Iron Intake and Bioavailability in Rural India (1975-2005)

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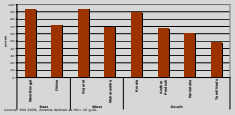
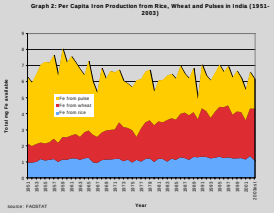
Background

South Asia's anemia prevalence is the highest in the world, and has been steadily increasing over the past 30 years. ACC/SCN reports estimate prevalence among non-pregnant adult women 15 and 49 years of age to be 57%, 67%, 72%, and 75% for 1972, 1981-1984, 1985, and 2000 respectively [1,2]. India's National Institute of Nutrition (NIN) find rates in rural areas as high as 91% by 2005 among adult non-pregnant non-lactating (NPNL) women (see Graph 1) [3] and 92% among children 1-5 in 2003 [4]. Reports show that across all age groups, anemia prevalence is roughly 10% higher in rural areas as compared to urban [5].

Iron deficiency in India is responsible for 22,000 maternal deaths each year [6] and accounts for $60 billion in unearned income, roughly 2% of the GDP [7] .



NIN data, from dietary monitoring in southern Indian states, show a steady and significant decline in iron intakes since 1975, from 18.0 to 12.3 mg/CU/day in rural areas [8]. They report a steady increase in vegetable, cereal, milk and fat consumption, and a steady decline in the consumption of pulses and traditional cereals. Consumption patterns have been affected by many changes in the economy over the past 40 years, most notably the Green Revolution in the 1960s, the subsequent income growth of the 1980s, and finally the gradual opening of the Indian economy since 1991 to the world market.



Graph 2 illustrates the per capita daily iron available from the production of three main grain commodities: rice, wheat and pulses. Due to the low iron content of rice, and the dramatic decline in pulses over this time, it is only wheat's growth and high iron content which keep levels consistently around 6mg daily per capita over the last 50 years. Unfortunately rice and wheat consumption tend to be mutually exclusive- with the South and East consuming predominantly rice and the north predominantly wheat. Other states vary or, like Karnataka, still heavily consume traditional cereal crops like millets and sorghum.

Iron Bioavailability

The impact of these dietary changes on the bioavailability of iron is particularly important, considering the predominant form of iron consumed in India is non-heme iron. In fact, some of the states with the highest intakes in iron, are also those with the highest prevalence of anemia. Inhibitors to iron absorption in the diet include calcium, phytates, and tannins. Phytate concentrations are highest in seeds and unrefined cereals (whole grains). Polyphenolic compounds, like tannins, are also found to inhibit iron absorption in the gut and are found in tea, coffee, millets and spices . Enhancers of iron absorption also exist which make ferric ions more bioavailable in the gut. These include ascorbic acid (vitamin C) and meats, which can increase absorption four-fold. Absorption of non-heme iron can vary from 2-20% depending on these factors whereas heme iron is absorbed in a range closer to 15-35% and is more dependent on an individual's iron status [10]. A whole diet context is needed in India to understand how iron absorption may be changing given changes in dietary composition of the last 30 years.

Objective

Given the increasing prevalence of anemia being observed in India, the purpose of this research is to examine the change in both iron intake and also iron absorption in India over the past 30 years.

Methods

Secondary data analysis was conducted on data from India's National Institute of Nutrition (NIN) located in Hyderabad, Andhra Pradesh. The NIN has collected 24-hour recall in rural villages since 1975. Four rounds of dietary surveys in 7 states were available for analysis: 1975-80, 1996-97, 2000-01, and 2004-05. The seven states are: Kerala, Tamil Nadu, Karnataka, and Andhra Pradesh in the South, Orissa in the East, and Maharashtra and Gujarat in the West. Based on an algorithm for iron bioavailability developed by Hallberg and Hulthen [11] , individual-level data were used to calculate iron absorption from intakes of heme and non-heme iron, phytates, tannin, ascorbic acid, calcium, meat, soy, egg, and alcohol. Observations included in this preliminary analysis include all adults (18 years of older) for whom dietary data was collected, a total of 45,026 individuals. Table 1 below provides a breakdown of the sampled population by various characteristics.

