V[TH] INTERNATIONAL WORKSHOP

Maternal and Extrauterine Nutritional Factors

Their Influence on Fetal and Infant Growth

F. Battaglia
F. Falkner
C. Garza
B. Salle
J. Rey
B. Lönnerdal
C. Pedraz
E. Doménech
J. Monleón
M. Moya
R. Jiménez
A. Martínez-Valverde
G. Sawatzki
J. Morán

Salamanca (Spain)
October 17th-18th 1995

ISBN: 84-86754-93-3
Depósito Legal: M-44400-1996
Printed in Spain

GENERATIONAL EFFECTS OF SUPPLEMENTARY FEEDING DURING EARLY CHILDHOOD

Juan Rivera, Mario Flores*, Reynaldo Martorell**, Usha Ramakrishnan**, Paul Melgar****

*National Institute of Public Health, Mexico. **The Rollins School of Public Health of Emory University, United States of America. ***Institute of Nutrition of Central America and Panama (INCAP), Guatemala.

ABSTRACT

Data obtained in three studies are presented: a) a longitudinal study of growth in children under 7 years of age carried out in four rural communities in Guatemala between 1969 and 1977; b) A later follow-up of the participants during adolescence and adulthood and c) a study, although unfinished, in which weight of the newborns of those mothers who participated in early studies was recorded.

The longitudinal study included the provision of two drinks: one rich in energy (91 Kcal/100 ml) and protein (6.4 g/100 ml) called "Atole" and one low in energy (33 Kcal/100 ml) and without protein, called "Fresco" Both drinks contained similar amounts of micronutrients. Two communities selected randomly received "Atole" while two others received the "Atole". The drinks were offered daily, on free demand, for the seven years of the study. Daily consumption of the drinks was recorded for those under 7 years of age and for the women during pregnancy and lactation.

The diet and nutritional condition of the children in the four communities was similar at the onset of the study. The children of the communities who received "Atole" had a net improvement in dietary intake while those who lived in the communities who received "Fresco" did not improve their diet substantially. As result, the children who received "Atole" recorded better growth during the first three years of life in comparison with those who received "Fresco". At three years of age, the average height of the girls who lived in the communities that received "Atole" during the critical period (gestation and the first three years of life) was 2.9 cm greater than the girls who lived in the communities that received the "Fresco" during this same period. This difference continued until adolescence and adulthood, although it was slightly decreased (2.1 cm).

From 1991 to now, the birthweight of the newborns whose mothers participated in the longitudinal study has been recorded. The weight of the children of those mothers who lived in the communities receiving "Atole" during the critical period, adjusted by several potentially confounding factors, was 200 g greater than those children of mothers living in the communities receiving the "Fresco". The difference decreased by about 25% when adjustment was made for maternal the height.

suggesting that part of the effect of the supplement was determined by this variable.

Supplementary feeding during the first three years of life, in populations with growth retardation, not only had positive effects on the nutrition of the beneficiaries also positively affected the birthweight of their descendants.

KEY WORDS

Maternal Nutrition. Birthweight. Child feeding. Growth. Supplementary.

INTRODUCTION

It is estimated that about 184 million of the world's children under five years of age (34% of the total) are severely underweight (weight-for-age below -2 S.D. of the NCHS/WHO reference population) as a result of the interaction between dietary deficiencies and infection (ACC/SCN, 1992). This is a matter of concern because underweight is associated with delayed psychomotor development, decreased immune response and increased risk of morbidity and death (Chandra, 1983; Pelletier et al., 1993).

Several controlled trials have shown that supplementary feeding improves growth and development during early childhood (Gopalan et al., 1973; Mora et al., 1981; Martorell, 1992; Habicht et al., 1995). One such trial is the longitudinal study of the Institute of Nutrition of Central America and Panama (INCAP) (Habicht and Martorell, 1992); it involved a supplementary feeding intervention which improved energy intakes and dietary quality in children receiving a beverage called "Atole," while maintaining unchanged the diet of children receiving a low-energy drink called "Fresco." As a result of these dietary changes, the growth and development of the children receiving Atole improved significantly in comparison to children receiving Fresco. The results of a follow-up study of former participants of the INCAP longitudinal were published recently (Martorell, 1995). One of the principal findings of the follow-up study was that benefits of supplementation on growth at three years of age persisted into adolescence and early adulthood, although slightly attenuated (Rivera et al., 1995).

