Contents

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The National Vitamin A Supplementation Program and subclinical vitamin A deficiency among preschool children in the Philippines

M. R. A. Pedro, J. R. Madriaga, C. V. C. Barba, R. C. F. Habito, A. E. Gana, M. Deitchler, and J. B. Mason

Abstract

The prevalence of vitamin A deficiency (serum retinol [SR] < 20 µg/dl) in children from one to five years of age in the Philippines rose from 35.8% to 38% between 1993 and 1998, despite a twice-yearly universal vitamin A capsule distribution program. The Philippines 1998 National Nutrition Survey, with one-time SR measurements from 11,620 children from one to four years of age, collected over an eight-month period from one month to more than six months after distribution of vitamin A capsules, was an opportunity to examine the impact of the program on the children's vitamin A status, using post hoc analysis. Overall, a detectable impact of vitamin A capsules on SR was limited to groups with the highest prevalence of vitamin A deficiency and lasted up to four months after dose administration. In highly urban cities in Visayas, where very high prevalences of deficient SR (SR < 10 µg/dl) were found, the prevalence of deficient SR was reduced from 27% to 9% one to two months after distribution of vitamin A capsules, and to 16% at three to four months. In Mindanao, a statistically significant reduction from 38% to 32% was seen in the prevalence of deficient to low SR (SR < 20 µg/dl) one to four months after distribution of vitamin A capsules. There was no overall reduction in the prevalence of vitamin A deficiency or deficient and low SR (SR < 20 µg/dl) in Luzon, but a significant interaction with stunting was observed in Luzon non-highly urbanized cities. Two aspects are of concern. First, the magnitude of the effect of high-dose vitamin A capsules on SR, and hence on the extent of reduction in deficiency, is limited. Second, the effect does not persist for six months, which is the interval between doses. Thus there is no decrease in the prevalence of deficiency over time. With more frequent dosing (especially to those most deficient in SR), a progressive reduction in vitamin A deficiency could, however, be expected; this hypothesis could be tested. The policy implication arising from these results is that a shift in resources is warranted. In areas of low prevalence of vitamin A deficiency, distribution of vitamin A capsules should be targeted to stunted children. In areas of high prevalence, vitamin A capsules should be distributed to children one to five years old at least three times a year.

Key words: Philippines, serum retinol, vitamin A, vitamin A deficiency, vitamin A supplementation

Introduction

In the 1970s, local surveys on xerophthalmia by the Nutrition Center of the Philippines [1] demonstrated that vitamin A deficiency among preschool children was a public health problem in Cebu and other provinces and in Metro Manila. Since 1982 the problem has been documented for the whole country by National Nutrition Surveys [1, 2]. In 1993 the government launched, and has since been implementing, the National Twice-Yearly (six-monthly) Vitamin A Supplementation Program for one- to five-year-old children in an effort to alleviate the problem of vitamin A deficiency and reduce childhood morbidity and mortality. The distribution of 200,000 IU vitamin A capsules is carried out on "Child Health Days" (previously called *Araw ng Sangkap Pinoy*, or ASAP) in April and November of each year, through the Department of Health, Local Government Units, and a network of community volunteers or *barangay* (the smallest political unit

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throughout the Philippines) health workers. Vitamin A supplementation of pregnant women at low dose levels and of postpartum women at high levels (200,000 IU) was piloted in one province in 2003 and will be implemented on a national scale to address vitamin A deficiency among children under one year of age and thereby prevent new cases of vitamin A deficiency among one-year-olds.

There has been no national and systematic effort to evaluate the impact of the country's high-dose vitamin A supplementation program. National Nutrition Surveys found that the prevalence of deficient to low SR among children six months to five years of age was 35.8% in 1993 and 38% in 1998. However, these two surveys employed different sampling frames. The 1993 survey included 3,773 children from a subsample representing 50% of the survey's 4,050 sample households, which was drawn by two-stage sampling with the barangay and the household as the primary and secondary sampling units, respectively [2]. The 1998 survey included 14,291 children who were randomly sampled, also by the use of a two-stage design, with the barangay and the individual, instead of the household, as the primary and secondary sampling units [3]. Nonetheless, the prevalence estimates are taken to be broadly comparable. At a minimum, the lack of an improving trend was cause for concern. Although the National Nutrition Surveys were not designed to evaluate the effectiveness of the vitamin A supplementation program, the 1998 National Nutrition Survey data* provided an opportunity to examine the relation of the vitamin A capsule distribution program to children's vitamin A status as assessed by SR. A summary of these findings was presented at the International Vitamin A Consultative Group (IVACG) meeting in early 2003 [4].

Methods

Description of the 1998 National Nutrition Survey

National Nutrition Surveys are carried out every five years in the Philippines to assess household dietary intakes and the nutritional status of various age groups of the population, using anthropometric, biochemical, and clinical indicators. The 1998 National Nutrition Survey included one-time SR measurements in blood taken from children six months to five years of age, collected over the eight-month period during which the survey was in the field. This period occurred more than six months after the national distribution of high-dose vitamin A capsules took place during the year.

*Food and Nutrition Research Institute-Department of Science and Technology. Philippine Nutrition Facts and Figures. http://www.fnri.dost.gov.ph

Survey sampling design and coverage

The 1998 National Nutrition Survey used a two-stage stratified sampling design that covered all 16 regions of the country, including the National Capital Region or Metro Manila, 76 of the 78 provinces, 10 cities, a cluster city-municipality in the case of the National Capital Region, and 10 highly urbanized cities. Barangays served as the primary sampling units and children six months to five years old as the secondary sampling units. A total of 778 barangays and 28,698 children zero to five years old were included in the sample [5]. For the Biochemical Nutrition Survey component of the National Nutrition Survey, only 763 barangays and 14,291 children were included. Two provinces, Basilan and Lanao del Sur, and Marawi City, in Mindanao, were excluded due to dangerous conditions at the time of the survey [3]. The number of primary sampling units ranged from 6 to 10 per province or city, or per cluster city-municipality, depending on the total household population.

