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Maternal Prenatal Nutrition and Birth Outcomes on Malnutrition among 7- to 10-Year-Old Children: A 10-Year Follow-Up

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Objectives To identify postnatal predictors of malnutrition among 7- to 10-year-old children and to assess the long-term effects of antenatal micronutrient supplementation on malnutrition.

Study design A follow-up study was conducted to assess the nutritional status of 7- to 10-year-olds (1747 children) whose mothers participated in a cluster-randomized double-blind controlled trial from 2002 to 2006.

Results The rate of malnourished 7- to 10-year-olds was 11.1%. A mixed-effects logistic regression model adjusted for the cluster-sampling design indicated that mothers with low prepregnant midupper arm circumference had boys with an increased risk of thinness (aOR 2.05, 95% CI 1.11, 3.79) and girls who were more likely to be underweight (aOR 2.01, 95% CI 1.05, 3.85). Antenatal micronutrient supplementation was not significantly associated with malnutrition. Low birth weight was significantly associated with increased odds of malnutrition among boys (aOR 4.34, 95% CI 1.82, 10.39) and girls (aOR 7.50, 95% CI 3.48, 16.13). Being small for gestational age significantly increased the odds of malnutrition among boys (aOR 1.75, 95% CI 1.01, 3.04) and girls (aOR 4.20, 95% CI 2.39, 7.39). In addition, household wealth, parental height, being picky eater, and illness frequency also predicted malnutrition.

Conclusions Both maternal prenatal nutrition and adverse birth outcomes are strong predictors of malnutrition among early school-aged children. Currently, available evidence is insufficient to support long-term effects of antenatal micronutrient supplementation on children's nutrition. *(J Pediatr 2016;178:40-6).*

Trial registration www.isrctn.com: ISRCTN08850194.

See editorial, p 7 and related article, p 34

Malnutrition leads to more than one-third of all child deaths every year worldwide.[1] Most studies of malnutrition have focused on children under 5 years of age, and school-aged children are often omitted from health and nutrition surveys or surveillance.[2] Poor nutritional status in schoolchildren, however, might have long-term consequences for their cognitive abilities,[3] educational attainment,[4] and productivity.[5] Given these findings, research is needed about the predictors of malnutrition across different environmental and sociocultural settings. The predictors of malnutrition extend from the antenatal to the postnatal period. However, studies on the factors that affect malnutrition are often cross-sectional.[6,7] In addition, the existing longitudinal studies have focused primarily on the predictors of malnutrition among children under 5 years of age.[8,9]

Maternal nutritional status prior to conception and throughout pregnancy is crucial for fetal growth. A meta-analysis did not find evidence of any benefit for antenatal multiple micronutrient (MM) supplementation (MMS) for the growth and nutritional status of children under 5 years of age.[10] However, few antenatal MMS studies have longitudinally studied a birth cohort through school age.[11,12]

This study assessed the nutritional status of Chinese 7- to 10-year-old children whose mothers received MMS during pregnancy using a cluster-randomized, controlled, double-blind trial. Our primary aim was to identify the predictors of

BAZ	BMI-for-age z-score
BMI	Body mass index
FA	Folic acid
HAZ	Height-for-age z-score
IFA	Iron-FA
LBW	Low birth weight
MM	Multiple micronutrient
MMS	MM supplementation
MUAC	Midupper arm circumference
SDVs	Social demographic variables
SGA	Small for gestational age
WAZ	Weight-for-age z-score
WHO	World Health Organization

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malnutrition from the antenatal stage to postnatal stages among 7- to 10-year-olds in rural western China. We also explored whether antenatal MMS have long-term effects on the nutritional status of children.

Methods

The participants in the present study were from a large cluster-randomized, double-blind, controlled trial, which examined the effects of antenatal micronutrients supplementations on perinatal outcomes (www.isrctn.com: ISRCTN08850194).[13] Briefly, the trial took place in 2 rural counties in Shaanxi Province of Northwest China from 2002 to 2006. To ensure geographic balance, all villages were stratified by county and randomized with a fixed ratio of treatments (1:1:1). Finally, there were 178 villages for folic acid (FA, 400 μg), 183 for iron-FA (IFA, 400 μg of folic acid and 60 mg of iron), and 170 for MMs (consistent with the suggested composition of MMS for antenatal use as recommended by the World Health Organization [WHO]).[14] All pregnant women in the same village received the same treatment, 1 supplement tablet daily from enrollment to delivery. In total, 5828 women were recruited, and there were 4604 single live births.

