The Nutrition Intervention Improved Adult Human Capital and Economic Productivity[1,2]

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Abstract

This article reviews key findings about the long-term impact of a nutrition intervention carried out by the Institute of Nutrition of Central America and Panama from 1969 to 1977. Results from follow-up studies in 1988–89 and 2002–04 show substantial impact on adult human capital and economic productivity. The 1988–89 study showed that adult body size and work capacity increased for those provided improved nutrition through age 3 y, whereas the 2002–04 follow-up showed that schooling was increased for women and reading comprehension and intelligence increased in both men and women. Participants were 26–42 y of age at the time of the 2002–04 follow-up, facilitating the assessment of economic productivity. Wages of men increased by 46% in those provided with improved nutrition through age 2 y. Findings for cardiovascular disease risk factors were heterogeneous; however, they suggest that improved nutrition in early life is unlikely to increase cardiovascular disease risk later in life and may indeed lower risk. In conclusion, the substantial improvement in adult human capital and economic productivity resulting from the nutrition intervention provides a powerful argument for promoting improvements in nutrition in pregnant women and young children. J. Nutr. 140: 411–414, 2010.

Introduction

In this article, we summarize key findings about the long-term impact on adult human capital and economic productivity of the nutrition intervention of the Institute of Nutrition of Central America and Panama (INCAP) Oriente Longitudinal Study (1969–77). The focus is on results from the 1988–89 and 2002–04 follow-up studies, which provide information about adult body size and composition, cardiovascular disease risk factors, schooling, intellectual functioning, and wages and income. These 2 studies, part of the longest running cohort study in a low- or middle-income country, describe the long-term effects on adult human capital and productivity of a nutrition intervention in early childhood.

The INCAP Oriente Longitudinal Study (1969–77)

The original study, described in greater detail elsewhere in this volume (1), was a community-randomized trial with 1 large and 1 small village receiving a nutritious supplement called *Atole* and 2 matched villages receiving a control drink called *Fresco*. *Atole* was a gruel-type drink providing micronutrients, energy, and protein, whereas *Fresco* was a light drink providing micronutrients and low amounts of energy but no protein [see the nutrient composition in Table 1 in Ramirez-Zea et al. (1)]. The *Fresco* was not expected to have nutritional impact on cognitive development or child growth, the key outcomes of the study. Rather, it was designed to control for the social interaction associated with attending the village feeding center, which could have been as often as twice per day for up to 7 y. It was feared that this interaction might improve cognitive development and thus needed to be present in the *Fresco* villages to better isolate the nutritional effect of the *Atole*.

The original study included all children <7 y of age when it began and incorporated all children born in the villages during the study. All of these children were followed until they turned 7 y of age or until the end of the study in 1977, whichever came first. This design resulted in a 15-y range in birth years from 1962 to 1977. Children were exposed to the supplements from 1969 to 1977, but this exposure occurred across a wide range of children's ages, a design feature that analyses have exploited.

All people in the villages were free to attend and consume the supplements, but women who were pregnant or breast-feeding and children <7 y of age were especially encouraged to attend. Attendance and supplement consumption were recorded for these 2 groups only. Children >7 y may have attended the supplementation centers, e.g. older girls accompanying younger siblings, but this was not recorded. Age patterns of attendance and consumption of the supplements for children <7 y are presented elsewhere (2).

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Dietary impact of the intervention was estimated from measures of home dietary intakes and supplement consumption. For children 15–36 mo of age, those in *Atole* villages had total intakes that were ~11% larger for energy [~95 kcal/d (398 kJ/d)] and ~40% larger for protein (~8.7 g/d) than their counterparts in the *Fresco* villages (3). Because a greater volume of *Atole* than *Fresco* was consumed at these ages (2), there were also differences in micronutrient intakes between the 2 types of villages. Schroeder et al. (4) reported that supplement was associated with growth rates only in the first 3 y of life. In this volume, Habicht and Martorell (5) present analyses in support of a causal effect of exposure to *Atole* compared with *Fresco* on height in children ≤ 3 y of age. Thus, the nutrition experiment was biologically efficacious in improving child dietary intakes and growth in height, with impact on growth evident only in the first 3 y.

