 longitudinally followed infants born between September 1984 and March 1987, composed of four selected groups from a village, a periurban slum area, an urban slum area and an upper middle class group. The urbanised upper middle class group functioned as the control group. The study design is described in detail elsewhere.¹¹

The first group was selected from a typical village about 40 km from Lahore. The periurban slum was selected from a mud hut area along a railway track, on the periphery of the city. A typical segment of people living in the old walled city comprised the third group - the urban slum area. The upper middle class group was scattered around the city.

An initial cross-sectional survey, including a population of around 5000 from the three areas, was initiated in March 1984. During this survey 2998 households were identified and basic socio-economic and demographic data were obtained. A total of 1607 pregnancies were registered over a period of 30 months, including 240 pregnancies selected from the upper middle class. Out of these, 117 pregnant mother either refused to participate, or moved. Thirty-six pregnancies ended in stillbirth and thus 1476 newborn infants were included in the cohort. The children from the upper middle class were selected through private obstetric clinics, with the inclusion criteria of having 3 or less than 3 children, an income above US \$ 275 per month, of owning a house with more than three bedrooms and of both the parents having at least ten years of schooling.

The new-borns were examined immediately after birth and were then followed by monthly home visits up to the age of 24 months. Attempts were made to record all major diseases during the past month. In addition to this, information on feeding, growth, psychomotor development and childcare practices was collected. A doctor together with a health worker made the examinations. Of the 1476 children entering the study, 485 came from the village, 398 from the periurban slum, 353 from the urban slum and 240 from the upper middle class. Of the live born, 159 (11%) died before reaching the age of 24 months and 289 (20%) moved from the area, or refused to participate in the study. At 24 months of age 1028 children (70%) were still in the study. The total number of examinations performed in our analysis was 21 200. We did not adjust for gestation length and sex in modelling the growth.

Family Characteristics

The four different selected groups showed different patterns in the family structure. For example, the birth order of the children included in the study varied between the four selected groups. The mean family size varied from 5.3 in the upper middle class to 6.8 in the village. The mean maternal age was 28 years and similar in the four groups. The families in the urban slum group had better housing standards, and were on a higher parental educational and economic level than in the other two poor areas. The socio-economic levels and housing standards along with family attitudes toward childcare and hygiene have been described elsewhere.^{12, 13}

Climate

The changes in climate over the year are substantial. The temperature, humidity and rain showed seasonal variations across the study years. The seasons are commonly divided in a 'temperate/cold' season including November, December, January and February, a 'warm' season, including March, April, September and October and a 'hot' season, including May, June, July and August.

The mean values of humidity at 5 a.m. and 5 p.m., maximum and minimum temperature and amount of rain for each month from January 1985 to December 1987 were obtained from the local meteorological office.

METHODS

Notation.

The response variable 'weight gain' was the individual gain in weight for the period of interest measured in hectograms (hg). 'Length gain' was the individual gain in body length for the period of interest. 'Weight for length' was 'weight gain' divided by 'length gain'. The climate variable 'temperature' was measured as the monthly mean of the lowest day temperature in degrees Celsius. Group number 1, 2, 3 and 4 refer to the village, the periurban slum, the urban slum and the upper middle class group.

Examinations

Health workers visited the children at home every month, collecting data. The health workers were specially trained in taking body measurements - weight, length and head circumference - in a standardised manner. During the research period the health teams were retrained once every month. The way of taking the body measurements was crosschecked between both the workers and the equipments. A difference of 100 g for weight and less than 1.0 cm for length and head circumference was acceptable. The weighing and measuring equipments were checked weekly and maintained by a trained mechanic. Pretested and standardised questionnaires were used to collect information concerning incidence of diarrhoeal episodes for the children in the study. All cases where the child had had more loose stools, or one or more watery stools per day during the period since last visited were

registered as cases of diarrhoea during the previous month. The duration of the episodes was not used in the analyses.

Statistical analyses

The analysis is explorative; thus no tests of hypotheses have been made. However, in some cases p-values are given as descriptive measures of the amount of information.

Our data are longitudinal. The children under study were followed in time with repeated observations as shown in figure Figure 1. At the preliminary modelling stages though, all observations were analysed cross-sectionally without regard to the longitudinal nature of the data in order to achieve a first overview. Linear regression analysis was used to model the relationship between 'weight gain' (dependent variable) and 'temperature' (independent variable).

Since the temperature varies in a cyclic manner through the year a multiple regression model with sine and cosine values of the calendar months as independent variables and 'weight gain' as dependent was evaluated in the following way:

The number of the months $\{1,12\}$ was transformed into values (t) within the range $\{0, 2\pi\}$. Then a graph of the equation $A\cos(t+B)$ was fitted to the seasonal variations in 'weight gain'. B allows the graph of $\cos t$ to be shifted B units horizontally and A allows vertical scaling of the graph, According to the Addition formula:

$$\begin{aligned} A\cos(t+B) &= A\cos t \cos B - A\sin t \sin B = \\ &= A\cos B \cos t - A\sin B \sin t \\ &\quad \left. \begin{array}{l} A\cos B = \beta_1 \\ A\sin B = \beta_2 \end{array} \right\} \Rightarrow \\ \Rightarrow A\cos(t+B) &= \beta_1 \cos t - \beta_2 \sin t \end{aligned}$$

By adding an intercept (β_0) to the model the graph can be shifted vertically. Our model was then:

$$\text{'weight gain'} = \beta_0 + \beta_1 \cos t - \beta_2 \sin t$$

This was done as a preliminary stage in order to compare the fit obtained in this model with the one from the model with climate variables as explaining variables.

A longitudinal approach ¹⁴ was then adopted for most analysis in order to describe change over time within individuals. One of the reasons for this was to be able to distinguish cohort and ageing effects. The variations between children due to unmeasured variables cause difficulties at the interpretation of the estimate of a cross-sectional regression coefficient. Also, the estimate of variance is a problem in cross-sectional analysis because successive individual measurements are related to each other. Instead the derived variable method was chosen to analyse how the individual growth rate is related to a climate variable. The regression coefficient of the individual multiple regression with 'weight gain' as dependent variable and 'temperature' and age in months as independent variables was considered a good summary statistic as it estimates the average impact of the explaining variables. This first step reduced the repeated measures of each individual to one summary variable. In a second step the summary variable created in the first step was analysed.

The SAS Statistical software was used when analysing the data.

RESULTS

As will be demonstrated in detail below there is a difference in 'weight gain' per month depending on the 'temperature' exposing the children living in the village, the periurban slum and the suburban slum. No relation between 'weight gain' and 'temperature' could be found among the children from the upper middle class group. Furthermore the impact of 'temperature' on 'weight gain' was different depending on the child's age.

The time of birth did not seem to affect the weight at birth and the pattern did not differ much between the different groups as shown in Figure 2.

The impact of season on 'weight gain' during the child's first six months was studied in the different groups. In Figure 3a all the groups were pooled and no significant differences in weight gain were detected. When the groups were studied separately we found that children born at the end of the 'hot' season had a higher weight gain during the first six months of life in group 1, 2 and 3. This was most pronounced in the village. The upper middle class children born after the 'cold/temperate' season showed the highest weight gain during the first six-month of life as shown in Figure 3b.

