

The Cultural Ecology of Iron Deficiency among Northern Kenyan Schoolchildren

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INTRODUCTION

Iron deficiency is reportedly the most common micronutrient deficiency worldwide, and in developing countries, the burden rests not only upon women and infants, but also on school aged children (Siekmann et al., 2003; Stoltzfus et al., 1997). Iron deficiency anemia bears serious costs including impaired learning and school performance (Pollitt, 1997), growth faltering and reduced physical fitness (Stephenson, 1993), and increased risk of infectious morbidity (DeMaeyer, 1989). While most attention has been focused on consequences of severe iron deficiency, which is accompanied by anemia, milder pre-anemic forms of iron deficiency (iron deficient erythropoiesis, or IDE) may also be associated with significant functional impairments (Haltermann et al., 2001). Iron deficiency arises when iron absorption is insufficient to meet the body's needs. The insufficiency may be attributed to low overall iron intake, or to increased need for iron from chronic blood loss due to parasites such as hookworm or *Schistosoma* (Stoltzfus et al., 1997). In addition, iron absorption is also influenced by bioavailability of iron. While heme iron (present in animal foods) has high bioavailability, the absorption of nonheme iron (present in plant foods) is influenced by meal composition. Enhancers, such as ascorbic acid, promote the absorption of nonheme iron, whereas inhibitors, such as phytates and polyphenols, decrease absorption of nonheme iron.

In community-based assessments of the prevalence of iron deficiency, indices of anemia – hemoglobin concentration or hematocrit – are the most commonly used hematological tests. These measures are, however, neither sensitive nor specific to iron deficiency (Stoltzfus, 2001). Although iron deficiency is often assumed to be the primary cause of anemia, there exist other potentially important causes of anemia, including chronic infection, blood loss or hemolysis from parasitic infection, hemoglobinopathies such as sickle cell or thalassemia, and other nutrient deficiencies such as folate and vitamin A deficiency (Johnston and Gillespie, 1998; Suharno et al., 1993; Weatherall and Abdalla, 1987).

Moreover, hemoglobin and hematocrit do not detect milder pre-anemic iron deficiency, which in some settings is the major form of iron deficiency (Shell-Duncan and McDade, 2004). Consequently, a combination of biochemical tests that are more specific for iron status and detect inflammation are needed to identify iron deficiency as a cause of anemia, and to detect IDE (see Shell-Duncan and McDade, 2004 (Shell-Duncan and McDade, 2004, for a discussion of a field-friendly multiple criteria model).

As DeMaeyer (1989) point out, the treatment and control of iron deficiency is technically quite simple, requiring only an increase in iron intake. Dietary modification can improve iron status in poor communities in two key ways: 1) increasing the overall iron content of the diet by modifying household food acquisition and allocation practices, and 2) increasing the bioavailability of iron ingested by promoting the consumption of iron absorption enhancers or reducing the ingestion of inhibitors. Numerous factors, however, make dietary modification difficult to attain. It is well recognized that economic constraints pose formidable barriers for both avenues of dietary modification. The most efficient manner of improving overall iron content or bioavailability of iron in communities with predominantly starch-based diets is to increase the consumption of meat, which not only provides heme iron, but also increases the absorption of nonheme iron (DeMaeyer, 1989; Engelmann et al., 1998; Murphy et al., 2003). In many communities high cost is an obstacle to obtaining animal foods. However, in households that do have access to heme iron, barriers to access to iron rich foods may be cultural, influencing food selection and household food distribution. Therefore, efforts to modify dietary intake need to consider both environmental and cultural factors influencing dietary iron intake.

The purpose of this study is to investigate the epidemiology of iron deficiency among northern Kenyan children, and to identify barriers to iron intake. We evaluate not only the biomedical and socioeconomic context of iron status, but also the cultural factors contributing to observed patterns of

iron deficiency. The results of this research are used to explore the possibility of dietary modification as a sustainable approach to preventing iron deficiency.