This paper is a brief review of the effects of supplementation during early childhood on attained growth at three years of age and at adolescence and adult age; it also contains preliminary results of an ongoing study among women who participated as children in the INCAP longitudinal study on the effects of supplementation prior to three years of age on birthweight of the next generation.

OBJECTIVES OF THE STUDY

a) In women, determine the effect of supplementary feeding during gestation and the first three years of life on the birthweight of their children.

b) Establish if these effects on birthweight are mediated by improvements in maternal height.

METHODS

1) Data sources

The data presented come from three studies conducted in four rural communities in Eastern Guatemala: a) a longitudinal study carried out between 1969 and 1977; b) a cross-sectional study, carried out between 1988 and 1989, in which the former participants of the longitudinal study were examined and c) a study of the birthweight of neonates born to mothers who participated in the above mentioned studies. Descriptions of the design methods and variables of each study follow

Table I **Description of cohorts according to age of exposure to the supplements**

Number of Cohort	*Dates of birth*	*Ages of exposure*
I	>1/MAR/1974	Gestation, partially from birth to 3 years.
II	1/MAR/1969-28/FEB/1974	Partially during gestation, from birth to 3 years.
III	1/JAN/1966-28/FEB/1969	Partially from birth to 3 years.
IV	>/JANUARY/1966	Without exposure during gestation and birth to 3 years.

1.1) The INCAP Longitudinal study (1969-77)

The communities were non-indian (i.e. Spanish/Indian in ancestry and Spanish speaking) and most of the families depended on agriculture for their subsistence. The staple foods in these poor communities were corn and beans. Children manifested a high prevalence of growth retardation and high rates of diarrhea and other diseases. Information was obtained on the health and nutrition of women during pregnancy and lactation and on the physical growth, morbidity, diet and mental development of children under seven years of age, among other variables. Two villages, chosen at random, received a high-protein (6.4 g/100 ml) and high-energy (91 Kcal/100 ml) drink, locally called "Atole;" two other villages received a low-energy (33 Kcal/100 ml), no-protein drink called "Fresco". The drinks were distributed in supplementation centers and were available on demand and ad-libitum to all community members. However, consumption of the drinks was recorded daily only for children under 7 years of age and their mothers. Detailed information on the history, design and methodology of this study is available in previous publications (Martorell et al., 1995).

1.2) Follow-up study (1988-89)

During 1988 and 1989, a group of investigators returned to the four communities to evaluate the former subjects of the INCAP longitudinal study who were by then between 11 and 26 years of age. Approximately 73% of the more than 2000 subjects previously studied were located and evaluated in their original communities or, if they had migrated, in near-by towns or in the capital city. Detailed information was gathered on body size and composition, physical and intellectual performance, and demographic and economic characteristics (Martorell et al., 1995).

Depending on age of exposure to the supplements, the subjects studied were classified into four cohorts (Table I). Cohort I was exposed to the supplements during the entire period of gestation and partially from birth to three years of age; cohort II was exposed during the entire period from birth to three years and had partial exposure during gestation; cohort III had partial exposure from birth to three years and was not exposed during gestation; cohort IV was not exposed during gestation or from birth to three years of age. Previous studies indicate that the greatest effects of supplementation occurred before three years of life (Shroeder et al., 1995). The cohort with maximum exposure prior to three years of age is Cohort II.