The 'weight gain' from six to twelve months of age is described in Figure 4 and it was clearly different according to birth month. The children born at the end of the 'temperate/cold' season and especially those born during the first months of the year (with an age of 6-12 months during later months of the year) seemed to have the highest weight gain in all groups, except the upper middle class where no obvious pattern was detected.

The impact of 'temperature' on 'weight gain' in different groups was demonstrated by linear regression. At this stage the longitudinal character of the data was not considered. The p-values should thus only be considered as rough indicators. In the village a temperature rise of one degree diminished the 'weight gain' by 0.1 hg per month. The children in the periurban slum had their 'weight gain' diminished by the same amount. In the urban slum the amount was 0,07 hg per month. This pattern was not evident in the upper middle class group. Here a temperature rise of one degree increased the 'weight gain' by 0.006 hg per month. In the village, the periurban slum and the urban slum the regression coefficient had a p-value < 0.0001, but for the upper middle class the p-value was 0.55. For the climate variables rain and humidity no relation to 'weight gain' was evident.

The relationship between 'temperature' and 'weight gain' per month was different according to the age of the child. When dividing the children into subgroups according to age in months and socio-economic group, an age specific pattern emerged. A newborn child's weight gain was not strongly influenced by day temperature in any groups. As an example, the linear regression in (Figure 5) uses only the data of children who are 19 months old and comes from the village. They had an impact on 'weight gain' by -0,18 hg per month for a temperature raise of one degree. To highlight the mean pattern of how age affects the relationship between 'temperature' and 'weight gain' the regression coefficient was calculated for each age in the same way as in Figure 5. The regression coefficients are plotted against age in Figures 6a-d. A smoothing spine was fitted to the data. With increasing age the children in the village, periurban slum and urban slum had a more negative relationship between 'temperature' and 'weight gain'. No evident pattern was found among the upper middle class children.

When using 'length gain' as response variable and 'temperature' as regressor no strong relationship was observed in any groups. Division into subgroups according to age did bring forth a pattern in the urban slum where the impact of 'temperature' was increasingly negative for higher values as shown in Figure 7c. In the village, the periurban slum and the upper middle class no clear relation between 'temperature' and 'length gain' could be seen as described in Figure 7a, 7b, and 7d.

'Weight for length' as response variable and 'temperature' as regressor was evaluated in a regression where every age group was treated separately as above. No significant pattern was displayed.

Impact of 'temperature' and 'age' (regressors) on 'weight gain' (regressand) as measured in a derived variable model is examined in (Table 1). The results show a negative relationship between growth rate and temperature in the village, a temperature rise of one degree diminishes the 'weight gain' by 0,13 hg per month (std. err. =0,07), in the periurban slum the relation was -0.16 hg per month (std. err. =0.05) and in the suburban slum -0.25 hg per month (std. err. =0.11). In the upper middle class the relationship was also negative -0.23 hg per month but the standard error was large (std. err. =0.22), hence this regression coefficient was not significant.

The regression with 'weight gain' as dependent variable and the sinus and cosinus values of the transformed calendar month as regressors is presented last. The village, periurban slum and suburban slum show a similar pattern whereas the upper middle class differs in both amplitude and phase as shown in Figure 8. The coefficient of determination, R^2 value of this model was 0.05. In the 'cross-sectional' regression model with 'temperature' as regressor this value was 0.04.

The mean incidence of diarrhoeal episodes in relation to calendar month was studied. This reveals a pattern with a higher incidence rate during the warm part of the year. This pattern is common to all groups, although less pronounced in the upper middle class (Figure 9).

DISCUSSION

In this study we show that variations in seasons affect early child growth in a developing country as described earlier.^{2, 10} A longitudinal analysis of our material adds the observation that this effect could be explained by the climate variable minimum day temperature. The impact of the mean day temperature on growth velocity differed according to socio-economic standard, as well as age. Children living in Lahore at a low socio-economic level are more affected in their growth velocity than the children living in the upper middle class. This is most prominent concerning weight gain but to some extent also noticeable in

length and weight for length. We propose that mean lowest day temperature of the month can be chosen as a continuous variable describing the seasonal influence on growth.

Growth regulation has in the industrialised world been shown to be affected by external factors, such as nutrition, physical activity or the light and dark cycle, which may vary during the year. It is well known that mean height velocity is higher in the summer than in the winter.¹⁵ A reduced length gain a few months after the summer has been described in developing countries.^{10,16} In our study we could not show that length was considerably influenced by the season although there was a tendency for children over 1 year of age to show a declined length velocity at higher temperatures, most clearly shown in group 3. This might be explained by the fact that as the children get older and spend more time outdoors where they may be more vulnerable towards the climate. Lower leg length velocity has been shown to be a sensitive measure to detect seasonal variations,¹⁷ but this measure was not used in our study. Length is a more stable variable than weight and it is not so closely related to nutritional status as weight.⁷

The children in the poorer groups in the study had a low weight gain during the hot season which agrees with several other studies showing a reduced weight gain during the summer months.^{16,18} Seasonal effects of weight gain have been reported to be attenuated over time along with increasing affluence in a developing society,¹⁹ and we show a different seasonal impact at different stages of urban migration. The reduced weight gain during higher temperatures in our study follows the prevalence of diarrhoeal disease during the same time in these groups. Diarrhoeal disease is affecting weight gain for young children and damage to the small intestine has been proposed to be a key feature in the pathogenesis to this faltering in growth.²⁰ However external factors as high temperature enhances the contamination of food and fluids which might be the reason for the higher prevalence of diarrhoeal disease during the hot season. The impact of temperature on weight gain was higher in children over 1 year of age after the time of weaning. Although little information is available it has been reported that breast-feeding might attenuate the seasonal variation in diarrhoeal disease.²¹ The causal relationship between diarrhoeal disease, breastfeeding and growth is to be further investigated in our material.

Temperature might be used as a variable in studies of short-term growth. Several models have been proposed for modelling seasonal influence when studying different health factors changing over time.^{22,23} The use of sin-cos model is appropriate in detecting seasonal variation²², although it describes variation over time mechanically, using a mathematical

function. Since the annual variation of 'temperature' looks similar to the pattern in the sin-cos regression (peaks in June and December), 'temperature' might be the variable most closely related to the cyclicity in the sin-cos model. The proposal that we put forward is that day temperature can be used as an easy continuous variable when there is a need to adjust for seasonal influence.

The season of the year has a major, but in research often neglected, impact on early child health. When studying determinants of child health in a developing country the implications of climatic seasonality are of major importance.^{24, 25, 26} In this study we show that children living in socio-economically poorer groups are more vulnerable towards the effect of climate regarding their weight gain. The impact of the climate on weight gain is age dependent. Together with age, sex and length of gestation season must be considered when comparing growth of children living in poor environments.

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Legends to figures

Figure 1

Weight by age for two boys in the study showing examples of development over time. Boy no 461 was breastfed during the whole study period. Boy no 791 was not breastfed at all. Both boys came from the village.

Figure 2

Mean birth weights at time of birth for the different study groups.

Figure 3a

Influence of the season on the 'weight gain' during the first six months, all groups pooled.

Figure 3b

Influence of the season on the 'weight gain' during the first six months for the different study groups.