The survey period was from May to December 1998. Because of the large area of coverage, data were collected from one region at a time. Most areas of the National Capital Region were surveyed from May to July. The survey teams covered the northern part of Luzon in June and July, and then moved south to the Visayas region from July to September and the Mindanao region from August to October. The survey teams returned to the National Capital Region in November and December to cover the remaining survey areas and complete data collection.

Collection of blood and serum samples

Blood samples were collected by fingerprick using disposable lancets. Approximately 0.4 ml of blood was collected in heparinized capillary tubes. Serum was separated from red cells by centrifugation, and serum samples were kept frozen at all times in the field and while in transit to the Food and Nutrition Research Institute (FNRI) laboratory. The samples were stored at –20°C for later analysis.

Laboratory analysis of SR

SR was determined by the high-pressure liquid chromatography (HPLC) method described by Furr et al. [6]. The accuracy of the method was assessed using a standard reference material for fat-soluble vitamins and cholesterol in human serum (SRM 968B). The interassay coefficient of variation for the SR analyses was 3.26 %. The cutoff points established by the World Health Organization/UNICEF/Helen Keller International/International Vitamin A Consultative Group (WHO/UNICEF/HKI/IVACG) [7] were used to interpret SR values. SR values < 10 µg/dl (0.35 µmol/L) were classified as deficient, values between 10 and < 20 µg/dl (0.35 and < 0.70 µmol/L) as low, and values of ≥20 µg/dl (0.70 µmol/L) as acceptable to high.

Other variables

The 1998 National Nutrition Survey included a number of other variables [8]; relevant here were "participation in ASAP," "months after ASAP," "infections," and nutritional status classification using weight-for-age, weight-for-height, and height-for-age indices and the National Center for Health Statistics (NCHS)/WHO reference [9]. ASAP referred to the Philippines micronutrient program, which included distribution of vitamin A capsules to children one to five years old, held in April–May and October–November 1998. "Participation in ASAP" was recorded as "yes" or "no" at any of the scheduled ASAP periods for the year. Since blood samples were collected at different months in different regions, "months after ASAP," i. e., the number of months since the last vitamin A capsule dose (whether April or October), was recorded for each child who participated in the vitamin A capsule program; those not participating were recorded as having received no dose. "Presence of infections" referred to a report of one or more episodes of diarrhea, cold, cough, sore throat, fever, or measles during the month that preceded data collection. The children's weight and height were measured by standard procedures [5]. Weight was measured with a calibrated 160-kg capacity platform-type beam-balance scale and recorded to the nearest 0.1 kg. Standing height, for children two years of age or older, was measured with a microtoise and recorded to the nearest 0.1 cm. For children under two years old, recumbent length was measured with an infantometer or wooden length board and also recorded to the nearest 0.1 cm. The child's age was based on the date of birth reported by the mother or caregiver and verified from birth or other health records during the interview.

Although the important contribution of dietary vitamin A intake to SR was recognized, the 1998 National Nutrition Survey, unlike that of other years, did not include a food-consumption survey component. The "month of data collection" nonetheless may reflect the season of the year and the availability of vitamin A–rich fruits.

Characteristics of data and data analysis

Data from the 1998 National Nutrition Survey were entered and processed by the Statistical Package for the Social Sciences (SPSS) program. For the analysis reported in this paper, sample children from one to five years of age and with SR less than 100 µg/dl were included (i.e., all data from children less than one year of age as well as from those with SR of at least 100 µg/dl were set as missing values). Infants less than 12 months of age were excluded because children in this age group were not given vitamin A capsules under the National Supplementation Program. The data (sample size, mean SR, and prevalence of low or deficient SR) were tabulated according to geographic area, month of data collection, receipt of vitamin A capsules, and number of months after the receipt of vitamin A capsules to note general characteristics. The data were then aggregated by major geographic areas of the country to distinguish differences in SR and prevalence of vitamin A deficiency that may be due to the months during which the survey or data collection was conducted or the season. The geographic groupings were Luzon (Northern Philippines, with the National Capital Region), Visayas (Central Philippines), and Mindanao (Southern Philippines) (fig. 1). The data were also aggregated by two- to three-month bands for month of data collection to distinguish seasons, and by two-month intervals of the number of months after receipt of vitamin A capsules.

The mean SR and prevalence of vitamin A deficiency in highly urbanized cities in Visayas and Mindanao, and the National Capital Region in Luzon, were different from the values in the rest of the provinces and in less urbanized cities within the geographic groups. Groups defined as Visayas highly urbanized cities, Mindanao highly urbanized cities, and the National Capital Region were therefore examined separately from the respective geographic groups without highly urbanized cities and excluding the the National Capital Region. For Visayas highly urbanized cities, the data were further disaggregated to low (≤ 10% prevalence of SR < 10 µg/dl) and high (> 10% prevalence of SR < 10 µg/dl) prevalence of vitamin A deficiency in some of the analyses, as described later.

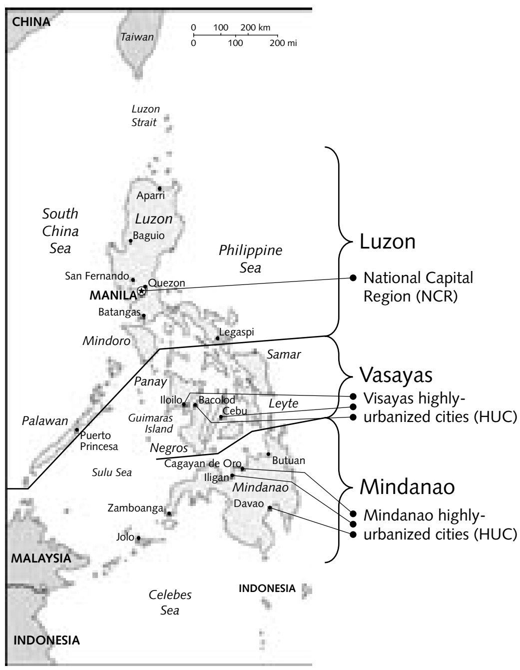

FIG. 1. Study areas in the Philippines. HUCs, highly urbanized cities

TABLE 1. Number of Filipino children one to five years of age with serum retinol (SR) < 100 μg/dl according to month of data collection, island group, and number of months after receipt of vitamin A capsules (VAC), 1998 National Nutrition Survey, Philippines