1.3) Birthweight Study (1991 - present)

A study of newborn characteristics, including birthweight, of the neonates born to mothers who participated as children in the prior longitudinal study began on February 1991. The study is ongoing and the information presented in this document summarizes data obtained up to June 1994. A community-based surveillance system is used to identify women at an early stage in pregnancy through visits every three months at which the date

of the last menstruation is obtained. During these visits, anthropometric measurements and obstetric and demographic information about the women are obtained as well. Once a pregnancy is detected, the subject is visited and examined more frequently at specified times until delivery. Prenatal care is provided free. Finally, anthropometric measurements of the mother and newborn are obtained as soon as possible after birth: gestational age is determined by the Capurro method (Capurro, et al. 1978).

2) Methods of data analysis

The analyses included comparisons between Atole and Fresco groups in terms of non-adjusted and adjusted means; the Student's t test was used in these comparisons. The adjusted means were obtained by the least square method, using generalized linear models. Differences in the percentage of newborns with low birthweight between supplement types were assessed by the chi-squared test. All analyses used the SAS statistical package.

RESULTS

1) Longitudinal study (1969-77) results

Diet and nutritional status of children were similar in the four communities at the beginning of the study in 1969. Figure 1 shows the energy consumption from home diet and from supplement in girls between 15 and 36 months of age and this is given by type of supplement received. The communities that received Atole had a net increase in supplement consumption of almost 90 Kcal per day. This increase in energy intake represents about 13% in relation to home diet consumption and can be considered important in this energy-deficient population. Figure 2 presents similar information for protein intake. The net effect of supplementation was even greater than in the case of energy: 8.8 grams of additional protein, equivalent to more than a 40% increase in relation to home diet consumption. However, this does not necessarily mean that the protein contribution was more important because energy may have been more limiting than protein in the local diet. The important observation is that total intakes of children receiving Atole were significantly improved in terms of both energy and protein when compared to those of children receiving Fresco.

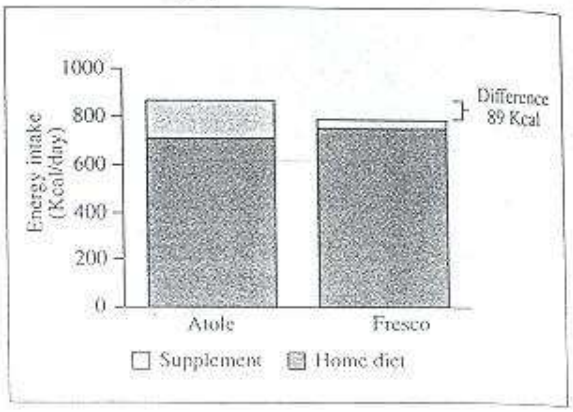

Figure 1. *Energy consumption from home diet and supplements in girls 15 to 36 months of age (Source: Martorell, J Nutr 1995;125:1127S-1138S).*

Figure 3 shows the percentage of children with severe retardation in length (below -3 S.D. of the WHO/NCHS reference population) at three years of age in the communities studied, by type of supplement received. At the onset of the study in 1969, the prevalence of severe retardation in length was very similar in the communities that received Atole and Fresco. The percentage of children with severe retardation showed no important changes in communities receiving Fresco; however, it decreased to less than half in the villages receiving Atole. At the end of the study, the average length of girls at three years of age was almost 3 cm greater in Atole compared to Fresco communities (Fig. 4).

2) Results of the follow-up study (1988-89)

Girls from cohort II were taller at 3 years of

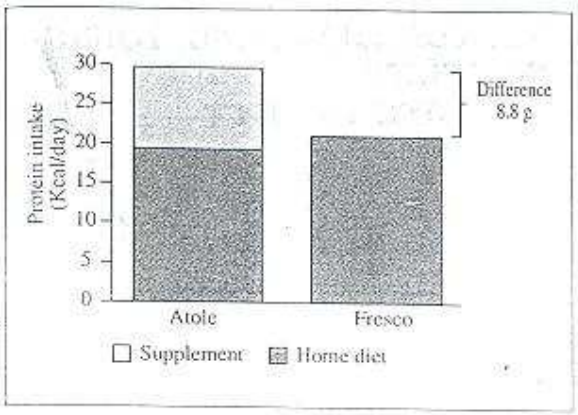

Figure 2. *Protein consumption from home diet and supplements in girls 15 to 36 months of age (Source: Martorell. J Nutr 1995;125:1127S-1138S).*