SUBJECTS AND METHODS

In July 1999, research was conducted in Marsabit District in northern Kenya among a population ethnically identified as Rendille. The Rendille are traditionally nomadic, subsisting through camel pastoralism in the Kaisut Desert. This desert is one of the harshest and least productive regions of East Africa, receiving on average less than 250 mm of annual rainfall (Nathan et al., 1996). It is also characterized by high levels of endemic disease stress, with respiratory infection, malaria and diarrhea being the leading source of morbidity (McDade and Shell-Duncan, 1998). Recently, in response to a series of droughts that diminished large portions of the livestock, many Rendille have become settled in permanent towns in the Kaisut Desert, and have shifted to alternative forms of subsistence, including dryland agriculture, milk marketing, trade, and blacksmith artisanship. Settlement of former nomads is accompanied by major changes in diet, away from an iron-rich diet of blood, milk and meat to a maize meal based diet (Nathan et al., 1996). This study investigates the prevalence of iron deficiency among settled Rendille school children, and evaluates the cultural ecology of dietary iron intake.

Blood samples and anthropometrics were obtained from 5 to 10 year-old Rendille children in two rural villages, Korr and Karare. Following the construction of community maps and a complete census of the 5- to 10-year old population in each village, 300 children were selected in a 30-strata sampling design. The strata represented the town center and surrounding *menyattas*—circular compounds comprised of homes of extended families. Children's ages were determined by reports from the parent or primary caretaker using a local event history calendar, and by the date of birth recorded on the clinic card. Discrepancies were resolved by relative ranking against other children of known age in the community. The study protocol was reviewed and approved by the Human Subjects Division at the University of Washington and the Ethics Committee at Kenyatta Hospital in Nairobi.

Assessment of Health and Iron Status: Sterile, disposable micro-lancets were used to collect free-flowing capillary blood to assess iron status and inflammation. Iron status was determined by combined measures of hemoglobin, the ratio of zinc

protoporphyrin to heme (ZPP:H), and transferrin receptor (TfR). This multiple criteria model has been previously assessed (Shell-Duncan and McDade, 2004). Because hemoglobin and ZPP:H may be altered in the presence of infection (Asobayire et al., 2001; Mockenhaupt et al., 2000), C-reactive protein (CRP) was used to identify individuals with inflammation.

Hemoglobin concentrations in capillary blood were determined in the field using the HemoCue B-Hemoglobin system (HemoCue, Inc., Mission Viejo, CA). Calibration was checked daily by measuring a sample with a known hemoglobin concentration determined by ICSH (International Committee for Standardization in Haematology) recommended reference methods (International Committee for Standardization in Haematology, 1978). Anemic subjects were identified by subnormal hemoglobin using the WHO age-specific cutoff values adjusted for ethnicity and altitude (Nestel, 2002).

ZPP:H was measured from whole blood collected in two heparinized capillary tubes, which were then sealed and stored for up to 2 weeks in a portable, car-battery powered refrigerator. The tubes were transported to the Clinical Nutrition Laboratory at the University of Washington and analyzed for ZPP:H using the ProtoFluor-Z Hematofluorometer (Helena Laboratories, Inc., Beaumont, TX). A cutoff value of 80 imol/mol is recommended for identifying elevated ZPP:H for all ages above one year (Labbe et al., 1999).

TfR and CRP were determined from capillary blood dried on filter paper. At least two drops of whole blood were collected on filter paper (Schleicher & Schull #903, Keene, NH, USA), allowed to dry for approximately four hours, and sealed in plastic bags with desiccant. Samples were refrigerated prior to transport to the Laboratory for Human Biology Research at Northwestern University, where they were stored at -20°C until analysis. Prior research has demonstrated that CRP is stable in dried blood spots for at least 14 days when stored at 4°C , and for up to one year when stored at -20°C (McDade et al., 2004). CRP levels were assayed following the ELISA protocol developed by McDade et al. for whole blood spots (McDade et al., 2004). TfR concentrations were measured using a commercially available ELISA kit (TF-94, Ramco Laboratory, Stafford, TX, USA), modified for whole blood spots (McDade and Shell-Duncan, 2002). Current plasma/serum protocols suggest a cutoff value of 8.5 for identifying iron deficiency (Asobayire et al., 2001; Cook et al., 1993). This corresponds to a whole blood spot TfR

concentration of 6.7 mg/L (McDade and Shell-Duncan, 2002).

Thick and thin smears were prepared on glass slides for the determination of malarial parasites. The slides were fixed and stained with Giemsa stain and screened for malaria parasites at the Laboratory of Medicine at the University of Nairobi. Only the presence or absence of malaria parasites was reported.

