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Prevalence and predictors of anemia in a population of North Indian children

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ABSTRACT

Objective: Anemia is an important health concern worldwide, particularly in poor populations such as in India. The objective of this study was to determine the prevalence and predictors of anemia and iron status.

Methods: One thousand children ages 6 to 30 mo were included in a study undertaken in low- to middle-income neighborhoods in New Delhi, India. Children of Tigri and Dakshinpuri were identified through a community survey. Plasma concentrations of hemoglobin (Hb), soluble transferrin receptor (sTfR), folate, vitamin B_{12}, and total homocysteine (tHcy) were measured. Predictors for plasma Hb concentration were identified in multiple linear regression models and considered significant if *P*-value <0.05.

Results: The prevalence of anemia (Hb concentration <11 g/dL) was 69.6% (n = 696) whereas the prevalence of iron deficiency (elevated sTfR i.e., >4.7 nmol/L) was 31% (n = 309). The main predictors for Hb concentration were plasma concentrations of sTfR (standardized beta coefficient [β], −0.49; $P < 0.001$), folate (β, 0.15; $P < 0.001$), vitamin B_{12} (β, 0.10; $P < 0.001$), tHcy (β, −0.11; $P < 0.001$) among the biomarkers. Length-for-age *Z* score (β, 0.08; $P = 0.002$) and family income (β, 0.06; $P = 0.027$) also predicted Hb concentration.

Conclusion: Anemia was common in this population. Iron, folate, and vitamin B_{12} status were important predictors for plasma Hb concentration. Improving the status of these nutrients might reduce the burden of childhood anemia in India.

Introduction

Anemia is an important health concern, particularly in poor populations such as India. More than 1.6 billion people are anemic worldwide including almost half of all preschool children, and one-third of these 300 million preschool children live in India [1]. The third National Family Health Survey estimated that approximately 79% of Indian preschool children were anemic [2]. Rural areas have generally been more affected than urban locations [3,4]. Despite an impressive economic development in India, particularly in the urban areas, the proportion of the population that is anemic seems to remain stable and has even increased in recent years [5,6]. It has been established that approximately half of all anemia cases are due to iron deficiency [2,7,8]. Iron deficiency is the most prevalent nutritional disorder in the world today and is also believed to be the most important cause of anemia among children in India [9]. It is related to poor nutritional iron intake, low iron bioavailability, and low socioeconomic status [10,11]. Other nutrients such as folate and vitamin B_{12} also probably play a role in childhood anemia, and deficiency of these nutrients also may result in anemia [12–14]. In this study of 1000 children from a low socioeconomic area of

ST, TAS, and NB designed the research. ST, TK, FA, MM, and SM conducted the research. CSY was involved in analysis of plasma specimens. BK was responsible for data management and data analysis. TK, ST, BK, and TAS analyzed the data and prepared the manuscript. TAS had primary responsibility for final content. All authors read and approved the final manuscript and there was no conflict of interest between the authors, and with the funding agencies.

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New Delhi, India we measured hemoglobin (Hb) concentrations to assess the prevalence of anemia. We also measured other biomarkers such as iron, vitamin B_{12}, and folate and used these and clinical, socioeconomic, and anthropometric variables to identify predictors for the Hb concentration.

Materials and methods

Study site and participants

The study was conducted in the low to middle socioeconomic settings of Tigri and Dakshinpuri in New Delhi with a total population of about 300 000. Details of the population have been described previously [15,16]. The present findings come from the baseline data of a randomized double-blind, placebo-controlled preventive field trial with a factorial design that evaluated the effect of supplementation with folic acid, vitamin B_{12}, or both on childhood infections. The results of the study have been published elsewhere [17].

Procedures

By means of a door-to-door survey, 1377 children ages 6 to 30 mo of either sex were identified and 1000 were enrolled in the study between January 2010 and September 2011 [17]. Children with severe systemic illness requiring hospitalization, severe malnutrition (weight for height z score [WHZ] <-3 Z), or severe anemia (Hb $<$ 7 g/dL), those taking folic acid and/or vitamin B_{12} supplements, and those not consenting, or moving away were excluded from enrollment (Fig. 1).

Weight was measured using digital Digitron scales with 50 g sensitivity (Digitron, S n S, Delhi, India). Length was measured using locally manufactured infantometer reading to the nearest 0.1 cm (Nikhil traders, Delhi, India).

Laboratory parameters

A blood sample ($\sim$3 mL) was obtained for all children and collected in EDTA-containing vaccutainers (BD, Franklin Lakes, NJ, USA). The blood was centrifuged at $\sim$450 *g* at room temperature for 10 min, plasma was separated and transferred into storage vials, and stored at -20°C until analysis (Remi Sales & Engineering LtD, Mumbai, India). Blood samples were analyzed for Hb concentration using HemoCue AB (HemoCue Hb Angelholm, Sweden). The HemoCue analyzer has been used extensively worldwide for estimating the concentration of Hb with capillary blood in field conditions, and has been found to provide accurate results, comparable to estimates from more sophisticated laboratory instruments [18]. The instrument has been validated against major automatic cell counters and was found to agree well with all tested systems [19]. Plasma concentration of folate and vitamin B_{12} were estimated by microbiologic assays using a chloramphenicol resistant strain of *Lactobacillus casei* [20] and colistin sulphate resistant strain of *Lactobacillus leichmannii*, respectively [21]. Plasma soluble transferrin receptor (sTfR; marker of iron status) was analyzed quantitatively using an immunoturbidimetric assay from Roche diagnostics on the Roche modular P800 (Roche diagnostics, Basel, Switzerland) [22] and plasma total homocysteine (tHcy) was analyzed using commercial kits (Abbott Laboratories, Abbott Park, IL, USA) [23].