Figure 4

Influence of the season on the 'weight gain' during six to twelve months for the different study groups.

Figure 5

Relation between 'mean weight gain and 'mean monthly minimum temperature' in the village (group 1) at an age of 19 months.

Figure 6a

Impact of 'temperature' on 'weight gain' measured by the regression coefficients by age in months for the children living in the village (group 1). Spline with 60% smoothing.

Figure 6b

Impact of 'temperature' on 'weight gain' measured by the regression coefficients by age in months for the children living in the periurban slum (group 2). Spline with 60% smoothing.

Figure 6c

Impact of 'temperature' on 'weight gain' measured by the regression coefficients by age in months for the children living in the urban slum (group 3). Spline with 60% smoothing.

Figure 6d

Impact of 'temperature' on 'weight gain' measured by the regression coefficients by age in months for the children in the upper middle class (group 4). Spline with 60% smoothing.

Figure 7a

Impact of 'temperature' on 'gain in length' measured by the regression coefficients by age in months for the children living in the village (group 1). Spline with 60% smoothing.

Figure 7b

Impact of 'temperature' on 'gain in length' measured by the regression coefficients by age in months for the children living in the periurban slum (group 2). Spline with 60% smoothing.

Figure 7c

Impact of 'temperature' on 'gain in length' measured by the regression coefficients by age in months for the children living in the urban slum (group 3). Spline with 60% smoothing.

Figure 7d

Impact of 'temperature' on 'gain in length' measured by the regression coefficients by age in months for the children in the upper middle class (group 4). Spline with 60% smoothing.

Figure 8

Sin-cos regression of 'weight gain' on 'month of examination' for the different study groups.

Figure 9

Average number of diarrhoeal episodes versus calendar month for children in the different study groups.

Figures

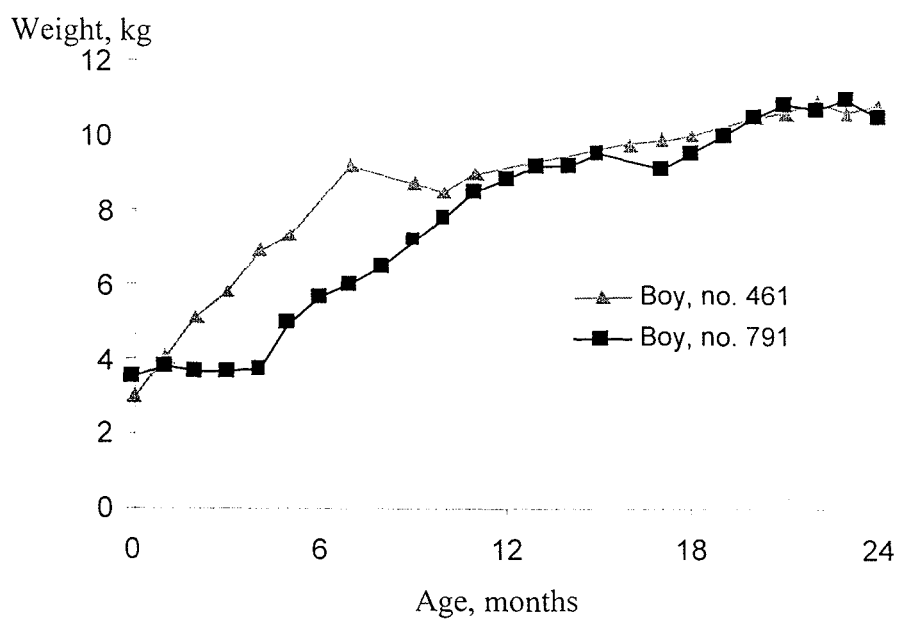


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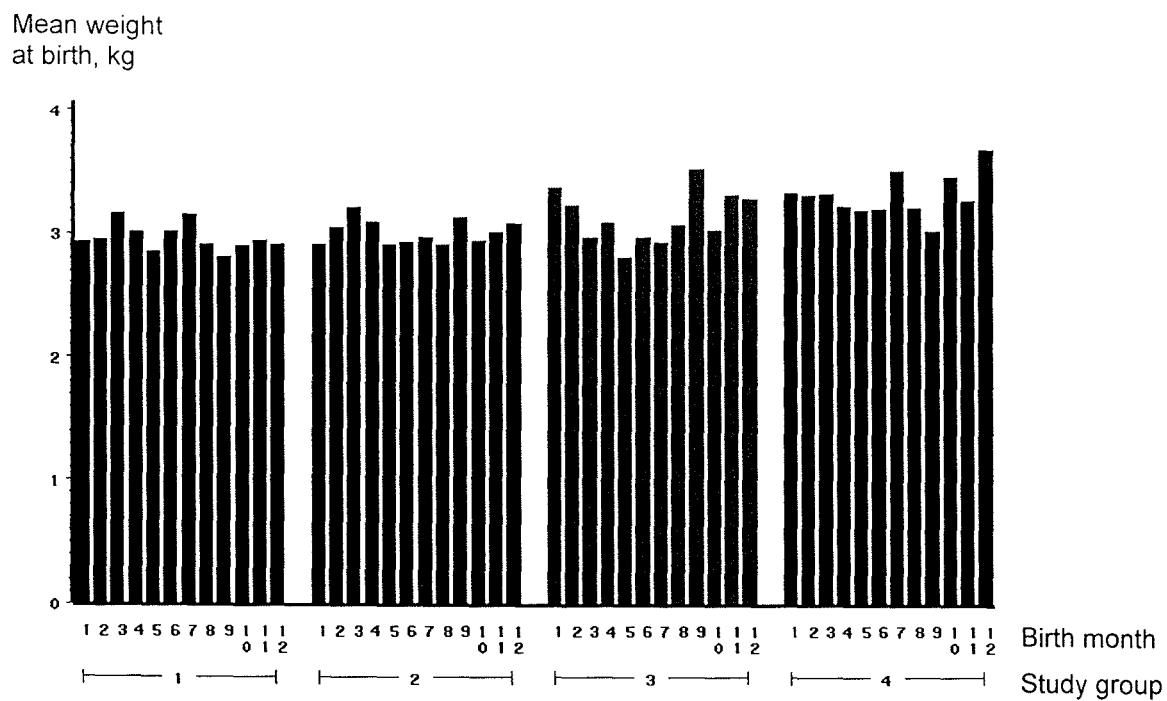