Urine samples were collected on the day of nutritional assessment to screen for microhematuria, which often arises from schistosomiasis (Prual et al., 1992; Savioli et al., 1990). Hematuria was tested using Hemastix® reagent strips (Bayer Corporation, Elkhart, IN, USA), which generally detects free hemoglobin levels from 0.015-0.062 mg/dl.

A general assessment of nutritional status was obtained through anthropometry, collected by a single observer using standard techniques described by Jelliffe and Jelliffe (Jelliffe and Jelliffe, 1989). Height was measured to the nearest mm with an anthropometer while subjects stood on a level platform. A Seca (Hanover, MD, USA) electronic digital LED scale was used to measure weight to the nearest 0.1 kg, with the subject wearing light clothing.

Dietary Intake and Child Feeding: Twenty-four hour dietary recall data were obtained from children and their caretakers according to methods described by Buzzard (Buzzard, 1998). When conducting the dietary intake interview, an enamel cup commonly used in northern Kenya was used as a reference for food quantities consumed. This cup was then used to determine equivalent ounces and gram weights of various food portions in ounces or grams. For combined foods such as stews and tea, recipes were obtained through participant observation and interviewing. Portions were measured using local utensils, and converted in to ounce or gram equivalents. Finally open-ended interviews centered on the mother's perception of the child's food preferences and aversions, as well the mother's beliefs and self-reported practices regarding child feeding.

Sociodemographic Data: A pre-tested questionnaire was used to interview the primary caretaker of each selected child regarding socioeconomic and demographic information, including attendance at school, the child's birth order, mother's age and level of education, whether the household was headed by a male or female, prolonged absence of the husband (more 6 months in the past year), household size, number of dependents, and economic status of the household. Following earlier

developed methods described in detail elsewhere (Shell-Duncan and Obiero, 2000), economic status is, for this analysis, dichotomized into poor vs. economically sufficient. Briefly, several items were used to create this index, including wage income, livestock holdings (quantified as total livestock units, with one unit set equal to 1 cow, .8 camels, or 10 goats or sheep), garden size, farm production, marketing or bartering of items such as milk, firewood, charcoal, and alcoholic beverages. Using earlier determined equivalence factors, holdings were converted into total livestock units, and families classified as "not poor" were those that owned more than a total of 4.5 total livestock units per capita.

Data Analysis: Iron deficiency was identified by a multiple criteria model defined as elevated ZPP:H in the presence of normal CRP and/or elevated TfR (Shell-Duncan and McDade, 2004). Iron deficiency anemia was (IDA) defined as iron deficiency in the presence of subnormal hemoglobin (hemoglobin in highland Karare <110 g/L for age 5, or 115 g/L for ages 6-10; hemoglobin in lowland Korr, 100 g/L for age 5 or, 105 g/L for ages 6-10). Iron deficiency was defined as elevated ZPP:H (>80 i) in the absence of inflammation (CRP <1.5 mg/L) and/or elevated TfR (TfR>6.7 mg/L). Pre-anemic iron deficiency, or iron deficiency erythropoiesis (IDE), was identified by iron deficiency in presence normal hemoglobin.

Anthropometrics were entered into EpiInfo (version 1.0.5, Centers for Disease Control and Prevention, Atlanta, GA, USA) to calculate sex-specific height-for-age and weight-for-height Z-scores (WHZ). For children aged 5 to 10 years, there is no accepted indicator for wasting (WHO, 1995). We used a WHZ below -3 SD to define severe wasting, which may independently cause anemia (Dempster et al., 1995).

Biochemical and survey data were analyzed using SPSS (SPSS Inc, Chicago, USA). To assess the magnitude of the association between iron deficiency and several risk factors, the odds ratio (OR) and correlation were calculated. The OR is defined as the prevalence of iron deficiency in the exposed group divided by the prevalence of iron deficiency in the non-exposed group (Kahn, 1983).

Backwards regression models were used to evaluate the effect of socioeconomic factors on iron status while controlling for individual-level factors (age and sex). Economic status was, in this analysis, dichotomized into poor vs. sufficient using a scale been previously described (Shell-Duncan and Obiero, 2000). In order to correctly specify the models and

more closely model real processes impinging on iron status, interactions between independent variables were also carefully evaluated. The final models include variables that remained after a stepwise backwards elimination process with $p < .05$.