1988–89 follow-up study

The first follow-up study was carried out in the late 1980s when the former participants of the study were 11–26 y of age (1). The study targeted all former participants living in the original or nearby communities (so-called nonmigrants) and those that had migrated to Guatemala City. About 73% of participants (1574/2169) were examined and interviewed, with 89% coverage among nonmigrants and 41% among migrants, the difference reflecting in part that there was no attempt to include migrants to any place other than Guatemala City. The young ages of participants at this time presented a number of challenges in assessing impact on human capital and economic productivity. Some of the individuals had not yet reached adult height and analyses of impact on body size had to control for skeletal age. Similarly, not all had finished schooling, chosen an occupation, entered the labor force, married, or formed unions. These factors combined to limit both the assessment of impact on schooling and particularly on economic productivity.

The analytic model used contrasted outcomes between *Atole* and *Fresco* villages for different birth cohorts as follows: I, those born ≥1 March 1974, exposed during gestation and partly in the first 3 y; II, those born between the start of the study on 1 March 1969 and 28 February 1974, exposed fully or partially during gestation and fully during the first 3 y; III, those born between 1 January 1966 and 28 February 28 1969, exposed partially during the first 3 y; and IV, the oldest group, born <1 Jan 1966, with no exposure during gestation or birth to 3 y. The expectation was that Cohort II would show maximal impact and Cohort IV minimal impact.

Rivera et al. (6) showed that among Cohort II members there were differences favoring *Atole* compared with *Fresco* in height (2.1 cm in females and 1.2 in males), weight (2.2 kg in females and 1.2 kg in males), and fat free mass (2.1 kg in females and 0.8 kg in males), with differences being significant in females in all cases. Differences in height at follow-up suggested some attenuation of differences observed at 3 y of age. Data on skeletal age (7) and menarche (8) showed no differences between *Atole* and *Fresco* villages and suggested no long-term impact on maturation. Work capacity, which was likely to be related to economic productivity in physically demanding occupations, also improved, particularly in males and particularly in Cohort II (9).

The findings on intellectual functioning (10,11) were among the most interesting in the 1988–89 follow-up. In contrast to the findings from the 1969–77 study that found only small effects on cognitive tests, the findings among youth suggested more substantial impact as measured by a battery of tests of knowledge, numeracy, reading and vocabulary, and to a lesser extent on information processing, as measured by tests of simple, choice, and memory reaction time (10). The impact was greater and more consistent among Cohort II embers. Also, interactions were found with socioeconomic status in early childhood and schooling, indicating that the impact of *Atole* increased in those of poorer socioeconomic status and those with more schooling. On the other hand, there was no evidence of impact on intelligence by the Raven's Progressive Matrices.

The analyses by Pollitt et al. (10,11) included only participants who were literate, because some of the tests required reading. Schooling was included as a confounding variable, because there were clear differences in parental schooling levels among the villages that appeared to persist among the youth; in other words, there seemed to be engrained differences in the levels of schooling across generations in the villages as well as possible differences in access to schooling across villages.

The main conclusion from the 1988–89 study was that improved nutrition in early childhood has important effects on human capital, as measured through body size, work capacity, and intellectual functioning. However, because of the young age of the participants, the study could not link the nutrition intervention to economic productivity. By reconnecting INCAP with former participants, however, the 1988–89 study provided a strong basis for several future studies, one of which we now describe.

The Human Capital Study 2002–04

The 2002–04 follow-up study targeted all migrants in the country, not just those in Guatemala City (1). The target sample was 1856 (78%) former participants of the 1969–77 study living in Guatemala and the study traced and reexamined/-interviewed 1571 (85%) of these. Coverage was 94% for those in the original and nearby villages and 64% in Guatemala City and elsewhere in the country (12).

The cohort was 26–42 y of age. Most had completed their formal schooling; fewer than 3% of the sample had continued beyond secondary school to undertake university or technical studies (13). Some 77% of women were married or in a union and 89% had living children; the corresponding statistics for men were 79 and 81% (14). Virtually all men (99%) participated in at least 1 income-generating activity, with 80% working for a wage, 43% on their own farms and 26% operated their own businesses. A lower percentage of women (70%) participated in the labor market. Some 33% of women worked for wages, 21% on their own farms and 34% operated their own businesses (15).

The 2002–04 follow-up study was designed to link the nutrition intervention to adult human capital and economic productivity. Schooling data were updated; as in the 1988–89 follow-up, reading comprehension and vocabulary were assessed using the Inter-American series and intelligence was measured by means of the Raven's progressive matrices test, using only scales A, B, and C (13). There also was great effort placed on measuring labor force participation and income (16) and household expenditure and wealth (17). To achieve this, economists from the International Food Policy Institute, namely John Hoddinott and John Maluccio, who has since moved to Middlebury College, and the University of Pennsylvania (Jere Behrman) were invited to join the research team. Also, the project hired a young Guatemalan economist, Luis Fernando Ramirez, to assist with data collection at INCAP.