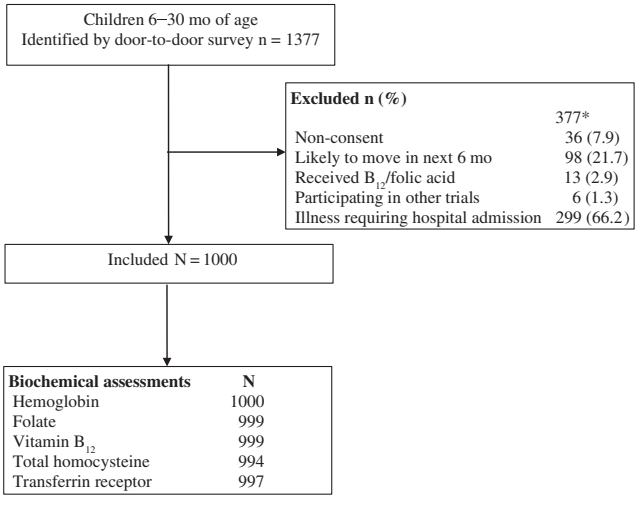

Fig. 1. Study profile.

Definitions

Anemia was defined as Hb $<$11 g/dL on the basis of World Health Organization (WHO) criteria [1,8]. Iron deficiency was defined as sTfR concentrations $>$4.7 nmol/L [24]. We defined vitamin B_{12} deficiency as plasma vitamin B_{12} $<$200 pmol/L and folate deficiency as a plasma folate $<$7.5 nmol/L [17,25].

Questionnaires used for the data collection were developed and compiled by experienced study investigators. All the questionnaires were pretested in the field, standard operating procedures were made, and dummy questionnaires were filled before administered to the study staff and participants.

A team of educated, skilled, and experienced fieldworkers, lab technicians, supervisors, and physicians collected the data. The study team went through extensive training sessions before the study start and only those who had reached a certain level of skills were allowed to collect data. Supervised and non-supervised visits were made at regular intervals.

The study staff was standardized in their respective tasks at the beginning as well as at regular intervals during the trial in activities such as blood collection techniques, anthropometrics, and temperature and respiratory rate measurements. Standardization sessions were repeated every 6 mo. The instruments used in the study were calibrated at regular intervals throughout the study period.

Ethics

This study was conducted according to the latest version of the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the ethics committees at Society for Essential Health Action and training New Delhi, Society for Applied Studies New Delhi, Christian Medical College Vellore, and Norwegian Regional Committee for Medical and Health Research Ethics (REK VEST) before the initiation of the study. Information obtained through community consultation was used to formulate the study design and procedures. Plain-language statements explaining the study were provided to and written informed consent was obtained from the guardians of all child participants involved in the study. Information consent forms were translated in a simple local language (Hindi) and those who were unable to read, the staff obtaining consent read out the information sheet in the presence of an impartial literate witness and those who were unable to sign, a thumb imprint was taken, witnessed (countersigned) by an impartial literate witness. If the caregiver wanted to keep a copy of the form to show to other literate family members before consenting, a copy was left with the caregiver and the caregiver was asked to come on next day for consenting.

Statistical analysis

The forms used for data collection were designed in visual basic.net in computer [26]. Double data entry by two data entry clerks followed by validation was completed within 72 h. Range and consistency checks were incorporated. Continuous variables were reported as means or medians and categorical variables as proportions in the baseline table. The statistical analyses were performed with Stata, version 12 (StataCorp, College Station, TX, USA).

Linear regression was used to identify predictors for Hb concentration. The associations were first evaluated in crude linear regression models and then in multiple-regression models in a stepwise process. Variables were retained in the multiple regression models if the *P*-value for their coefficient remained $<$0.05. Three different statistical models were developed. The first model contained the demographic, clinical, and anthropometric variables; the second model contained only the biomarkers; and in third model included all variables of the previous two models. Because of covariability between tHcy and vitamin B_{12}, these two variables were not included in the statistical models simultaneously. Standardized beta coefficients (β) were calculated for the estimation of the strength of the associations. Biomarkers of folate, vitamin B_{12}, and iron status, as well as other variables, were log-transformed to achieve normality when necessary. We used generalized additive model (GAM) plots in the package "mgcr" in the statistical software R [27,28] to depict the "dose-response" relationship between sTfR, tHcy, vitamin B_{12}, and folate concentration with Hb concentration. In the GAM models, biochemical variables were adjusted for age, breast-feeding status, family income, possession of items, and length-for-age (HAZ) *Z* score.

Results

One thousand of the 1377 screened children were found eligible for the study and enrolled. The baseline characteristics of the enrolled children are shown in Table 1. The mean age of