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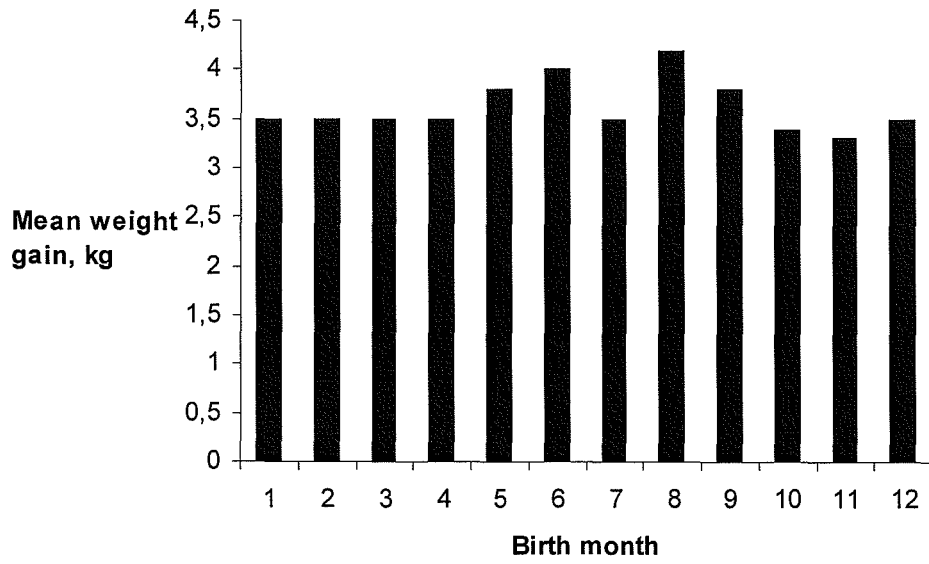


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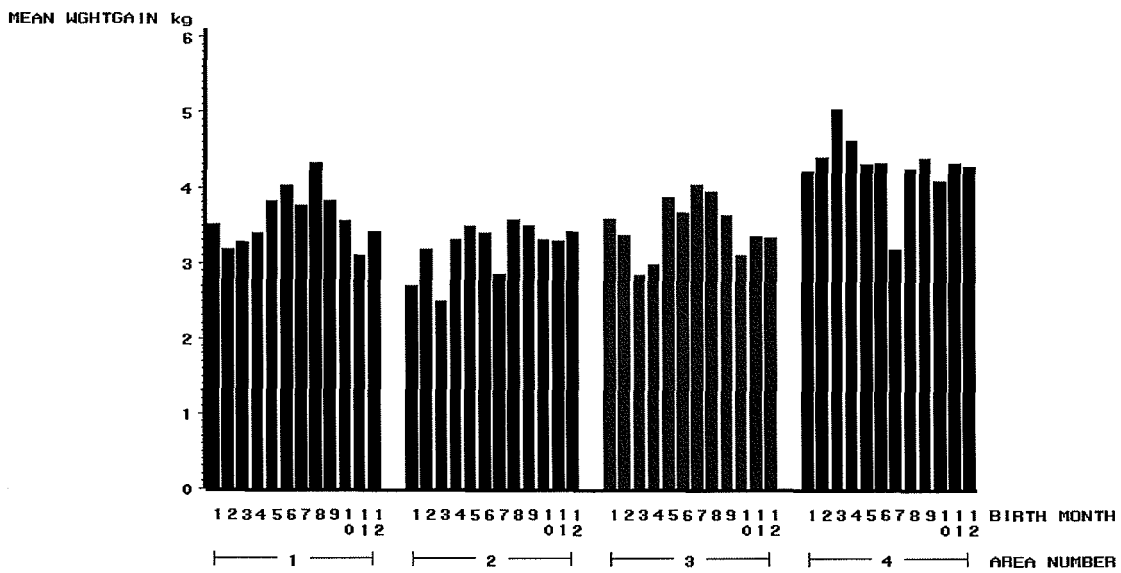


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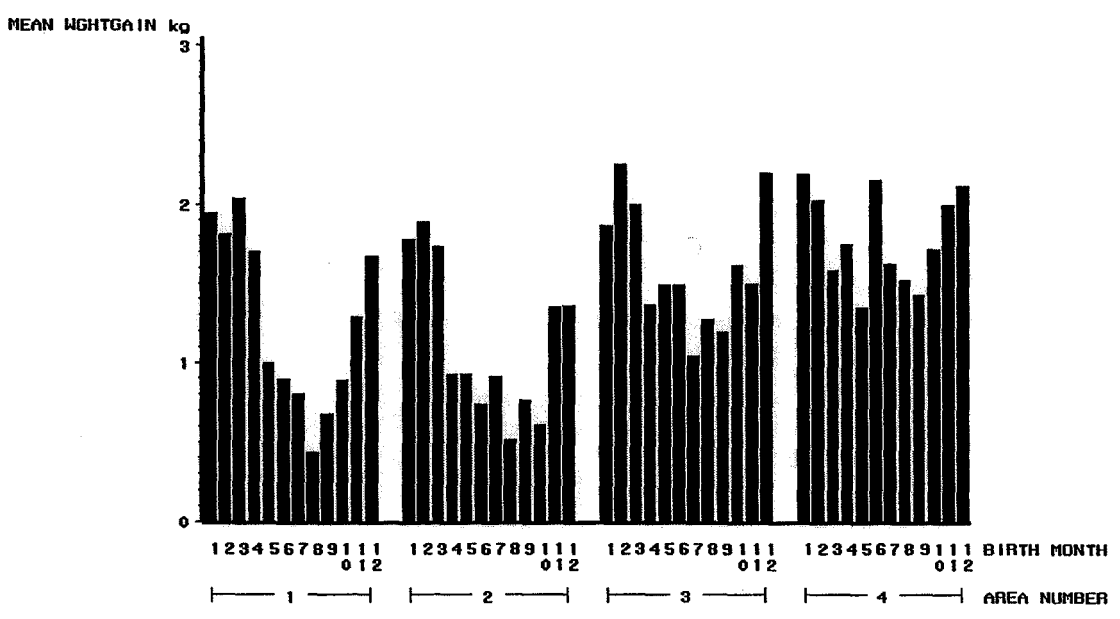


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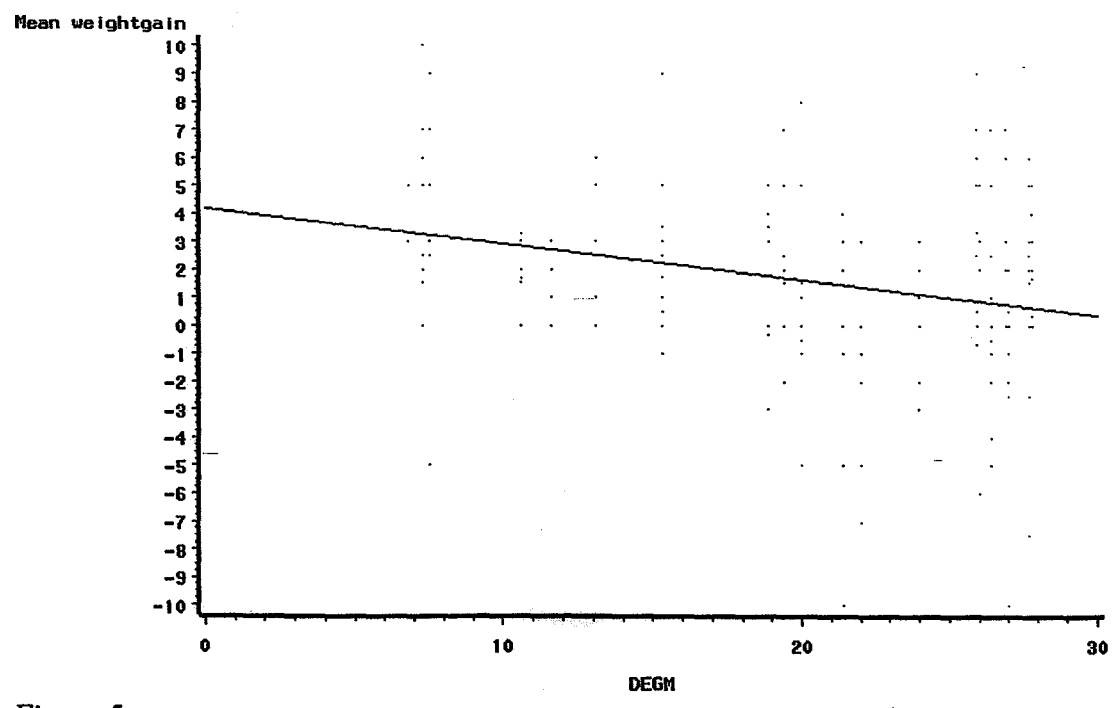


