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The effects of preschool nutritional supplementation work capacity in rural Guatemalan adolescents

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INTRODUCTION

The positive impact of nutritional supplementation on physical growth and behavioral development in preschool-age children from less developed countries has been well documented. Most of the documented benefits of supplementation and other nutritional interventions have been seen during or shortly after the intervention has occurred. Published research from India, Colombia and Brazil (1,2,3) have examined the effects of past nutritional status, inferred from past or current anthropometry, on adolescent growth, maturation and physical performance. While the evidence from these studies has been suggestive of a long term impact of early nutrition on later development, they have all been either retrospective or used indirect methods to ascribe causality to nutritional effects.

In this paper we test the hypothesis that improved nutrition during early life results in improved physical work capacity during adolescence and early adulthood using a prospective research design with a nutritional intervention.

METHODS AND PROCEDURES

The hypothesis will be tested in a sample of Guatemalan adolescents and young adults who were participants in a nutritional supplementation trial while they were of preschool age. The population characteristics and study design have been described by Dr. Rivera in the first paper of this symposium (4). Approximately 25 percent of the subjects identified as residing in the original study villages at the time of the follow-up were selected at random for participation in the work capacity portion of the research after stratifying by treatment, sex and cohort. A total of 364 subjects are included in the analysis presented in this paper.

All anthropometry was taken by trained personnel using standard procedures (5). Fat free mass (FFM) was estimated for each subject from anthropometry and bioelectrical impedance analysis (BIA) using regression prediction equations specifically developed for this population (6). Skeletal maturity was estimated for all subjects under 18 years of age by assessing skeletal age with the Tanner-Whitehouse II (TW2) procedure (7). Physical work capacity was determined as the oxygen consumption at maximum physical exertion (VO2max) on a motorized treadmill in a temperature controlled field laboratory following standard open-circuit spirometry techniques similar to those described by Spurr and Reina (3).

RESULTS

Male adolescent and young adult subjects living in atole villages (high energy and protein supplemented) tend to be taller, heavier and have more FFM than those from fresco villages (no protein and low energy supplemented) after controlling for age. These treatment effects are only observed for height in females. Both males and females tend to be delayed in their skeletal development relative to British adolescents, but their deviations from chronological age do not differ according to treatment.

The results of ANCOVA, controlling for age, village size, socioeconomic status and volume of supplement

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consumed, indicate that there are no treatment group differences in maximum heart rate, confirming that both groups reached similar levels of exertion and that these heart rate levels are consistent with published values that suggests that subjects reached maximum exertion.

The age-adjusted means for physical performance measures at maximum exertion show that oxygen consumption at maximum exertion (VO2max) is 30 percent greater in males than females and increases with age in both sexes. VO2max is significantly higher in atole as compared to fresco subjects when all cohorts are compared. This is seen in both sexes and regardless of whether VO2 is expressed as l/min or after adjusting for FFM. Significant atole (2.62 l/min) versus fresco (2.30 l/min) differences are also observed for VO2max in the 14 to 18.9 year old males, while the younger and older cohorts show lesser, but still significant, treatment effects. Among females, only the youngest cohort, 11 to 13.9 years old, has significantly greater VO2max in atole (1.42 l/min) compared to fresco (1.28 l/min) subjects.

To assess the plausibility of these treatment effects, measures of physical work capacity were related to the amount of supplement consumed by individual subjects. If the subjects who consumed atole have higher VO2max values because they ingested more energy and/or protein from the supplement, then there should be a positive relationship between V02max and the amount of supplement ingested during the critical first three years of life. This relationship was analyzed for males and females separately, with the following sample restrictions: only subjects in the cohort of 14 to 18.9 years of age, since they were exposed to the intervention throughout the period from conception through 3 years of age, and only subjects from atole villages since the range of intakes was wider than in fresco subjects (atole had three-times the energy content per volume than fresco) and would therefore be a better test for this dose-response relationship. Linear regression procedures was used to model VO2max as the dependant variable, with age, village size, and SES controlled as covariates, and kilocalories of supplemental energy consumed during the first 3 years (kcal/day) as the independent variable. The analysis indicates that a 100 Kcal/day increase in supplement ingested from atole during the first 3 years results in a significant ($p=.05$) 190 ml or 0.4 standard deviation increase in oxygen consumed at maximum exertion. The relationship in atole females, however, is not statistically significant.