The analytic model used in most papers examining the 2002–04 data has been the double difference or difference-in-difference

(DD) approach, rather than the previously used 4 cohort approach. Used in evaluation research, DD typically subtracts differences at baseline between intervention and control samples from differences between these groups after the intervention. This approach can be adapted to assess differences in outcomes between *Atole* and *Fresco* villages for particular windows of exposure to the supplements, with those not in the window serving as a control group.

Let us consider the case of exposure at ages 0–36 mo (**Fig. 1**). Because supplementation was offered between 1969 and 1977 and birth years range from 1962 to 1977, the sample can be divided into those that were too old to have been exposed fully from 0 to 36 mo, those who were exposed fully during this period, and those too young to have been exposed fully. The DD for any outcome for the window of exposure of 0–36 mo is then estimated as:

DD = (average outcome for those exposed to *Atole* 0–36 mo completely − average outcome for those exposed to *Fresco* 0–36 mo completely) − (average outcome for those NOT exposed to *Atole* 0–36 mo completely − average outcome for those NOT exposed to *Fresco* 0–36 mo completely).

The first difference captures the average difference in the outcome across children exposed 0–36 mo to *Atole* compared with *Fresco*. The second difference removes the average difference in the outcome across the village types for those outside the critical exposure range being considered, i.e. for those not expected to have been affected. This approach would not work if *Atole* had a similar impact at all ages. To the extent it does have effects outside the exposure window for a given analysis, it may be that the DD provides conservative (i.e. underestimated) estimates of impact.

The approach can be extended to test various windows of interest. A problem with this approach, however, is that for overlapping windows, e.g. 0–24 and 0–36 mo of age, there will be considerable overlap in the individuals included, making discernment of the relative impact of overlapping windows difficult for the given sample size. This is less of a problem for nonoverlapping windows, e.g. 0–36 and 36–72 mo.

Analyses of human capital outcomes also have included control for potentially confounding variables at individual, family, and community levels. Individual characteristics included sex and age and family characteristics included variables derived from the 1969–77 study such as family's socioeconomic status, schooling of father and mother, age of the mother when the participant was born, and height of the mother. Village fixed effects were taken into account through dummy variables for 3 of the 4 villages. A novel approach is the use of census data and village histories to capture key demographic, social, and economic changes in the villages and keyed to specific ages of the participants rather than just points in time. Examples of such variables are the presence of a permanent, cement-block primary school and student:teacher ratios, when the individual was 7 y old. Other variables used 18 y of age as the reference point, when most were entering the labor force, and included the availability of electricity, the price of maize, and wages in the construction sector, among others. A fuller presentation of these historical variables is given elsewhere (15,13).

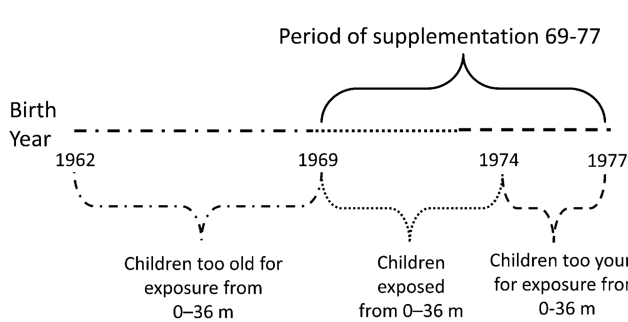

FIGURE 1 Assessing exposure to either *Atole* or *Fresco* from 0 to 36 mo of age.

Using data from 1471 participants, Maluccio et al. (13) found that exposure to the *Atole* from 0 to 36 mo of age resulted in 1.2 greater completed grades of schooling for women (but not men) and one-quarter SD increases in reading comprehension and intelligence tests, in both men and women. These estimates were very similar and remained significant for all possible 30-mo windows within the range of 0 to 42 mo but were strongly attenuated and were not significant when the window of exposure was defined as 36–72 mo. There was no statistical interaction between early life exposure to *Atole* and years of schooling on either reading comprehension or intelligence (18). In addition, the impact of the *Atole* on reading was somewhat attenuated by schooling, suggesting that part of the impact is mediated through schooling; there was no similar attenuation for intelligence, suggesting that the impact of *Atole* on intelligence is independent of schooling.