Month	Island group	No VAC	No. of months after VAC							
			1	2	3	4	5	6	> 6	Total
May	Luzon	49	180				1	1	3	234
	Subtotal	49	180				1	1	3	234
Jun	Luzon	285	431	471	54	1		30	19	1,291
	Subtotal	285	431	471	54	1		30	19	1,291
Jul	Luzon	236	2	480	823	24	2	2	126	1,695
	Visayas	34	6	45	150	8	1		1	245
	Subtotal	270	8	525	973	32	3	2	127	1,940
Aug	Luzon	78	9	10	341	285	83	174		980
	Visayas	144	8	25	226	433	46	49	1	932
	Mindanao	152	23	4	191	207		27	1	605
	Subtotal	374	40	39	758	925	129	250	2	2,517
Sept	Luzon	36	95			230	79	8		448
	Visayas	184	53	62	29	373	428	153		1,282
	Mindanao	310	199	17	12	279	275	44	1	1,137
	Subtotal	530	347	79	41	882	782	205	1	2,867
Oct	Luzon	18	41					4		63
	Mindanao	232	662	14		1	160	304	1	1,375
	Subtotal	250	703	14		1	160	308	1	1,438
Nov	Luzon	67	598	170		13	3	99	2	952
	Subtotal	67	598	170		13	3	99	2	952
Dec	Luzon	12	63	247	15			37	7	381
	Subtotal	12	63	247	15			37	7	381
Total		1,837	2,370	1,545	1,841	1,854	1,078	932	163	11,620

Table 1 shows the number of children in the 1998 sample one to five years of age with SR levels < 100 μg/dl according to the month of data collection, island group, and number of months after receipt of vitamin A capsules. The geographic group is shown, corresponding to the progress of the fieldwork through the country (thus, for example, only in August and September were all three island groups covered). A total of 11,620 children from one to five years old were included in the analysis.

The main outcome variables for the analysis were the mean SR concentration and the prevalences of deficient and deficient and low SR. Tabulation, descriptive analysis, simple linear regression using SPSS, and logistic regression using Stata were carried out. In the regression analyses, mean SR and classification of deficient and deficient and low SR (as dummy variables*) were dependent variables. Independent dummy variables VAC 1–2 (received vitamin A capsules one to two months before serum collection), VAC 3–4 (received vitamin A capsules three to four months before serum collection), and VAC 5–6 (received vitamin A capsules five to six months before serum collection) were entered in the regression equation, to determine the effects of supplementation at various periods after the administration of the dose, and to test their significance, as compared with the no-dose group. The month of data collection, nutritional status, and presence of infections at the time of data collection (variables that tend to affect a child's SR level as well as the child's participation in the national vitamin A capsule

* The dummy variables were as follows. VAC 1–2: 1 = received vitamin A capsule one to two months before serum collection; VAC 3–4: 1 = received vitamin A capsule three to four months before serum collection; VAC 5–6: 1 = received vitamin A capsule five to six months before serum collection. Stunted: 1 = height-for-age Z score ≤ 2; infection: 1 = had one or more episodes of diarrhea, cold, cough, sore throat, fever, or measles during the month that preceded data collection.

TABLE 2. Mean serum retinol (SR) level and prevalence of SR levels below 20 μg/dl in children 12 to 59 months old according to island group, season of data collection, and months after receipt of a vitamin A capsule (VAC), 1998 National Nutrition Survey, Philippines[a]

Island group	Season	No VAC	No. of months after VAC 1–2	3–4	5–6	Total
Luzon	May–Jun	24.1 33% (334)	25.9[b] 26% (1,082)	29.2 18% (55)	[23.5] 38% (32)	25.5 27.9% (1,525)
	Jul–Sep	23.7 35% (350)	24.6[b] 33% (596)	23.6[b] 34% (1,703)	23.0 30% (348)	23.9 33.3% (3,123)
	Nov–Dec	22.4 38.1% (97)	21.8 39.5% (1,119)	[18.7] 46.4% (28)	21.2 41% (143)	21.7 39.7% (1,396)
	All	23.7 34.8% (781)	24 33% (2,797)	23.7 33.9% (1,786)	22.5 33.8% (523)	23.8 33.4% (6,044)
Visayas	Jul–Sep	20 50% (362)	22.3[b] 41.6% (199)	22.5 39.3% (1,219)	20.3[b] 45.9% (677)	21.5 41.8% (2,458)
Mindanao	Aug–Oct	21 45.0% (694)	25[b] 30% (919)	23[c] 37% (690)	21.2 43% (810)	22.7 38.2% (3,117)
Total for all areas and periods		22 41.6% (1,837)	24.1[b] 32.7% (3,916)	23.2[b] 35.9% (3,695)	21.2[b] 41% (2,010)	23 36.5% (11,620)

a. From top to bottom, the values in cells are as follows: mean SR level (μg/dl), prevalence of SR levels < 20 μg/dl (%), and sample size (n) (in parentheses). The mean SR levels are in square brackets [ ] where $n < 50$.

b. $p < .05$ (paired contrasts in one-way ANOVA) comparing SR level with the previous value in the row to test whether the mean SR level within an island group changed significantly with time after receipt of vitamin A capsules. The level 1–2 months after receipt of capsules is compared with the level among those not receiving capsules.

c. The level 3–4 months after receipt of a vitamin A capsule is compared with the level among those who did not receive a vitamin A capsule. For the comparison between the levels 5–6 months after receipt of a vitamin A capsule and the levels among those who did not receive vitamin A, no differences were significant. The columns labeled "No. of months after VAC" do not include children whose SR was measured more than 6 months after receiving vitamin A; the "Total" column does include children whose SR was measured more than 6 months after receiving vitamin A.

program) were added into the regression equation to check the extent to which these may have influenced the effect of vitamin A capsules. Logistic regression was done to validate the results of the linear regression analysis, in which dummy variables for deficient and deficient and low SR were the dependent variables.