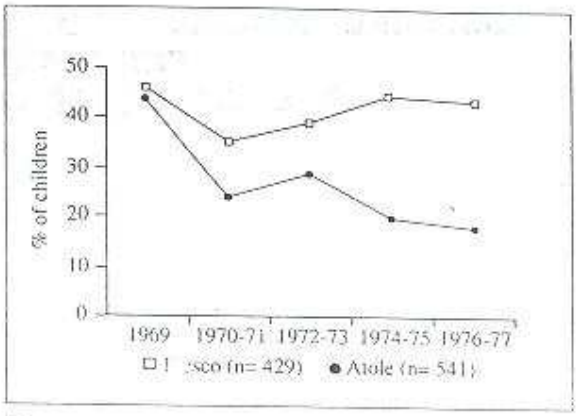

Figure 3. *Time trends in the percentage of children with severe stunting (≤ – 3 S.D. of WHO/NCHS reference) at three years by type of supplement (both sexes). (Source: Martorell. Food Nutr Bull 1993;14:270-277).*

age ($p<.05$) and at adolescence ($p<.05$) in Atole villages compared to Fresco villages (Figure 4). However, differences in height between Atole and Fresco were reduced somewhat at adolescence. When adjustment for length at three years of age is made, differences in height at adolescence between Atole and Fresco villages are reduced dramatically and cease to be statistically significant, indicating that the differences observed at adolescence between supplement types are explained by differences in length at three years of age.

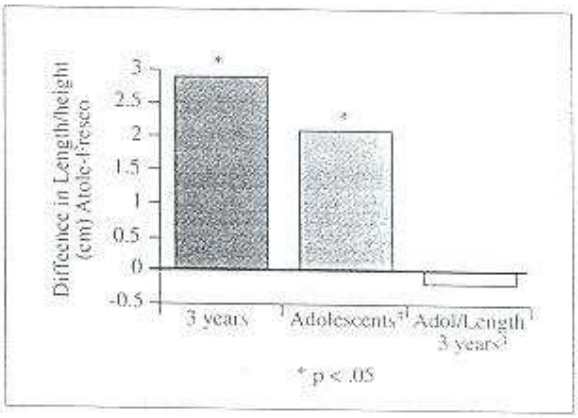

Figure 4. *Mean-adjusted differences' (Atole-Fresco) in length at 3 years of age and height in adolescents (females). (1. By home energy intake, time with diarrhea, socioeconomic status, maternal height and skeletal age (only adolescents). 2. 14-20 years of age. 3. During adolescence, adjusted by length at 3 years, N.S. (Source: Rivera. J Nutr 1995;125:1068S-1077S).*

3) Birthweight study results (1991-94)

Table II presents, for Atole and Fresco samples, unadjusted means for birthweight and other covariates used in the analysis. The differences that were statistically significant were weight and length at birth and maternal height and all these differences favored the Atole sample. Also, these differences were observed for both male and female newborns (results not presented). The results suggest that differences in birthweight in favor of Atole communities are not the result of potentially confounding factors; however, in order to improve the precision of the estimated effect, the differences were adjusted for gestational age, sex of the newborn, time between birth and anthropometric measurement, maternal age and parity.

Figure 5 shows that unadjusted and adjusted differences in birthweight favor the Atole sample. The unadjusted difference was 121 g, while the adjusted difference was 100 g; both differences were statistically significant ($p<0.05$). When maternal height was included in the adjustment, the difference decreased to 75 g and ceased to be statistically significant ($p>0.05$).