From 2012 to 2013, we followed up all single live births, whose mothers participated in the antenatal MMS trial and remained as residents in the study areas. We excluded those children who had migrated. Many potential confounders that may be associated with nutritional status of children could not be well estimated for the children who had migrated. Those with congenital diseases or who had died were also ineligible. The purpose of the follow-up study was fully explained to the parents, and written informed consent was obtained. Finally, we followed up 1747 eligible children. The Science and Research Ethics Committee of Xi'an Jiaotong University approved this follow-up study.

Primary Outcomes

Child height and weight were measured using the standard techniques.[15] The measurement equipment was calibrated regularly, and all measurements were taken at similar times of day. Children were measured with light clothing and no shoes. Standing height was measured in duplicate using a standard steel strip stadiometer to the nearest 0.1 cm (type SZG-210; Shanghai JWFU medical apparatus factory, Shanghai, China). Weight was measured twice with a digital scale to the nearest 0.10 kg (type BC-420; Tanita, Tokyo, Japan). We recorded 2 successive measurements and used the mean for analysis.

Body mass index (BMI) was derived from body weight in kilograms divided by height in meters squared. The raw anthropometric data (height, weight, and BMI) were converted into normalized z-scores for sex and age using the WHO 2007 reference data.[16] Stunting, underweight, and thinness were defined as a height-for-age z-score (HAZ) below -2, a weight-for-age z-score (WAZ) below -2, and a BMI-for-age z-score (BAZ) below -2, respectively.[17] Malnutrition was defined as any one of HAZ, WAZ, or BAZ values below -2.

Predictors and Confounders

After physical measurements, the children and their parents were interviewed to collect information about social demographic characteristics and children's eating habits, medical history, and physical exercises. Maternal antenatal nutrition and birth outcomes were recorded in the original trial.

Social demographic variables (SDVs) included household economic status (lower-, middle-, and upper-class); parental educational level (primary and below, secondary and above); occupation (farmer or others); height (both below the mean within participants, one of them below the mean within participants, and both equal to or above the mean within participants); maternal age at pregnancy (<25 or ≥25 years); and parity (primiparous or not). Maternal antenatal nutrition included maternal prepregnant midupper arm circumference (MUAC; <23.5 or ≥23.5 cm), anemia (hemoglobin concentration <110 g/L in the third trimester), micronutrient supplementations during pregnancy (FA, IFA, or MM), and the number of supplement tablets consumed (<180 or ≥180). Birth outcomes included preterm (<37 weeks' gestation), low birth weight (LBW, ≤2500 g), and small for gestational age (SGA, birth weight below the 10th percentile of the gestational age-sex specific US reference for fetal growth[18]). Postnatal factors included being a picky eater, eating habits (poor, balanced, or rich), illness over the past few years (often or occasionally), and physical activity (often or occasionally). A wealth index was constructed from an inventory of 15 household assets or facilities using a principal components analysis,[19] and categorized into tertiles indicating the lower-, middle-, and upper-class households.

The caregiver was asked "Is your child a picky eater?" Those responding "often" and "always" were categorized as picky eaters. Physical activity was also assessed by a questionnaire. The caregiver was asked "How often does your child participate in sports and vigorous physical activity?" Those responding "often" and "always" were categorized as often, and those responding "never" and "occasionally" were categorized as occasionally.

We used a structured questionnaire to document the children's food intake frequency. Dietary patterns were constructed on the base of the kind of food and the food intake frequency. Briefly, we first applied a principal component analysis to identify groups of interrelated food categories. Subsequently, the factor scores were used in a cluster analysis that revealed a 3-cluster solution. The "poor dietary pattern" was characterized by a high intake of vegetables and pickled foods combined with a low consumption of proteins. The "rich dietary pattern" was characterized by a high intake of meat and fruits and snacks. The "balanced dietary pattern" was characterized by a balanced intake of meat, milk and eggs, vegetables, and fruits and snacks.

Statistical Analyses

We performed range and logical assessments of the data for accuracy. We compared baseline characteristics between follow-up participants and those lost to follow-up; we also compared physical growth and malnutrition prevalence between boys and girls. Continuous data were analyzed using *t* tests, and cat-