Results

Table 2 shows the SR levels and the prevalences of low and deficient SR (< 20 μg/dl) according to island group and season of data collection, in relation to the number of months after receipt of a vitamin A capsule. To simplify analysis and presentation, paired tests of significance are shown reading along rows, examining whether mean SR changed with time after receipt of the vitamin A capsule by comparing each value with that in the previous cell. For example, in Luzon during July to September, the mean SR for children receiving a vitamin A capsule in the preceding two months was 24.6 μg/dl ($n = 596$), significantly higher than the value of 23.7 μg/dl ($n = 350$) in the group that had not received a dose in the last six months. The group in the next cell ($n = 1,703$) had a mean SR of 23.6 μg/dl three to four months after receiving a vitamin A capsule, a significantly lower value than that at one to two months (24.6 μg/dl). The value at five to six months was 23 μg/dl; this was not significantly lower than that in the previous cell (23.6 μg/dl), but it was also not significantly different from that in the group that had not received a vitamin A capsule in the preceding six months (23.7 μg/dl) (see notes to table 2). Significance is tested on the means (hence on the overall distribution, using one-way ANOVA with post hoc multiple comparisons), and the results are also shown, for additional interpretation, as prevalences. Thus, the trend in the prevalence of SR levels less than 20 μg/dl was 35%

for those not receiving vitamin A capsules. For those receiving a capsule, the trend in prevalence was 33% one to two months after receiving the capsule, rising to 34% at three to four months, then falling to 30%; the last change is considered more likely to be due to seasonal effects than to the vitamin A capsule.

It should be noted that the "No VAC" group may not be directly comparable with the groups receiving vitamin A; for example, they may have less access to services as a contributing reason for not receiving the vitamin A capsules. This can be tested to some extent by using stunting, which was not significantly different between the "No VAC" group and the "1–2 months after vitamin A capsule" group, in any of the island group areas. This indicates that the "No VAC" group is at least not grossly noncomparable with the groups receiving vitamin A.

The findings can also be stratified by stunting levels, to control for some potential differences between groups. Doing this for the analysis shown in table 2 indicates somewhat greater increases in SR for the stunted children, but generally the findings remain similar; this was investigated by other methods, as described below.

Interpreting the shape of the response, taking account of the "No VAC" group but recognizing that it may not be fully comparable, is also helped by comparing the latest measure (at five to six months after the dose) with the "No VAC" group. In no cases were these significantly different. Thus, the general pattern is of a rise in SR followed by a return to predose levels after three to four months. These results are now described according to area and season in table 2.

The extent of vitamin A deficiency is greatest in the Visayas, with an average prevalence of deficient and low SR (< 20 μg/dl) of 41.8% and a mean SR of 21.5 μg/dl. The mean SR rose significantly following dosing in months one to two and three to four, then fell back to about the predose level in months five to six; this pattern was reflected in the prevalence of SR levels less than 20 μg/dl, with a drop of about 10 percentage points up to three to four months after the dose. This trend was similar in Mindanao, averaging over the three periods with a lower underlying prevalence than Visayas. Again, 8 percentage points of improvement in prevalence was seen up to three to four months after the dose. In Luzon, where the underlying prevalence was generally the lowest, the drop in prevalence was hardly detectable, emerging when these are separated by season (see May–June), but still less than in the other regions, for up to three to four months after dosing.

In the Visayas and Mindanao, the overall picture is of a greater (and an important increase relative to the VAD problem) increase in mean SR of around 2 to 4 μg/dl in the first one to two months after dosing, falling but still detectably elevated in months three to four, then returning to predose levels by months five to six. The prevalence trends show the corresponding pattern.

This pattern was somewhat enhanced, but with a more transient impact, for stunted children, particularly in Mindanao, as shown in table 3. The prevalence of deficient and low SR (< 20 μg/dl) was lower by 16 percentage points in the stunted group one to two months after dosing, and by 13 percentage points in the nonstunted group. The improvement in SR did not persist into months three to four among the stunted children. A similar significant but smaller difference in mean SR related to stunting was seen in the Visayas, but not in Luzon.

TABLE 3. Mean serum retinol (SR) level and prevalence of SR levels below 20 μg/dl in stunted and not stunted children 12 to 59 months old in Mindanao, August–October 1998, according to months after receipt of a vitamin A capsule (VAC), 1998 National Nutrition Survey, Philippines[a]

Stunting status	No VAC	No. of months after VAC 1-2	3-4	5-6	Total
Stunted	20.6 47.3% (243)	25.4[b] 31.4% (293)	22.4[c] 41.6% (245)	20.3 47.4% (310)	22.2 41.8% (1,094)
Not stunted	21.5 42.1% (428)	24.9[b] 28.9% (603)	23.4 33.9% (440)	21.9 40.1% (491)	23.1 35.7% (1,963)

a. From top to bottom, the values in cells are as follows: mean SR level (μg/dl), prevalence of SR levels < 20 μg/dl (%), and sample size (*n*) (in parentheses).

b. $p < .05$ (paired contrasts in one-way ANOVA) comparing SR level with the previous value in the row to test whether the mean SR level changed significantly with time after receipt of vitamin A capsules. The level 1-2 months after receipt of capsules is compared with the level among those not receiving capsules. For the comparison between the levels 5-6 months after receipt of a vitamin A capsule and the levels among those who did not receive vitamin A, no differences were significant. The columns labeled "No. of months after VAC" do not include children whose SR was measured more than 6 months after receiving vitamin A.