Twenty-four hour dietary recall data were analyzed using two programs: Nutritionist IV Software Program (First Data Bank, 1995, Indianapolis, IN, USA), which computes macronutrients and micronutrients including total dietary iron; and WorldFood 2 Dietary Assessment System, version 2.0 (Calloway et al., 1994), which calculated bioavailable iron. Food composition data for Kenyan foods were obtained from the database for WorldFood 2, and values of northern Kenyan foods not included in this database (e.g., blood, camel's milk) were obtained from published food composition tables (FAO/WHO, 1968; Galvin, 1985; West et al., 1987; Yagil, 1982).

Recipes of combined foods were entered into Nutritionist IV, and used to estimate composition of specified portions. WorldFood 2 calculates the bioavailability of iron using an algorithm developed by Murphy et al. (Murphy et al., 1992). It assumes that heme iron constitutes 40% of the iron in meat, poultry, and fish, and that heme iron is 25% available. The availability of nonheme iron ranges from 5% to 15%, depending on the enhancing and inhibiting factors consumed in the same meal. Since iron absorption is also influenced by individual iron status (Monsen et al., 1978), it is assumed that each individual has a basal iron status that is high enough to prevent anemia. Although iron status may be better for many individuals, this provides an estimate of bioavailability to maintain at least this low level of iron status. In World Food 2, the weights of foods and ingredients were entered in grams. For foods measured by volume using local cups, conversion to grams was based on test weights of foods per measured volume.

Content analysis was used to analyze qualitative data on child feeding practices (Bernard, 1995). Emergent themes identified common food proscriptions and restrictions in each community.

RESULTS

Characteristics of Study Subjects: Complete demographic and health data were collected from 300 children ages 5 to 10 years and their mothers or primary caretaker. Descriptive data show a mean household size of 5.5, with an average of 3.5 dependents (children under 15 years of age) per

household. Seventy percent of children were currently attending primary school, and 30% were currently not in school. Most households participated in subsistence agriculture, milk marketing or bartering of items such as firewood, while less than 12% of households had wage-earning adults. In general, living conditions in these communities are considered poor by Kenyan standards. Using our socioeconomic status index, 42% of households were categorized as poor.

Prevalence of Anemia and Iron Deficiency:

Descriptive statistics for biochemical indices are given in Table 1. Only 8.0% of children had

Table 1: Descriptive statistics for biochemical indices.

Biochemical indices	Median (min, max)	% beyond cutoff ¹
Hb (g/L)	133.0 (30.0, 163.0)	8.0
ZPP:H (imol/mol heme)	69 (34, 458)	32.0
TfR (g/L)	4.5 (2.3, 232)	18.5
CRP (mg/L)	.04 (0, 21.2)	15.6

¹ Cutoff values: Hemoglobin in highland Karare <110 g/L for age 5 or < 115 g/L for ages 6-10; Hemoglobin in lowland Koror < 100 g/L for age 5 or < 105 g/L for ages 6-10; ZPP:H > 80 imol/mol; TfR > 6.7 mg/L; CRP > 1.5 mg/L.

subnormal hemoglobin, whereas 32% showed elevated ZPP:H. Using the multiple criterion model, we found that the overall prevalence of iron deficiency was 31.2%. (Fig. 1). Additionally, we found that preanemic iron deficiency (23.1%) was significantly more common than IDA (8.1%), and that overall levels of iron deficiency (IDE and IDA combined) were significantly higher in Karare (39%) than in Koror (24%).

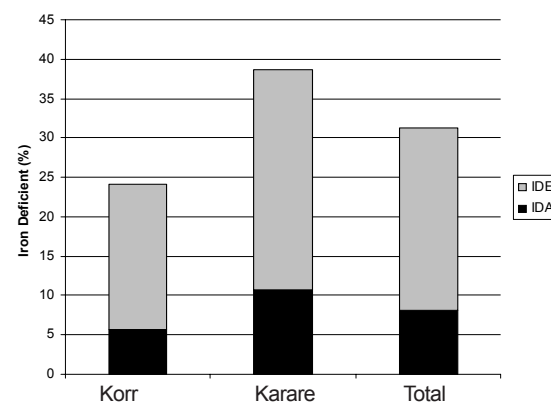


Fig. 1. Prevalence of Iron Deficiency

Health Risk Factors Associated with Anemia:

Several health and nutritional risk factors were examined in relation to their association with iron

deficiency (Table 2). Hematuria, which is often used to screen for urinary schistosomiasis (69% sensitivity and 89% specificity according to Savioli et al. (Savioli et al., 1990), was found in 4.2% of subjects. All but two cases were in children from the town of Karare. Malaria, which may contribute to the etiology and severity of anemia through several mechanisms, including destruction of parasitized red blood cells, immune mechanisms, and dyserythropoiesis (Weatherall and Abdalla, 1987), was confirmed in only 1.3% of subjects, and was not significantly correlated with iron deficiency. Severe wasting, assessed as WHZ <-3 SD, was found in only 1.3% of subjects, and was not significantly correlated with iron deficiency. The results exclude wasting as important preventable risk factors for iron deficiency, but the importance of other parasitic infections, such as hookworm, remain unclear.

Table 2: Health risk factors and their association with iron deficiency

<i>Risk factor</i>	<i>Prevalence of risk factor (%)</i>	<i>Odds ratio</i>	<i>Correlation with iron deficiency (p)</i>
Hematuria	4.2	1.24	Ns
Malaria	1.3	2.06	Ns
Severe wasting (WHZ < -3SD)	1.3	0.79	ns

Ns, Not significant; WHZ, weight-for-height Z score.

Nutritional Risk Factors for Iron Deficiency:

The nutritional nature of iron deficiency in this study population is investigated by analysis of dietary intake data and corresponding biomarkers. As shown in Table 3, the median daily dietary intake of iron in Karare approached the recommended levels, whereas the median intake in Korr was only 65% of recommended dietary allowances. Levels of iron deficiency were, however, higher in Karare than Korr. Therefore, it is essential to examine bioavailability of iron, and dietary constituents that enhance or inhibit iron absorption. The bioavailability of children's diets was low in both locations: 4.3% of total iron intake in Karare and 7.7% in Korr. The median bioavailable iron intakes were well below the median absorbed iron requirements for growth and maintenance, especially for 7- to 10-year old children (Hallberg et al., 2000).

Vitamins that have been reported to influence hemopoiesis and iron absorption include ascorbic acid, vitamin A, vitamin B-12 and folate (Fishman et al., 2000; Garcia-Casal et al., 1997; Layrisse et al., 2000). Folate intakes were high in both communities

Table 3: Median 24-hour intake of energy and select micronutrients by sublocation.

	<i>Community</i>		
	<i>Korr (% age-specific RDA)</i>	<i>Karare (% age-specific RDA)</i>	<i>RDA*</i>
Total kcal	1164.0 (60)	1496.0 (79)	1800 ¹ -2000 ²
Iron (mg)	6.5 (65)	9.3 (93)	10
Ascorbic acid (mg)	28.1 (62)	23.1 (51)	45
Vitamin A (ig RE)	104.6 (17)	239.3 (41)	500 ¹ -700 ²
B ₁₂ (ig)	0.68 (57)	1.14 (102)	1.0 ¹ -1.4 ²
Folate (ig)	216.6 (256)	235.4 (276)	75 ¹ -100 ²

¹ RDA for 5-6 year old children.

² RDA for 7-10 year old children.

* Recommended Dietary Allowances, 1989 (National-Research-Council, 1989)

(median 216.6 and 235.4 ig in Korr and Karare, respectively), whereas median daily ascorbic acid and vitamin A intakes were low. Because the RDAs are set high to maximize sensitivity, it has been suggested that a value of $\frac{3}{4}$ be used to determine inadequate nutritional intake (National-Research-Council, 1986). By this standard, intakes of both vitamin A and ascorbic acid are inadequate among children in both communities.