Table 1: Sample Frequencies

N (% by round)	Survey Round 1975-80	1996-97	2000-01	2004-05	Total
Kerala	868 (13%)	1656 (20%)	2099 (15%)	2210 (14%)	**6833**
Tamil Nadu	969 (14%)	640 (8%)	1913 (13%)	1987 (13%)	**5509**
Karnataka	1524 (22%)	1188 (14%)	2166 (15%)	2050 (13%)	**6928**
Pradesh	1010 (15%)	1356 (16%)	2008 (14%)	2166 (14%)	**6540**
Maharashtra	1022 (15%)	1043 (12%)	2094 (15%)	2378 (15%)	**6537**
Gujarat	988 (14%)	1032 (12%)	1855 (13%)	2420 (16%)	**6295**
Orissa	537 (8%)	1520 (18%)	2080 (15%)	2247 (15%)	**6384**
Female	3565 (52%)	4401 (52%)	7395 (52%)	8086 (52%)	**45026**
Scheduled Tribe	249 (4%)	1144 (14%)	1169 (8%)	1414 (9%)	
Scheduled Caste	1047 (15%)	1842 (22%)	2781 (20%)	3048 (20%)	
Hindu	6106 (88%)	7431 (88%)	12650 (89%)	13623 (88%)	
Muslim	203 (3%)	206 (2%)	480 (3%)	548 (4%)	
Christian	306 (4%)	447 (5%)	622 (4%)	426 (3%)	

Iron Bioavailability from Indian Cereals

In Table 2 we applied the Hallberg & Hulthen algorithm to the most common cereals in the Indian diet to see how they compared. Rice is the most efficient cereal, having the highest fraction of iron absorbed (6.4%), but it does not make up for its low iron content. As seen below, 100g of milled rice, the form most commonly consumed in India, provides 0.05 mg of bioavailable iron, or about half that provided by the same quantity of wheat flour. Only sorghum and finger millet have lower absorbable iron.

Table 2: Bioavailable iron in 100g of various cereals common in India

CEREAL	Iron (mg)	Calcium (mg)	Tannin (mg)	Phytate (mg)	Absorption ratio	Absorbed iron**	versus white rice
Pearl Millet (Bajra)	8.0	42.0	12.9	493.5	3.1%	0.247	5.54
Wheat flour (whole)	4.9	48.0	21.9	836.5	2.0%	0.098	2.20
Rice, parboiled, milled	1.0	9.0	0.0	290.5	6.4%	0.064	1.44
Wheat flour (refined)	2.7	23.0	28.0	133.0	1.8%	0.049	1.10
Maize	2.3	10.0	24.1	1071.0	2.3%	0.054	1.20
Rice, milled	**0.7**	**10.0**	**0.0**	**290.5**	**6.4%**	**0.045**	**1.00**
Sorghum (Jowar)	4.1	25.0	77.0	602.0	0.7%	0.029	0.66
Finger Millet (Ragi)	3.9	344.0	360.0	731.5	0.3%	0.013	0.30

** calculated using Hallberg & Hulthen (2000) algorithm, assumes 10mg ascorbic acid consumed with 100mg cereal
nutrient values taken from Nutritive Value of Indian Foods [12]

Preliminary Findings

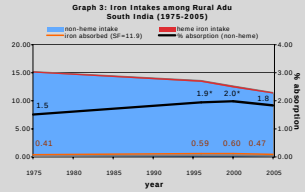
Using 24-hour recall data from rural adults in 7 states in India, we obtain results on iron bioavailability based on the whole diet. As expected, results show that about 15 - 22% of heme iron is absorbed depending on iron stores. However, mean results for non-heme iron absorption range from 0.4% in Karnataka to 5.5% in Kerala a range much lower than expected. This non-heme absorption range is low, even after adjusting for a low iron status (the range is 1.1%-15.1% at serum ferritin= 8 g/dL).