c. SR 3-4 among stunted children is significantly lower ($p < .05$) than at 1-2 (or the previous value in the row), meaning the improved SR levels at 1-2 months was not sustained through 3-4 months

The results were disaggregated further by area, in particular to examine the relation with urbanization. The prevalence of deficient and low SR was highest in the highly urbanized cities in the Visayas, where the mean SR was 16.9 µg/dl, the prevalence of SR levels less than 20 µg/dl was 40%, and the prevalence of SR levels less than 10 µg/dl was 27%. In the areas of the Visayas highly urbanized cities with the highest prevalences of vitamin A deficiency, the mean SR was 12.6 µg/dl, and 38% of the one- to four-year-olds had SR levels under 10 µg/dl—an extremely high prevalence of severe deficiency. The prevalences of deficient and low SR (< 20 µg/dl) in Mindanao and in Visayas non-highly urbanized cities were within the range of 37% to 39%.

Seasonal changes in SR could be observed in Luzon, where the data collection spanned eight months, as indicated in table 2, which shows lower mean SR and higher prevalence of deficient and low SR among children whose serum samples were collected between November and December than among children whose serum samples were collected between May and June ("No VAC" and "Total" columns). The seasonal effect is also shown in figure 6; this was largest in Luzon non-highly urbanized cities, where the mean SR and the prevalence of deficient and low SR (< 20 µg/dl) were 22.5 µg/dl and 43.8% respectively, among children who did not receive VAC and whose serum was collected in November to December and 25.1 µg/dl and 32.1% among those whose serum was collected in May to July. These differences between the values of mean SR and vitamin A deficiency prevalence in May to June and October to December may be explained by the decreased availability of vitamin A–rich fruits in October–December compared with May–June. Vitamin A deficiency was of least magnitude in the National Capital Region. The mean SR and the prevalences of deficient and low and deficient SR were 25.9 µg/dl, 19.7%, and 2.5%, respectively.

The areas most severely affected by vitamin A deficiency also tended to show the greatest improvements in the dosed groups. In the highly urbanized cities in the Visayas, as shown in figures 2 and 3, one to two months after the administration of the dose, the mean SR increased by 7.36 µg/dl (p = .00) and the proportion of children with deficient SR decreased by 18 percentage points (p = .08). The effect of vitamin A capsules in these areas tapered and remained significant up to the three- to four-month band after the dose: the increment in mean SR was 4.02 µg/dl (p = .00), and there were reductions of 11 (p = .04) and 20 (p = .00) percentage points in the prevalences of deficient SR (< 10 µg/dl) and deficient and low SR (< 20 µg/dl). In the areas of the highly urbanized cities in the Visayas with a high prevalence of vitamin A deficiency (≥ 10% with SR < 10 µg/dl) (shown in figs. 2 and 3), mean SR increased from 12.6 to 18.0 µg/dl, while the prevalence of deficient SR dropped from 38.3% to 20.6% three to four months after the administration of vitamin A capsules, then slid back towards baseline levels (figs. 2 and 3). No significant effects were evident in the areas of the Visayas highly urbanized cities with low prevalences of vitamin A deficiency (figs. 2 and 3). The extent of severe vitamin A deficiency (SR < 10 µg/dl) was less in the Mindanao highly urbanized cities than in the Visayas highly urbanized cities, and the apparent effects of vitamin A capsules appear to be correspondingly

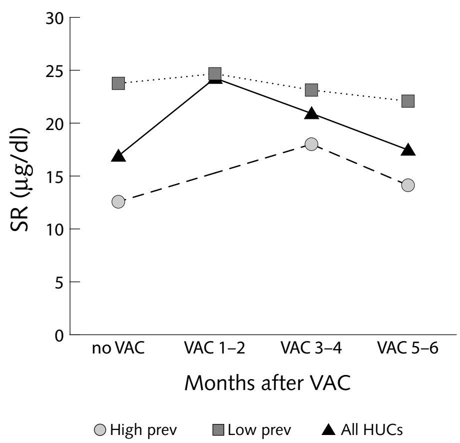

FIG. 2. Mean serum retinol (SR) of one- to five-year-old children in areas of Visayas highly urbanized cities (HUCs) with high (≥ 10%) and low (< 10%) prevalence of vitamin A deficiency (SR < 10 µg/dl) according to receipt of vitamin A capsules and the number of months after receipt of vitamin A capsules (VACs)

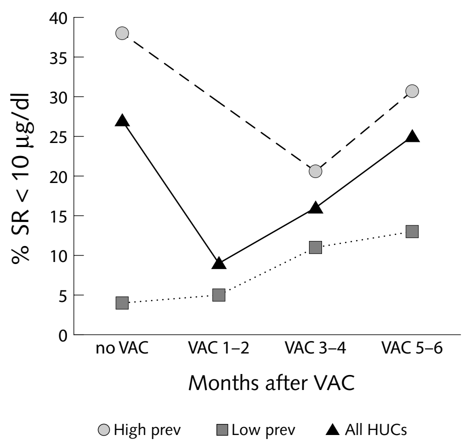

FIG. 3. Prevalence of vitamin A deficiency (serum retinol [SR] < 10 µg/dl) among one- to five-year-old children in high- (≥ 10%) and low- (< 10%) prevalence areas of Visayas highly urbanized cities (HUCs), according to receipt of vitamin A capsules and number of months after receipt of vitamin A capsules (VACs)