Table II Comparison of key variables by type of supplement received by the mothers during their early infancy

	Atole[1]		Fresco[1]		
Variables	*mean*	*(s.d.)*	*mean*	*(s.d.)*	*p*[2]
Birthweigth (g)	2978	(400)	2857	(445)	0.01
Length at birth (cms)	48.3	(1.9)	47.7	(2.0)	0.01
Gestational Age (weeks)	39.5	(1.1)	39.3	(1.6)	0.24
Time between birth and anthropometry (hours)	13.3	(16.5)	11.5	(16.0)	0.38
Maternal age (years)	22.9	(3.7)	23.4	(4.4)	0.40
Parity	2.1	(1.7)	2.2	(1.8)	0.80
Maternal Height (cm)	150.0	(5.6)	147.5	(4.8)	0.00
Maternal Weight (Kg)	49.5	(7.0)	48.8	(9.0)	0.48
Maternal BMI (Kg/m^2)	22.0	(2.8)	22.3	(3.5)	0.37
Maternal EFFM[3] (Kg)	33.9	(4.5)	33.4	(5.3)	0.38

[1] Sample size: Atole (n=153) except for EFFM (n=129); Fresco (n=118) except for EFFM (n=99).
[2] Probability value (student t test). [3]Estimated fat free mass = -1.8883 + 0.7018 weight (Kg) + 0.1221 Height (cm) -0.1858 Waist circumference (cm).

Figure 6 presents the percentage of newborns with low birthweight (<2500 g) by supplement type. The prevalence of low birthweight was nearly twice as great in Fresco compared to Atole communities.

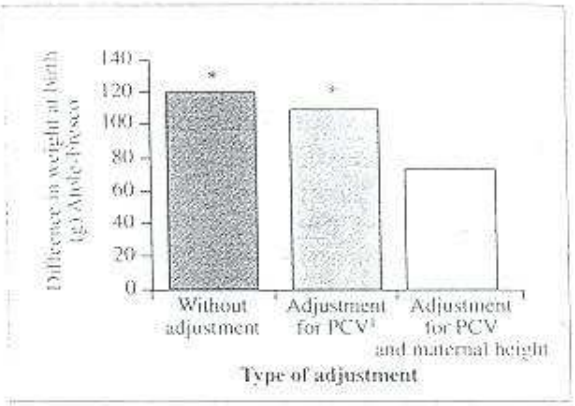

Figure 5. *Difference in birthweight by type of supplement received by the mother during her childhood (all Cohorts). (* P < 0.050 [Potentially. Confounding variables:])[1] Gestational age, sex, birth-anthropometry time, maternal age and parity).*

DISCUSSION

The results suggest that nutritional supplementation of mothers during pregnancy and direct supplementation to the child during the first three years of life has, in the case of women, positive effects on birthweight of their descendants. The magnitude of the intergenerational effect is similar to that obtained by supplementing the maternal diet during pregnancy. For example, Lechtig et al. (1975) studied the effect of supplementation during pregnancy on birthweight in first generation mothers (i.e. the women who gave birth to the children of the 1969-77 longitudinal study). They found that the newborns of women who received more than 20,000 Kcal during pregnancy were 111 g heavier than those of mothers who received 20,000 Kcal or less. Shifting the distribution of birthweights by 111 g had the effect of decreasing the percentage of low birth weight by 50% (i.e. from about 20 to 10%). Thus, the effects are considered to be biologically important because low birthweight infants have a greater risk of disease and death and disadvantages in psychomotor development compared to those of normal

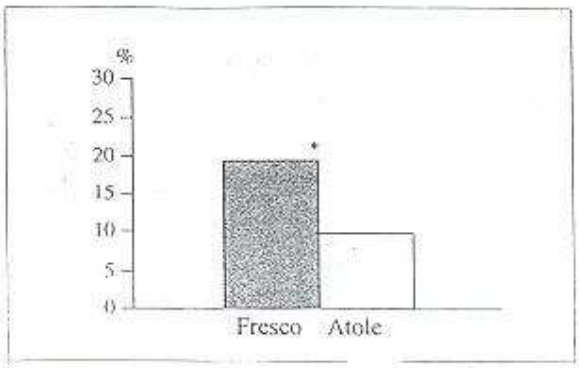

Figure 6. *Percentage of low birthweight children (<2500g) by type of supplement received by the mother during her childhood (*p< 0.5).*

birthweight. In short, our studies suggest that supplementary feeding of needy women during pregnancy combined with supplementation of girls in their first three years of life leads to improved child growth and larger adult body sizes and also results in larger newborns when these women have children.