The main dietary staples among Rendille children were maize meal (cooked as a stiff porridge, *ugali*, or a thin porridge, *ugi*), tea with milk and sugar, and *githeri*, a dish made from red beans and maize. These foods contain nonheme iron, as well as several inhibitors of iron absorption (tannins in tea, phytates in maize, polyphenols in legumes, calcium in milk). Heme iron, which enhances the absorption of nonheme iron, was consumed in the form of meat and blood by only 13% of children. Additionally 89.9% of children were reported to consume tea with at least one meal. The leading food sources of iron, as well as ascorbic acid and vitamin A, which have been reported to improve iron absorption (Garcia-Casal et al., 1997; Hallberg et al., 1986; Hallberg and Rossander, 1984; Layrisse et al., 2000), are shown in Table 4. Potatoes and milk were the main source of ascorbic acid. Camel milk, which was consumed most often in Korr, contains 3 times the levels of ascorbic acid as does cows milk. This contributes to the higher ascorbic acid intake among Korr children. Fruits were consumed by only 4.1% of children, and were not a significant source of ascorbic acid. Although vegetables were consumed by only 10% of children, and sukuma, a dark green leafy vegetable, contributed to ascorbic acid intake, as well as vitamin A among children in Karare. Milk was the leading

source of vitamin A, and maize meal and legumes were sources for approximately 75% of iron consumed. Overall, this diet is low in bioavailable iron. In Korr iron deficiency appears to be caused by low dietary iron intake, while in Karare, iron deficiency appears to be attributable more so to poor iron bioavailability than to low iron intake per se.

Table 4: Leading food sources for iron, ascorbic acid and vitamin A

	Median Quantity	
	Korr	Karare
<i>Iron (mg)</i>		
Total	6.5	9.3
Maize meal	3.8	4.0
Legumes	1.6	3.1
Meat	.4	.5
Blood	.2	.3
<i>Ascorbic Acid (mg)</i>		
Total	28.1	23.1
Potatoes	11.3	8.1
Dairy	6.9	2.3
Legumes	1.8	2.3
<i>Vitamin A (ig RE)</i>		
Total	104.6	239.3
Dairy	52	44
Meat	12	25
Sukuma	11	132

Socioeconomic and Cultural Context of Iron Deficiency: In a backward stepwise regression controlling for the effects of community and individual level factors, a number of socioeconomic variables were evaluated as predictors of iron deficiency (IDA and IDE), including age and school attendance of the child, child's birth order, mother's age and level of education, whether there is a male or female head of the household, prolonged absence of the husband (more than 6 months of the past year), household size, number of dependents (under 15 years old), and economic status.

Community was found to have a highly significant effect, and in order to more clearly evaluate socioeconomic factors, separate analyses were performed for subjects from each town, Korr and Karare. In Karare, all socioeconomic factors failed to significantly predict iron deficiency. The only significant predictor was age, with the risk of iron deficiency declining with age in 5 to 10 year olds. Qualitative data analysis did not, however, reveal age-related food proscriptions or preferences.

In Korr, by contrast, age was not found to be a significant predictor of iron deficiency. A backwards regression revealed that economic status, as well as the interaction between sex and economic status are significant predictors of iron deficiency. As shown

in table 5, children in poor households had a higher risk of iron deficiency. The interaction with sex reveals that in poor households, all children have an elevated risk of iron deficiency. However, in economically sufficient households, girls are 2.4 times as likely to have iron deficiency as boys.

Qualitative information on food practices and beliefs sheds light on the cultural factors contributing

Table 5: Prevalence (%) and odds ratios of iron deficiency by economic status and sex in Korr

	Male	Female	OR
Poor	32.4	27.0	0.833
Not Poor	11.5	28.1	2.44

to the observed pattern of iron deficiency. Caretakers were asked to describe their beliefs about good and harmful foods for children, and asked whether and how often they followed food proscriptions. In Korr, food proscriptions are highly gender-specific. Many informants reported a preference for feeding girls "soft foods." The category "soft foods" includes rice, milk and *uji* (a maize meal porridge), and these foods are described as soft because they are easily digested. Soft foods are believed to be adequate for girls since they perform lighter household tasks such as cooking and caring for young children. Boys, by contrast, are thought to benefit from "hard foods," including iron-rich blood and meat, as well as *ugali* and *githeri* (a bean and maize dish). Blood in particular is singled out as good for boys and harmful for girls. Boys are believed to benefit from "hard foods" because they give boys strength and energy for performing labor-intensive tasks such as herding and watering animals.

The response to how often caretakers follow described food proscriptions was sharply divided by economic status. Respondents from poor households often indicated that they could not afford "hard foods," and were forced to feed children inexpensive foods, largely maize meal and tea. Consequently, in poor households boys as well as girls are provided with diets low in bioavailable iron. In economically sufficient households that can afford iron-rich foods such as blood and meat, these foods are preferentially allocated to boys, resulting in a much lower prevalence of iron deficiency.