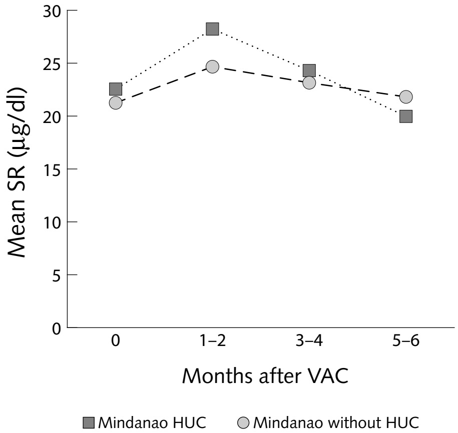

FIG. 4. Mean serum retinol (SR) of one- to five-year-old children in areas of Mindanao with and without highly urbanized cities (HUCs), according to receipt of vitamin A capsules and number of months after receipt of vitamin A capsules (VACs)

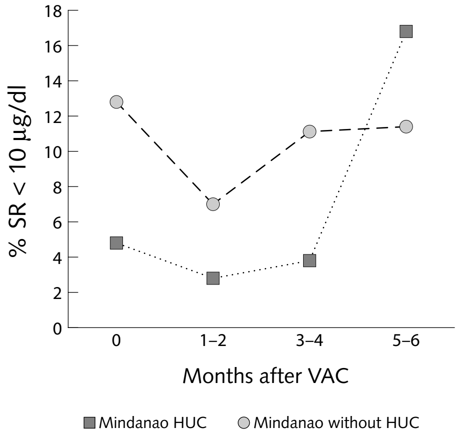

FIG. 5. Prevalence of vitamin A deficiency (serum retinol [SR] < 10 μg/dl) among one- to five-year-old children in areas of Mindanao with and without highly urbanized cities (HUCs), according to receipt of vitamin A capsules and number of months after receipt of vitamin A capsules (VACs)

less, although significant (figs. 4 and 5). Here the comparison was made between highly urbanized cities and those less highly urbanized (non-highly urbanized cities). In Mindanao, the prevalence of untreated SR deficiency (< 10 μg/dl) was highest in the less urbanized areas (non-highly urbanized cities), in contrast to the Visayas. In these areas (non-highly urbanized cities), mean SR increased by 3.4 μg/dl ($p = .00$) and 1.9 μg/dl ($p = .00$) (fig. 4), and the prevalence of SR deficiency (< 10 μg/dl) decreased by 5.8 ($p = .00$) and 1.8 ($p = .02$) percentage points (fig. 5), at one to two and three to four months after vitamin A capsule administration, respectively. The significant effect on the prevalence of SR deficiency occurred up to three to four months after the distribution of vitamin A capsules and was seen only in the less urbanized areas (without highly urbanized cities) (see figs. 4 and 5, "Mindanao without HUC").

In Mindanao's highly urbanized cities, the effects of vitamin A capsules on mean SR and the prevalence of deficient and low SR were also transient, lasting only up to one or two months after the distribution of vitamin A capsules. Mean SR increased by 5.7 μg/dl ($p = .00$); the effect on the prevalence of deficient SR within the same period was not significant. In fact, after the fourth month from distribution of the vitamin A capsules, the prevalence of deficient SR appeared to increase by 12 percentage points over the baseline prevalence (fig. 5). This increase was not explained by infection or stunting, since the dummy variable remained significant for five to six months after dosing, as shown in figure 5.

In Luzon, the apparent overall effect of vitamin A capsule supplementation was limited (fig. 6). It was discernible only among children from whom serum was collected in June or July, and only up to one to two months after the distribution of vitamin A capsules. Mean SR increased by 1.25 μg/dl in non-highly urbanized cities ($p = .06$) and by 0.78 μg/dl in the National Capital Region ($p = .06$). In the National Capital Region, the prevalence of deficient and low SR decreased by 7.6 percentage points ($p = .07$; not shown).

There was, however, a significant interaction of receipt of vitamin A capsules (one to two months after dosing) with stunting in Luzon non-highly urbanized cities. Among the stunted children who received vitamin A capsules, the mean SR was 24.1 μg/dl, compared with 21.7 μg/dl among those not receiving vitamin A capsules ($p = .09$) (fig. 7). The prevalences of deficient SR and deficient and low SR were respectively 5.8 percentage points ($p = .06$) and 16.2 percentage points ($p = .01$) lower in the supplemented group. In contrast, the mean SR was much the same in the nonstunted group, with or without vitamin A capsules (top line in fig. 7). In other words, the results suggest that the effect of vitamin A capsules is greater and more significant in the stunted children one to two months after receiving the vitamin A capsule.

A similar interaction was noted in Mindanao non-highly urbanized cities, such that the SR of stunted children who received vitamin A capsules was greater than those who did not: 23.4 μg/dl compared with 20.4 μg/dl ($p = .00$). The prevalence of deficient and low SR was correspondingly 8 percentage points lower ($p = .05$).

In summary, a significant association between the Philippines semiannual vitamin A capsule supplementation program and changes in SR among one- to five-year-old children was shown where the prevalence of vitamin A deficiency was high. This association was observed in the highly urbanized cities of the Visayas region as well as in the non-highly urbanized cities of

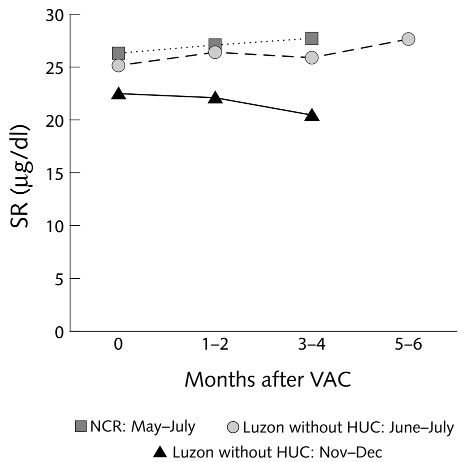

FIG. 6. Mean serum retinol (SR) of one- to five-year-old children in areas of Luzon without highly urbanized cities (HUCs) and in the National Capital Region (NCR) according to month of data collection, receipt of vitamin A capsules and the number of months after receipt of vitamin A capsules (VACs)