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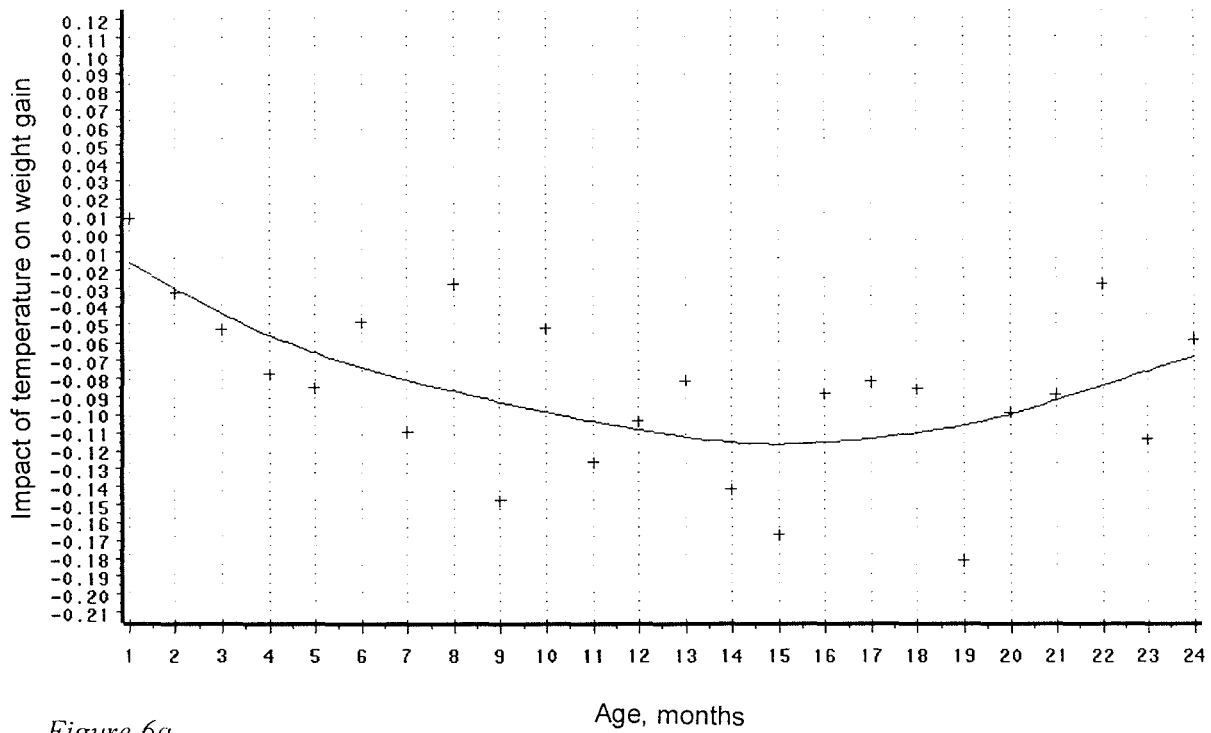


Figure 6a.