DISCUSSION

The results of this study confirm that iron deficiency is a significant nutritional disorder among Rendille children, with a prevalence of 31.2% among

5 to 10 year olds. This finding contributes to a growing body of research documenting poor iron nutrition among African schoolage children (Prual et al., 1992; Stephenson et al., 1993; Stoltzfus et al., 1997; Tatala et al., 1998), and underscores the importance of examining this age group when assessing the need for intervention.

Several disease conditions were examined in relation to iron deficiency. During the study period, parasitic infections from malaria and schistosoma had a very low prevalence, and were not significantly associated with iron deficiency. Malaria, however, is known to be a very serious health problem in this regions (McDade and Shell-Duncan, 1998), and does not influence iron deficiency, but may influence levels of anemia in a seasonal fashion. Hookworm infection has been reported to be significantly correlated with anemia in Zanzabari schoolchildren (Stoltzfus et al., 1997), but was not investigated in this study. Wasting, which may independently contribute to the development of anemia (Dempster et al., 1995; Tatala et al., 1998), was also not significantly associated with iron deficiency.

The role of dietary intake in the etiology of iron deficiency was investigated through the analysis of 24-hour dietary recall data. These data suffer from a number of limitations. Accurate estimation of food portions is difficult, particularly for children, and it is possible that the mother or caretaker may not have observed all child feeding events. Hence, estimation of portions, even with the aid of visual aids and appropriate references, is only an approximation of true amounts consumed (Huss-Ashmore, 1996). Additionally, the computation of nutrient values from 24-hour recall data assumes that recipes were similar for all informants, that food composition data are accurate for local Rendille foods (Gibson, 1990), and that foods are free from contamination with iron (Tatala et al., 1998). Nonetheless, it has been shown that 24-hour dietary recall data can provide unbiased estimates for community or sub-group means (Buzzard, 1998). Finally, the algorithm used to estimate the bioavailability of iron assumes iron stores are depleted, but that clinical signs of iron deficiency are absent (Calloway et al., 1994). This may lead to an under- or over-estimation of iron absorption in individuals with poorer or better iron status, respectively.

Iron deficiency was found among Rendille children within a dietary context constrained by economic, cultural and environmental factors that limit food availability. Meat and blood, which have high bioavailable heme iron, are consumed

infrequently by children. The staple foods were mainly maize cooked as a porridge, ugali or ugi, and tea with milk and sugar, which contain nonheme iron that is often poorly absorbed because it is accompanied by compounds that inhibit absorption. Although the overall dietary iron intake was very low in Korr (median, 6.5 mg), it was approaching recommended levels in Karare (median, 9.3 mg). However, bioavailable iron intakes were below metabolic requirements in both locations when enhancers and inhibitors of absorption were taken into account. The estimated bioavailable iron was 4.3% to 7.7% of the total iron intake after adjusting for both enhancers and inhibitors.

The diets were also found to be alarmingly low in vitamin A. Several studies have documented an association between retinol and biochemical indices of iron status (Kahn and Baseer, 1996; Suharno et al., 1992), and supplementation studies document that vitamin A enhances recovery from iron deficiency (Garcia-Casal et al., 1997; Kahn and Baseer, 1996; Mejia and Chew, 1988; Northrop-Clewes et al., 1996; Suharno et al., 1993). Additionally, Garcia Casal et al. (Garcia-Casal et al., 1997) have shown an enhancing effect of vitamin A and β -carotene on the absorption of nonheme iron from cereal-based diets. Consequently, the effect of low dietary vitamin A on iron status among northern Kenyan children merits further investigation.

One approach to preventing iron deficiency may be to improve bioavailability by increasing intakes of enhancers, such as meat, or more - likely because of economic constraints - vitamin A and ascorbic acid. Both experimental and population-based studies report substantial increases in iron bioavailability when ascorbic acid is added to a maize-based diet (Hallberg et al., 1986; Hallberg and Rossander, 1984). Fresh fruits and vegetables rich in vitamin C are available at the Marsabit market, where many Karare women sell milk. Therefore, intervention efforts could promote modified food purchasing and consumption. Tatala and colleagues also recommend dietary modification that alter traditional food processing techniques, such as soaking, germinating, or lactic acid fermentation of cereals (Tatala et al., 1998).