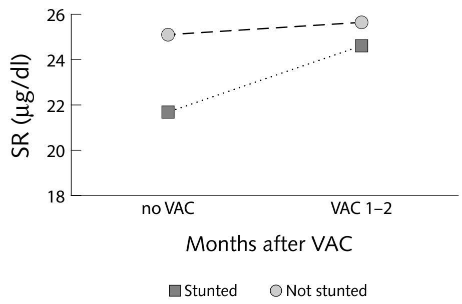

FIG. 7. Mean serum retinol [SR] of one- to five-year-old stunted and nonstunted children in areas of Luzon without highly urbanized cities one to two months after receipt of vitamin A capsules

Mindanao, although it was of less magnitude in the latter region. The impact in all these cases was transient, lasting about four months. In Mindanao highly urbanized cities, the effect of vitamin A capsules was discernible only up to two months after the dose was administered. These results are also generally in line with the extent and timing of the earlier efficacy trial by Perlas et al. [10]. In Luzon, which is generally more progressive in terms of household incomes [11] and diversity of processed and fortified foods, the effect was limited, although perhaps statistically significant in stunted children.

Two aspects are of concern: first, the size of the effect of high-dose vitamin A capsules on SR, and hence on the extent of reduction in deficiency, is limited; second, the effect does not persist for six months, which is the interval between doses. Thus, there is no ratcheting down of the extent of deficiency over time. With more frequent dosing (especially to those most deficient in SR), a progressive reduction in vitamin A deficiency could, however, be expected, and this could be tested.

Similar findings were also reported recently by Gorstein et al. [12] from Orissa, India, where the prevalence of vitamin A deficiency (indicated by deficient and low SR, < 0.7 μmol/L) was 63.8%, which was as high as that in the high-prevalence areas in the Visayas region in the Philippines study. Improvements in the various parameters of vitamin A status for the overall sample (prevalence of Bitot's spots and deficient SR) that were noted by the 4th week after administration of high-dose vitamin A capsules were not sustained through the 16th week; the SR levels of children with vitamin A deficiency at baseline increased more at 4 weeks, and remained slightly above their baseline values at the 16th week. Thus, both studies show that the benefits of vitamin A supplementation are greater among children who are most depleted or at risk; this may be indicated at the population level by higher prevalences of deficient SR or possibly by anthropometric measurements. As far as we are aware, the Orissa study and the present Philippines study are the only ones to assess changes in SR related to a routine national- or state-level high-dose vitamin A supplementation program. The consistency of the results suggests that policy changes should be considered to enhance the impact, and that other such investigations should be undertaken.

Discussion and conclusions

A United Nations Administrative Coordinating Committee/Subcommittee on Nutrition (ACC/SCN) Consultative Group stated in 1993 that the eradication of vitamin A deficiency can be achieved through an appropriate combination of interventions, including dietary modification, breastfeeding promotion, and food fortification and supplementation, and that the combination may change over time, depending on the trends in the level of deficiency, program outreach to vulnerable groups, and other factors [13]. This was based on a review of experience (up to 1993) that showed periodic high-dose supplements to be the most common, for practical reasons, noting that more frequent doses were likely to be more effective [14].

The elimination of vitamin A deficiency as a public health problem by universal vitamin A supplementation has been identified as a priority health measure by the Philippines Department of Health, based on reported findings of recent National Nutrition Surveys on the magnitude of the problem of vitamin A deficiency in the Philippines. As such, universal supplementation has been considered more cost-effective in terms of a targeted approach [15].

The picture that has been drawn from the results of the analysis, however, reveals that the extent of vitamin A deficiency and the impact of vitamin A supplementation vary across regions, warranting a review of the policy and guidelines for vitamin A supplementation. The differences in the extent of vitamin A deficiency and the impact of vitamin A supplementation may be attributed to the combination of the extent of distribution of vitamin A supplements, the dietary intake of vitamin A, other micronutrient and related public health promotion interventions, and the presence of other underlying factors that affect vitamin A status in the regions. For example, fortified foods are more available in the National Capital Region than in other parts of the country, and more available in Luzon than in Visayas or Mindanao. In terms of socioeconomic status, the National Capital Region has the lowest incidence of poverty in the country, while provinces in Luzon, excluding NCR, are among the least poor provinces in the Philippines [11].

The policy implications drawn from the analysis—similar to the conclusions reached by Gorstein et al. [12]—suggest a shift in resources from areas of low prevalence of vitamin A deficiency (where distribution of vitamin A capsules might be changed to a targeted scheme) to areas of high prevalence, where a three-times-yearly schedule is warranted. Specifically, three recommendations are indicated:

» In order to eradicate vitamin A deficiency as a public health problem, which is the stated policy of the government, using distribution of high-dose vitamin A capsules, administration at least every three to four months appears to be necessary.
» Since there are areas with very high prevalences of severe deficiency (SR < 10 μg/dl), and in these areas the response to dosing seems greatest, there is a case for targeting a more frequent vitamin A capsule program to the most affected areas. From the current data, this applies particularly to highly urbanized cities in the Visayas.
» Since stunted children appear to have a greater response, in terms of raised serum retinol, to receipt of vitamin A capsules, screening to detect stunted children to receive vitamin A capsules more frequently might be considered in less severely affected areas.

Like the Philippines, many other countries have invested considerable effort in establishing a program for distributing vitamin A capsules regularly to children, with a high rate of coverage. Research of this type (i.e., in-depth analysis of national nutrition survey data), or operational research designed to explicitly test whether provision of vitamin A capsules every three to four months to the groups most deficient in vitamin A will progressively reduce and eliminate the public health problem of vitamin A deficiency, even in other contexts, will need to be done. It would be a great achievement now to fine-tune the program and demonstrate a progressive reduction in vitamin A deficiency, and undoubtedly the health and survival of many children would benefit.