Time trends show a significant increase in non-heme iron bioavailability since 1975 in pooled results (from 1.41% to 1.72% in 2000 (p<0.05)) but a small and insignificant drop in 2005. The resulting effect being a significant improvement in absorbed iron by 2000 of around 0.15 mg, from 0.399 to 0.557 mg.

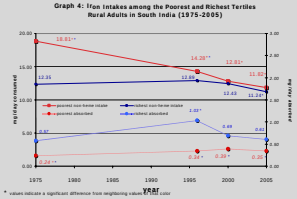
A Closer Look : South India

Data from the four states of South India (Kerala, Tamil Nadu, Karnataka and Andhra Pradesh) are analyzed separately. South India is a major rice consuming area, and has seen the greatest increase in anemia prevalence over the past 5 years. Trends in Graph 3 show a steady and significant decline in iron absorption over time, an improvement in absorbed iron (0.41 to 0.60 mg) until 2000 due to higher absorption rates (1.5% to 2.0%) but a significant drop in absorbed iron by 2005 (0.47 mg from 1.8% absorption.

In Graph 3 we see a slow and steady decline in non-heme iron intakes since 1975, a significant improvement in iron absorption (percent and actual) until 2005 when we see a decline in all three.



Analysis by per capita income reveals a similar but more extreme scenario among the poorest tertile in rural South India. The poorest third consume 6.5 mg less iron than they did in 1975, while absorbing 0.1 mg more (see Graph 4 below). Unfortunately their absorption ratios are lower than those of the richest tertile. Currently both groups consume the same average amount of iron (~11mg), but the richest are absorbing almost 0.3 mg more. Absorption ratios have been consistently better among the richest, so despite lower intakes, they have absorbed more iron than the poorest, across time. In both cases, iron intake and absorption rates are much lower than required.



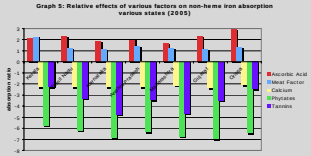
In Graph 4 blue lines represent the richest third and the red lines represent the poorest third. Iron intakes for the poorest have seen dramatic declines over the past 30 years. Absorbed iron has increased slightly. Very little change in either intakes or absorption has been seen among the richest third.

Bioavailability and Anemia in 2005

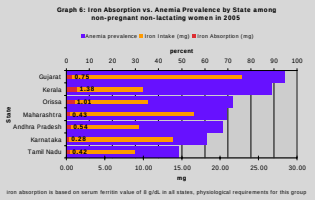
Trends in the bioavailability of iron since 1975 vary by state but generally all have improved, with the exception of Maharashtra and Gujarat. In these two states millets, high in phytates, are still consumed daily. Improvements seen are due to increased consumption of ascorbic acid and flesh foods, as well as decreased intakes of phytates and tannins.

The relative effect of the absorption factors calculated in the Indian diet in 2005 can be seen in Graph 5, by state. Iron bioavailability is highest in Kerala (4.18%) and Orissa (3.02%) and lowest in Karnataka (0.79%) and Maharashtra (0.86%).

Generally, phytates have the largest effect on iron, followed by tannins. Calcium and ascorbic acid balance each other out- ascorbic acid doubling absorption and calcium halving it.



Finally, in Graph 6 we match our results with the 2005 anemia prevalence data. States with the higher absorbed iron values tend to have higher prevalence of anemia, and vice versa. Iron deficiency is clearly a problem, but it doesn't seem to be the determining factor for anemia in these states.



The anemia data is based on a subsample of roughly one half of the women for whom dietary data was collected. Absorption is based on serum ferritin = 8 g/dL. Physiological needs for NPNL women are estimated to be 3.0 mg absorbed iron/day.

Conclusions

These initial results have shown that bioavailable iron in India is very low. The Hallberg & Hulthen algorithm is useful in showing relative changes in iron bioavailability across states and over time. Dietary trends since 1975 have generally increased iron absorption, due mostly to improvements in ascorbic acid intake and to moderate declines in both phytate and tannin levels in the diet. Recent declines in both iron intakes and absorption rates are of concern. Further analysis is planned to examine the relationship between cereal consumption and iron bioavailability.

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