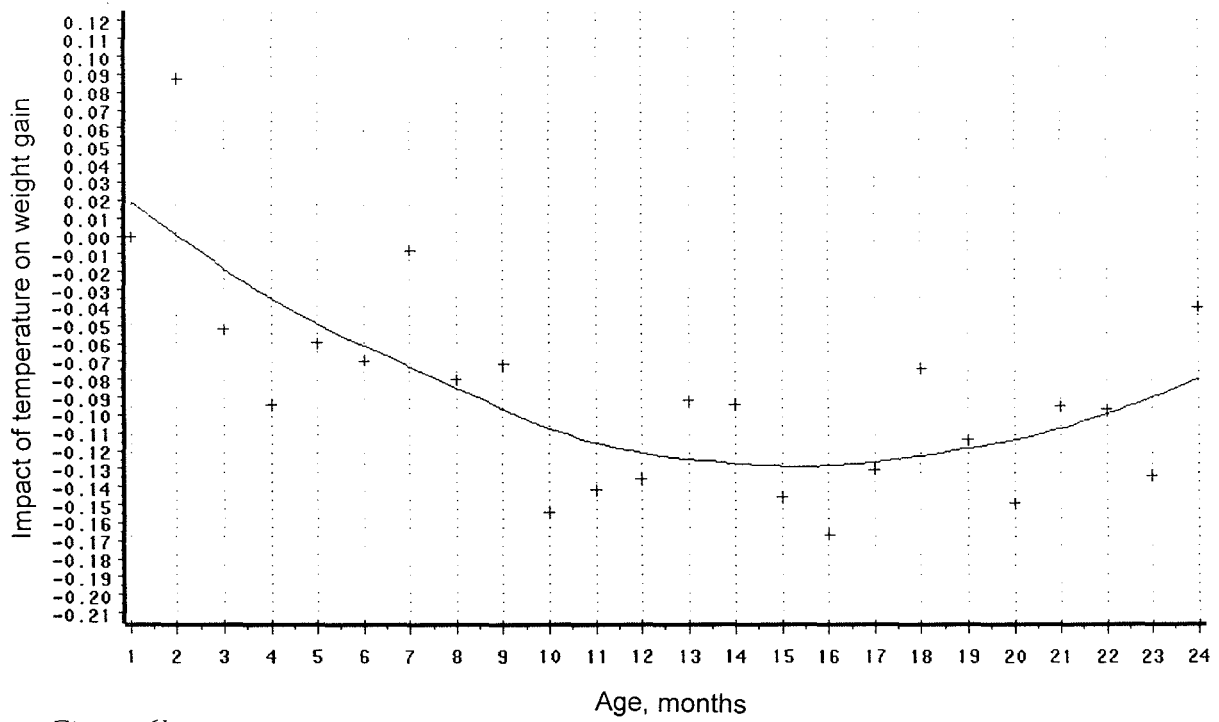


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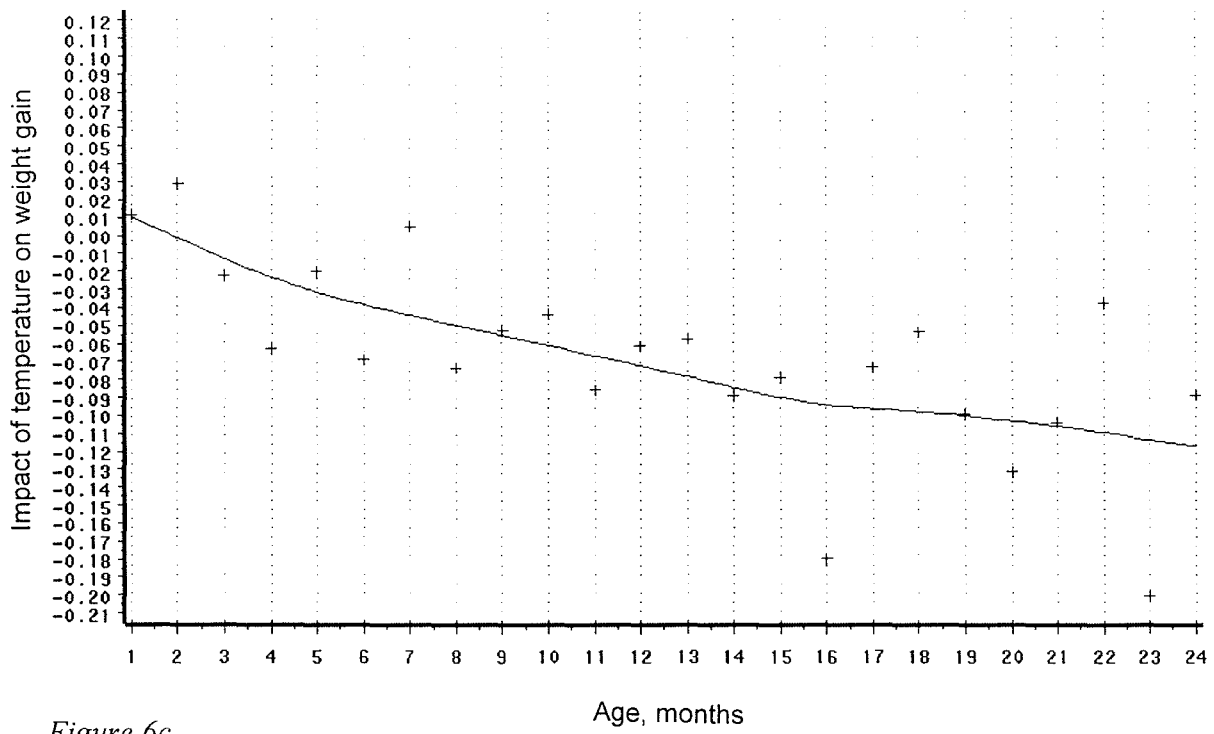


Figure 6c.

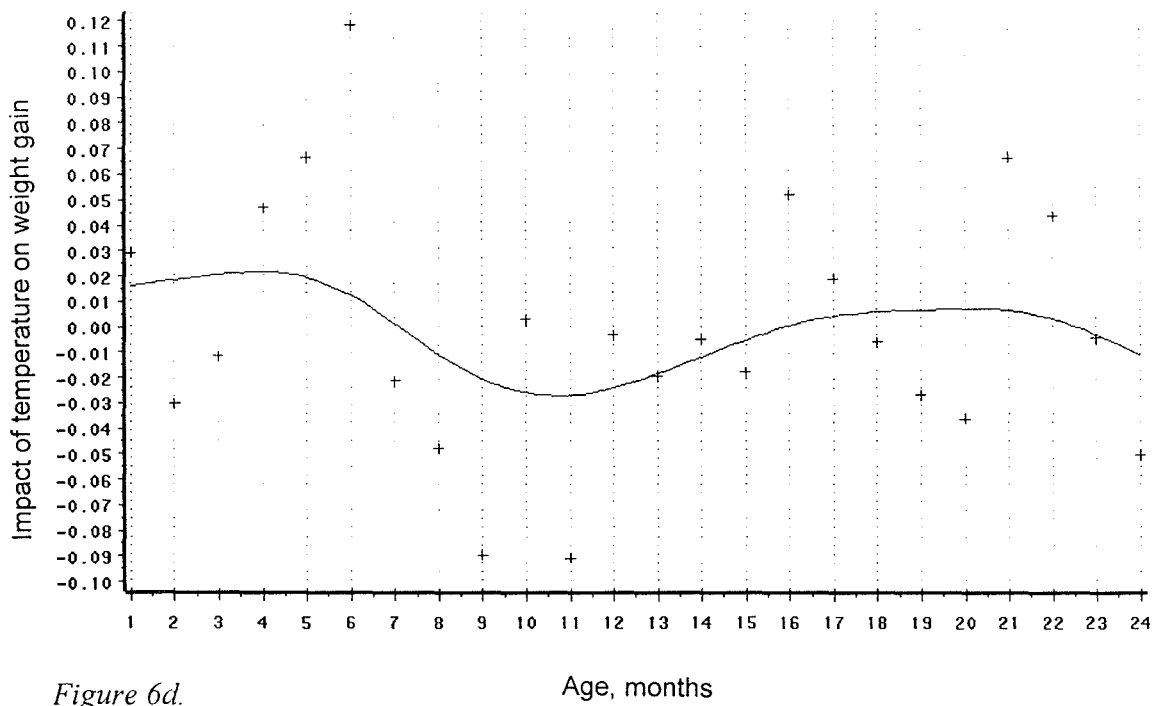


Figure 6d.

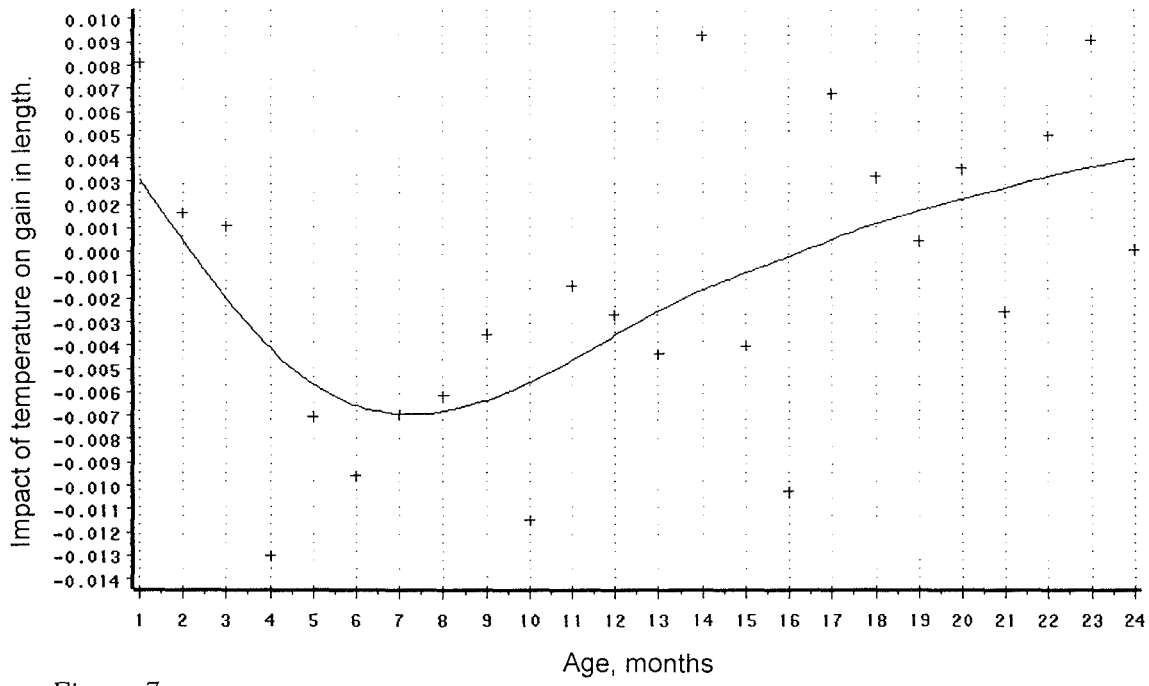


Figure 7a.