In the town of Korr, cultural beliefs regarding child feeding act as a further barrier to iron intake. Although the prevalence of iron deficiency, at 24%, was lower than in the town of Karare, the average daily iron intake was estimated at only 65% of daily recommended allowances. Iron deficiency is therefore not merely the outcome of low bioavailability, but overall inadequate iron intake. A regression analysis

of sociodemographic factors reveals a significant interaction between sex and economic status as a predictor of iron status. A bivariate analysis showed a similar prevalence of iron deficiency among boys and girls in poor households. Girls in economically sufficient households were 2.4 times as likely to have iron deficiency as boys. Although poverty is a barrier to accessing iron-rich foods, cultural factors also influence the distribution of iron-rich foods along gender lines. Key iron-rich foods are classified as "hard foods," and are proscribed to be fed to boys, whereas "soft foods" such as uji, rice and tea are believed to be beneficial for girls. Therefore, in households economically able to purchase foods high in bioavailable iron, these foods are often preferentially fed to boys.

Development efforts are currently aimed at overcoming economic barriers; marketing and income generating projects, particularly channeled through women's organizations, are intended to increase the ability of women to purchase food and medicine (Fratkin, 1991). It is believed that an outcome of improved economic conditions will be better health and nutrition (Nathan et al., 1996). Although improved energy intake is often correlated with reduced iron deficiency (DeMaeyer, 1989), cultural practice surrounding food distribution in Koror pose an additional barrier to iron intake for girls. The findings of this research indicate that economic development may improve iron status for boys, but is unlikely to benefit girls in the absence of dietary modification intervention. Gender-based food proscriptions defining "soft foods" as culturally acceptable for girls must be modified to include iron-rich foods, and such modification may provide a sustainable approach to controlling and preventing iron deficiency.

The finding of different constraints on dietary iron intake in two Rendille communities underscores the fact that local answers are needed to questions of cause of vulnerability and acceptable avenues for dietary modification. Natural food-based interventions may be a sustainable approach to preventing iron deficiency, but for these approaches to be effective, it is necessary to identify cultural and environmental barriers to adequate iron intake.

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KEYWORDS Bioavailable Iron. Iron Deficiency. School Age Children. Parasitic Infection. Transferring Receptor. Zinc Protoporphyrin. Hemoglobin. Food Proscriptions

ABSTRACT The purpose of this study was to examine the context of iron deficiency and feeding patterns of iron-rich foods among northern Kenyan school-aged children. A nutrition survey was conducted among 300 subjects in two Rendille communities, Korr and Karare. The objectives were to determine the prevalence of iron deficiency as it relates to parasitic infection, dietary intake, and sociodemographic factors, as well as cultural food proscriptions influencing child feeding. Sociodemographic and qualitative data on food beliefs and child feeding practices were obtained from the primary caretaker of each subject. From pediatric subjects 24-hour dietary recall data were obtained with the help of the primary caretaker, and capillary blood from a finger stick was used to detect iron deficiency based on measures of hemoglobin, zinc protoporphyrin to heme ratio, C-reactive protein and transferrin receptor. With an overall prevalence of 31.2%, iron deficiency was found to be associated with dietary iron intakes constrained by diverse economic, cultural and environmental factors among Rendille children. In Karare, where children's iron intake approached recommended levels (only 4.3% of total iron intake), iron deficiency was found to be attributable to low bioavailability of iron, rather than low dietary intake per se. By contrast, in Korr average daily iron intake was estimated at only 65% of recommended allowances, indicating that iron deficiency was not merely the outcome of low bioavailability, but rather overall inadequate iron intake. Sociodemographic analysis showed a significant interaction between sex and economic status, revealing that girls in economically sufficient households were 2.4 times as likely to have iron deficiency as boys. This difference in risk parallels culturally defined gender-based proscriptions for child feeding: girls are believed to benefit from "soft foods", including rice, maize porridge and tea, whereas boys benefit from "hard foods", including meat, blood and beans. Consequently, in households economically able to purchase iron-rich foods, these foods are being preferentially fed to boys. Economic development may result in improved iron status for boys, but will be unlikely to benefit girls in the absence of a dietary modification intervention. A modification of culturally acceptable "soft foods" to include iron-rich foods may provide a sustainable approach to controlling and preventing iron deficiency in this population.

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