One of the purposes of the study was to investigate if the effects of early supplementation on birthweight of the following generation were mediated by increases in the body sizes of women. Adjusting for maternal height attenuates the intergenerational effect by almost one third, suggesting that at least part of the effect is mediated through maternal size.

CONCLUSIONS

1. In populations with significant growth retardation, supplementary feeding of the mother during gestation and of girls during the first three years of life increases birthweight of the next generation.

2. At least part of the generational effect on birthweight is mediated through effects of supplementation on maternal body size.

ACKNOWLEDGMENTS

Many professionals, field staff and support personnel from the Institute of Nutrition of Central America and Panama (INCAP) contributed, in different periods, to the successful completion of the three studies that serve as the basis for this paper. We express our deepest appreciation to all of them. We also thank the inhabitants of the four communities studied for their decided collaboration during the development of these studies.

This study was supported by the Thrasher Research Fund (No 2805-5) and by the National Institutes of Health of the United States (NIH, grant 5-R01-HD22440-08).

REFERENCES

1. Administrative Committee on Coordination-Subcommittee on Nutrition (ACC/SCN). *United Nations. Second Report on the World Nutrition Situation.* Volume I. Global and Regional Results. 1992.

2. Capurro H, Konichezky S, Fonseca D, Caldero-Barcia R. A simplified method for diagnosis of gestational age in the newborn infant. *J Pediatr* 1978; **93:** 120.

3. Chandra RK. Nutrition, Immunity and Infection: present knowledge and future directions. *Lancet* 1983; **1:** 688-691

4. Gopalan C, Swaminathan MC, Kumary VKK, Rao DH, Vijayaraghavan K. Effect of calorie supplementation on growth of under-nourished children. *Am J Clin Nutr* 1973; **26:** 563-566.

5. Habicht J-P, Martorell R. Objectives, research design, and implementation of the INCAP longitudinal study. *Food Nutr Bull* 1992; **14:** 176-190.

6. Habicht J-P, Martorell R, Rivera J. Nutritional impact of supplementation in the INCAP longitudinal study: Analytic strategies and inferences. *J Nutr* 1995; **125:** 1027S-1041S.

7. Lechtig A, Habicht J-P, Delgado H, Klein R, Yarbrough C, Martorell R. Effect of food supplementation during pregnancy on birthweight. *Pediatrics* 1975; **56:** 508-520.

8. Martorell R. Overview of the long-term nutrition intervention studies in Guatemala, 1968-1989. *Food Nutr Bull* 1992; **14:** 270-277.

9. Martorell R. Results and implications of the INCAP Follow-up study. *J Nutr* 1995; **125:** 1127S-1138S.

10. Martorell R, Habicht J-P, Rivera JA. History and design of the INCAP longitudinal study (1969-77) and its follow-up (1988-89). *J Nutr* 1995; **125:** 1027S-1041S.

11. Mora JO, Herrera MG, Suescun J, Navarro L, Wagner M. The effects of nutritional supplementation on physical growth of children at risk of malnutrition. *Am J Clin Nutr* 1981; **34:** 1885-1892.

12. Pelletier DL, Frongillo E, Habicht J-P. Epidemiologic evidence for a potentiating effect of malnutrition on child mortality. *Am J Public Health* 1993; **83:** 1130-1133.

13. Rivera JA, Martorell R, Ruel MT, Habicht J-P, Haas JD. Nutritional supplementation during the preschool years influences body size and composition of Guatemalan adolescents. *J Nutr* 1995; **125:** 1068S-1077S.

14. Schroeder DG, Martorell R, Rivera JA, Ruel MT, Habicht JP. Age differences in the impact of nutritional supplementation on growth. *J Nutr* 1995; **125:** 1051S-1059S