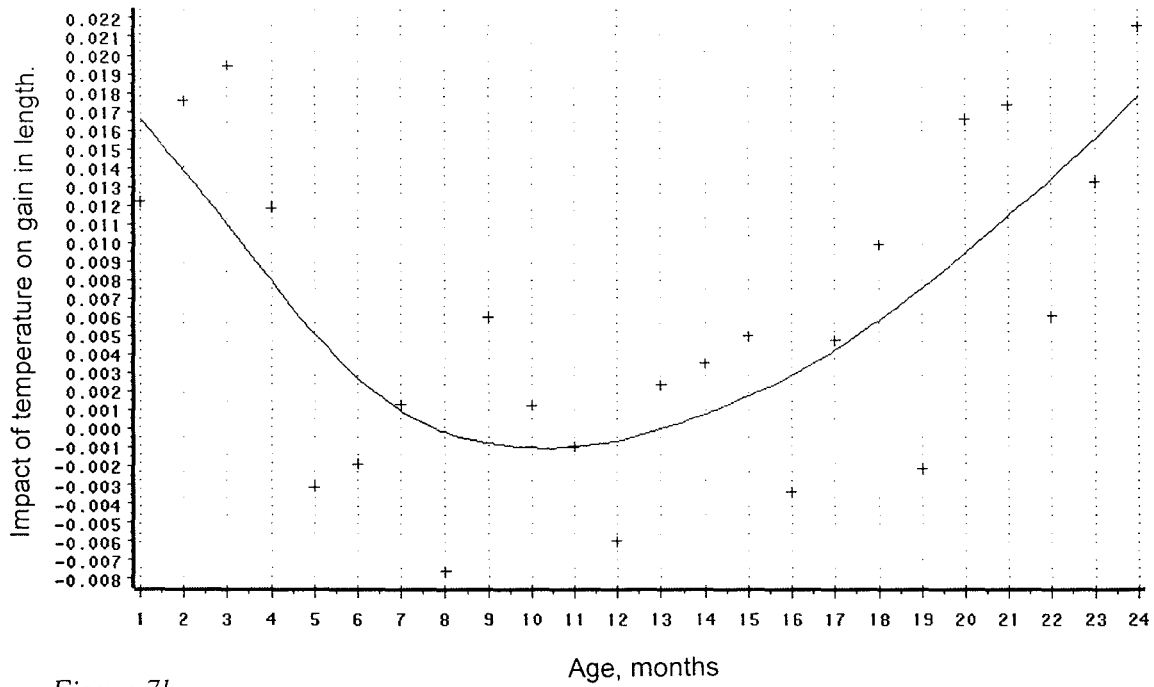


Figure 7b.

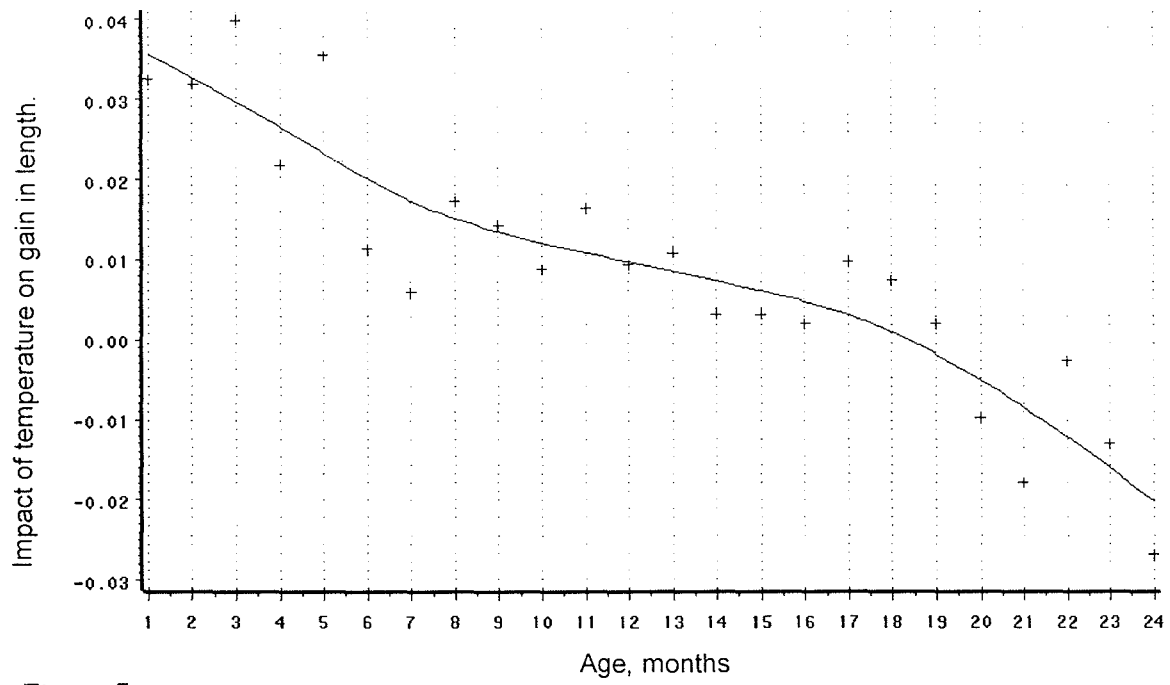


Figure 7c.