Using the 1988–89 data, Pollitt et al. (10,11) reported an interaction between *Atole* and schooling on reading, but this was not found in the analyses of the 2002–04 data (18). The difference in findings has several possible explanations. By 2002–04, most participants had competed schooling, whereas in 1988–89 many of the younger ones had not. Also, the earlier analyses considered only primary school attendance, up to grade 6 in Guatemala, and excluded illiterate participants, who comprised ~18% of the sample in the 2002–04 study (13). Finally, the analytic approaches differed; Politt et al. (10,11) contrasted *Atole* and *Fresco* for specific cohorts, whereas Stein et al. (18) used the DD approach.

Perhaps the most important paper to come out of the 2002–04 follow-up is that of Hoddinott et al. (15), which presented results of exposure to *Atole* in early life on wages and incomes. There was a significant impact of exposure to *Atole* within the 0- to 36-mo window on wages in men only (**Fig. 2**). When the window of exposure was set to 36–72 mo, there was no evidence of impact. Within the range from 0 to 36 mo, the greatest impact was for exposure from 0 to 24 mo. In this period, wages were increased by US \$0.67/h (95% CI: 0.18, 1.19), an increase of 46%. Annual hours worked, on the other hand, tended to be reduced by 222 (95% CI: −572 to 128). The product of these 2, annual incomes, increased by US \$914 (95% CI: −\$190, \$2018). Annual incomes in 2002–04 among men were ~US \$3300. The fact that impact was observed in men only may be due to the lower participation of women in the labor market.

Finally, effects on cardiovascular disease risk factors also have been assessed using various windows of exposure (19). The findings suggest heterogeneity across outcomes. Exposure to *Atole* (0–36 mo) resulted in lower triglyceride levels [22.2 mg/dL, 95% CI: 0.4, 44.1 (1.22 mmol/L, 95% CI; 0.02, 2.42)] and higher HDL cholesterol concentrations [males only; 4.7 mg/dL, 95% CI: 1.5, 7.9 (0.26 mmol/L, 95% CI; 0.08, 0.43)]. Also, exposure to *Atole* from 24 to 60 mo led to lower systolic blood pressure (3.0 mm Hg, 95% CI: 0.4, 5.6) whereas exposure from 36 to

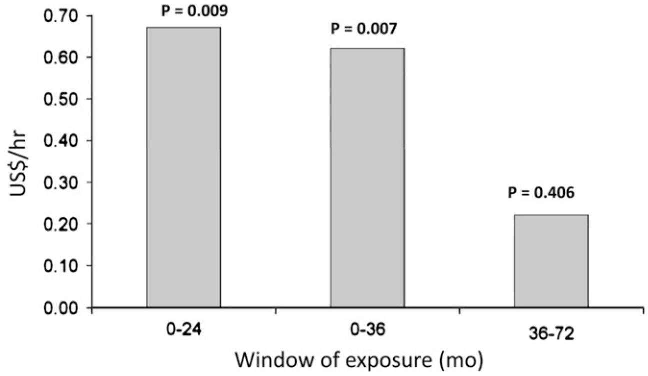

FIGURE 2 Impact of exposure to *Atole* during early life on income (in 2004 US$) earned per hour; *n* = 602 men; age ~32 y. Drawn from data in (21). *P*-values refer to contrasts of exposure to *Atole* compared with *Fresco* for each window of interest.

72 mo resulted in lower fasting glucose [7.0 mg/dL, 95% CI: 0.5, 13.5 (0.39 mmol/L, 95% CI; 0.03, 0.74)]. There was no association between *Atole* exposure at any window and diastolic blood pressure, total or LDL cholesterol level, or prevalence of the metabolic syndrome. The study suggests that the concern that improved nutrition in young children growing in a context of poverty and malnutrition may increase future cardiovascular disease risk is unfounded, concluding that "[i]nterventions designed to address nutrient deficiencies and ameliorate stunting that are targeted at pregnant women and young children are *unlikely* to increase cardiovascular disease risk later in life and *may instead lower the risk*" (18) (italics added).

Conclusion

In conclusion, the findings from the original 1969–77 study and the 1988–89 and 2002–04 follow-up studies have contributed greatly to our understanding of the impact of improving nutrition during the critical stages of intrauterine life and the first 3 y in both the short and long term. The substantial improvements in adult human capital and economic productivity provide a powerful argument for promoting improvements in nutrition in pregnant women and young children. These findings have many implications for the design of nutrition programs and for advocacy, a topic addressed by Marie Ruel (20) in the final article in this supplement.

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R.M. wrote the paper in discussion with the other authors and had primary responsibility for its final content. P.M., J.A.M., A.D.S., and J.A.R. provided critical review of the paper. All authors read and approved the final manuscript.

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