DISCUSSION

The hypothesized effect of early nutritional supplementation on work capacity at adolescence was observed in this sample of rural Guatemalans. The results indicate a strong treatment effect in males and a weaker one in females. In cohort-2, a significant positive dose-response relationship of energy consumed from supplement and VO2max was seen in males, giving partial support for the plausibility of the observed supplementation group differences. However, this could not be confirmed in females.

Before we can accept these results as support of the hypothesis it is necessary to examine the internal and external validity of the results. Even with adequate randomization of subjects (villages) to atole and fresco groups there are still possibilities that major confounding factors might distribute themselves differentially across treatments. Several of these confounders (age, socioeconomic status and level of participation in the supplementation) were controlled through statistical procedures and the treatment effects persisted.

Physical work capacity is affected by biological maturation status. The degree of relative skeletal maturity, measured by the difference between skeletal age and chronological age, does not differ between atole and fresco villages. Therefore, biological maturity is not likely to be a confounder in this analysis. When skeletal age is used as a covariate (in place of chronological age) to test for atole-fresco differences, the result are unchanged.

Other individual confounders were not controlled in this analysis but indirect evidence suggests that they probably did not play an important role in explaining the reported supplementation effects. Most prominent of these are physical activity and anemia.

Work capacity is enhanced in individuals who are physical active. Evidence from preliminary analysis suggests that physical activity from 24 hour recall probably does not account for the significant treatment effects in males but may have obscured the effects in females, who were very inactive after 14 years of age.

Anemic individuals have a reduce capacity to transport oxygen to the working muscles and suffer from reduced aerobic work capacity. Preliminary analysis of hematological data for the entire field sample suggests a very low prevalence (< 5%) of anemia severe enough to compromise work capacity. While anemia can not be ruled out as a possible confounder, it appears unlikely that enough subjects in the subsample were anemic to account for the systematic effects of supplementation seen across both sexes and 3 cohorts.

The results reported here are generally consistent with those reported by other researchers examining the relationship between chronic undernutrition and work capacity in adolescents. The values for height and VO2max (l/min and ml/kg FFM/min) for atole males and females are comparable to those reported by Spurr and Reina (3) for Colombian subjects who were underweight. The Colombian underweight children and the atole adolescents are below Colombian normal weight children in height and VO2max (l/min). The fresco subjects are well below the Colombian underweight children regardless of age or sex. However, these two study samples differ when VO2max is expressed per kg FFM. Spurr and Reina (3) and others (1,2) have consistently report that the differences in work capacity (VO2max in l/min) between undernourished and control subjects is eliminated when work capacity is expressed per body weight, and often the trend is reversed in favor of the undernourished when expressed per kg FFM. The results from this study indicate that the differences in work capacity remain significant in favor of the atole subjects even after controlling for FFM. Thus, the conclusion of other investigators that the effects of chronic undernutrition on work capacity is mediated through its impact on reducing body size and muscle mass is not supported in this sample of Guatemalan adolescents. Several factors could explain these differences.

The relationship between previous nutritional status and work capacity may be non-linear with the strongest effect seen below a threshold of nutritional status. Examination of the anthropometry reported for the Colombian adolescents studied by Spurr and Reina (3) indicates that the Guatemalans experienced a greater degree of growth retardation perhaps as a result of more severe chronic undernutrition. The presence of a threshold of previous nutritional status affecting work capacity during adolescence is seen in the study of Indian males (1).

Another major difference between the Colombian and Guatemalan studies is the way subjects were classified.

The Colombian subjects, as well as those studied for similar effects in Brazil (2) and East Africa (8), were classified by current anthropometric indicators of chronic and/or acute undernutrition. Since current height and weight are only proxies of past nutritional status, and are themselves highly correlated to current FFM, the expression of work capacity per kg of weight and FFM would logically lead to a reduction in group differences in uncorrected V02max (l/min). The results reported by Satyanarayana et al (1) are more consistent with ours, possibly because they classify nutritional status based on height during the preschool period rather than retrospectively at adolescence.

CONCLUSIONS

In conclusion, these results show that early nutritional supplementation has an impact on physical work capacity, an important measure of functional competence, even when measured many years after the supplementation has terminated. These results along with those reported here earlier by Dr. Rivera for physical growth (9) indicate that investments in early childhood nutritional programs are likely to have a long-term benefit that may assist poor families to break the vicious intergenerational cycle of malnutrition that is so common in developing countries.

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