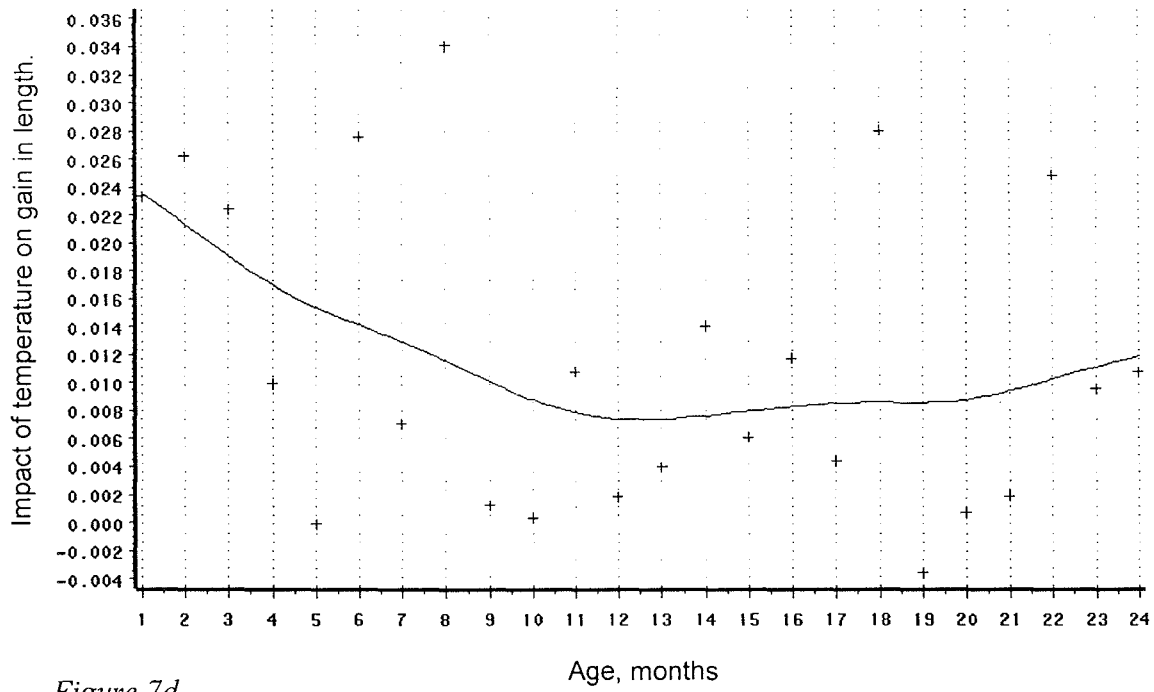


Figure 7d.

Weight gain, hg

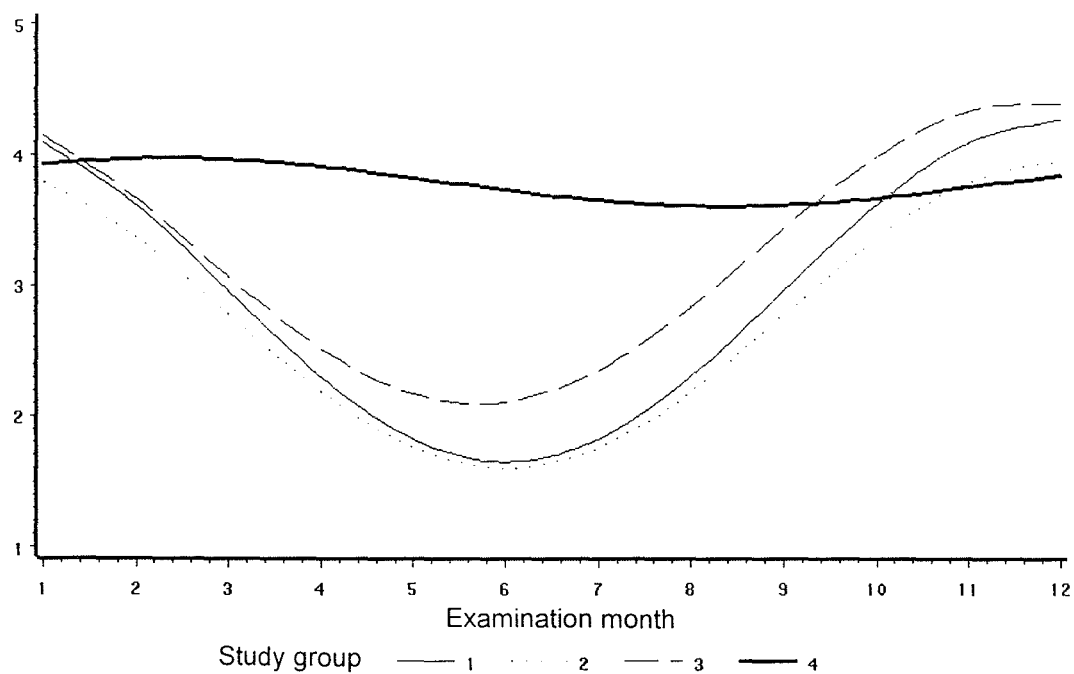


Figure 8.

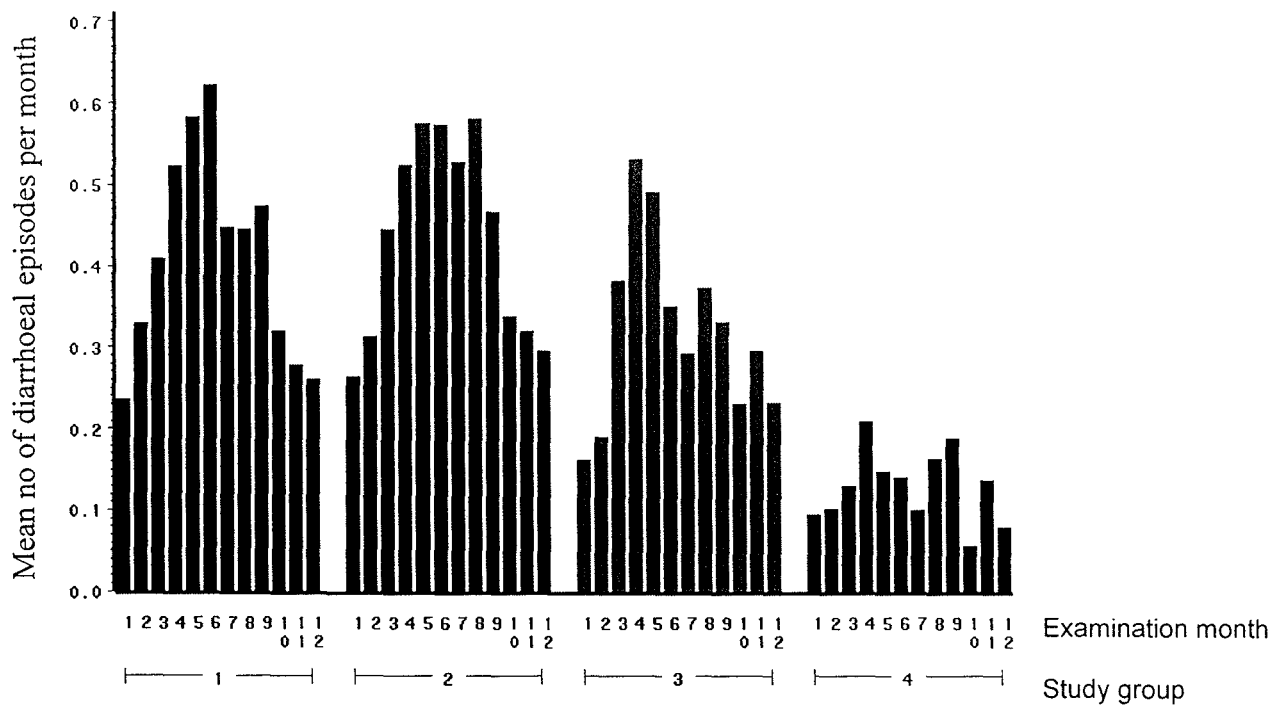


Figure 9.

Legends to table

Table 1.

Summary statistics of individual regression analyses for each child in the different areas.

Table

Variable	Village		Periurban slum		Urban slum		Upper middle class	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Intercept	9.64	2.45	8.21	0.94	10.8	2.62	13.6	5.95
Temperature	-0.125	0.069	-0.157	0.046	-0.245	0.112	-0.226	0.224
Age	-0.753	0.407	-0.190	0.129	-0.204	0.253	-0.390	0.074

Table 1.

Research Report

- | | | |
|--------|----------------------------|--|
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| 1999:9 | Afsarinejad, K.: | Trend-free repeated measurement designs. |