Vitamin A supplementation is indeed important to alleviate vitamin A deficiency; however, it remains a short-term and costly solution. In the long term, a multipronged approach including a combination of food fortification, promotion of locally available and culturally acceptable vitamin A–rich foods, and other public health measures will bolster a sustained eradication of vitamin A deficiency as a public health problem.

The present study provides a model for systematic program development using national surveys for program monitoring and evaluation, and applying these to progressively improving the program and enhancing the impact until the problem is overcome.

Acknowledgments

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Fatty acids in Chinese edible oils: Value of direct analysis as a basis for labeling

John C. Wallingford, Rebecca Yuhas, Shufa Du, Fengying Zhai, and Barry M. Popkin

Abstract

Edible oil is an important element in the diet of most transitional countries; nevertheless, little is known about the fatty acid composition of these oils. We examined the consumption of edible oils and the fatty acid composition of these oils obtained from a market survey conducted in seven Chinese provinces and in Beijing. Three days of measured household food intake from the 1997 China Health and Nutrition Survey households provided data on the consumption of edible oils. Edible oils sold in the capital cities of eight provinces were purchased. One hundred twenty-six samples, representing 14 different oils according to their labels, were assayed for their fatty acid content in 2001. Fatty acids were analyzed by standard gas chromatographic methods. More than 76% of households in China consume edible oil, providing an average of 29.6 g of edible oil per day to persons aged two years or older. Rapeseed was consumed by one-quarter of individuals. Rapeseed is rich in C22:1n9 cis *(erucic acid). About 33% of edible oils differed from their labeled identification. Rapeseed oil, identified by the presence of C22:1n9 (erucic acid), was most frequently not labeled as such. In another 28% of the samples,* trans *isomers of linolenic acid were detected. Deviations from the label identification were more common in southern than in northern provinces. Regulations requiring complete labeling of mixed edible oils in China might help prevent unintentional consumption of fatty acids associated with adverse health outcomes. In particular, consumption of erucic acid and* trans *fatty acids might be reduced. The results suggest the need for closer control of food oil labeling in China, especially in the South.*

Key words: China, edible oils, erucic acid, fatty acid composition

Introduction

In low- and moderate-income countries in Asia, Africa, and the Middle East, edible oil represents a major element in the diet. As income increases and as urbanization occurs, the intake of edible oil goes up rapidly, particularly in low- and middle-income households [1, 2]. In the United States, labeling of saturated fats and other fats and widespread public education are used to promote consumption of more healthful edible oils. In 2003 the US Food and Drug Administration (FDA) added a requirement that foods must be labeled for their content of *trans* fatty acids, although the requirement does not go into effect until 2006. Recently the FDA reopened the period for comments on its consideration of adding criteria for *trans* fatty acids to health claims. Despite the greater importance of edible oils in the food-consumption pattern in transitional and poor economies, comprehensive food labeling is not typical in most countries, and little is known about the actual composition of many marketed edible oils. The Chinese diet is rapidly changing, with a remarkable increase in the consumption of affordable plant oils from 15 to 37 g per capita per day in the eight years from 1989 to 1997 [2, 3]. There has been extensive focus on the possible role of dietary oils as a key element in the shift from a high-fiber, low-fat diet to a refined carbohydrate-based diet of much higher energy density. In particular, the focus is on the role of such food-choice patterns in the development of obesity

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and associated chronic diseases [4]. However, little attention has been given to the changes in intake of fatty acids and the consequent potential health effects [4]. Given the increasing importance of oils in dietary intake in these countries in transition, it is important to begin to examine their composition. Some plant oils are promoted for their healthfulness, because they are unsaturated or contain omega-3 fatty acids or gamma linoleic acid. Other oils, however, may have high levels of saturated fatty acids, *trans* fatty acids, or other fatty acids that have potential adverse health effects, such as erucic acid or *trans* isomers of linolenic acid [5–9]. To understand more clearly the potential health implications of dietary fat changes in China, we examined consumption patterns of key edible oils and then assayed a representative sample of commercially available plant oils from Beijing and seven provinces in this food-consumption survey. The oils sampled were from various types of markets, a reflection of distribution channels in the provinces. The fatty acid profiles of the oils were assayed and compared with the information on the labels. We report here that there are numerous occurrences of mislabeling of commercial oils, and that some mislabeled oils may contribute undesirable fatty acids to the new Chinese diet. Our findings identify potential adverse outcomes related to particular fatty acids that may be revealed as the total dietary fat in China increases.

Methods

Edible oil samples

A total of 126 oil samples were collected and analyzed. The samples were collected by the Institute of Nutrition and Food Hygiene at the Institute of Nutrition and Food Safety, Chinese Center for Disease Control and Prevention. Samples were collected from Beijing, Shangdong, Henan, Jiangsu, Hubei, Hunan, Guizhou, and Guangxi Provinces. These are seven of the nine provinces represented in the current China Health and Nutrition Survey and one "mega-urban" area, Beijing, chosen to reflect the most modern eating patterns found in the elite urban areas of China. In each province all edible oils manufactured by local companies were purchased, and some oil samples not manufactured in the seven provinces plus Beijing were also purchased if the total number of samples from a province was less than 10. The oils were collected most frequently from supermarkets (62 samples, 49%), open markets (43 samples, 26%), the manufacturer (15 samples, 12%), and state stores (6 samples, 5%; all from Hubei). The labels on each bottle of oil were translated and interpreted at the Chinese Center for Disease Control and Prevention. The University of North Carolina-Chapel Hill coordinated receipt and shipment of survey samples, and sent coded samples to Wyeth Nutrition for analysis.

Fatty acid composition

Fatty acid analyses were conducted at Wyeth Nutrition (Radnor, Pa., USA). As an internal check, 12 coded samples selected at random were assayed at the University of North Carolina-Chapel Hill using different gas chromatographic parameters. Fatty acid methyl esters were prepared and extracted using a modified Morrison and Smith [4] boron trifluoride:methanol protocol. Gas chromatographic conditions used a Supelco Omegawax column (32 m, 0.32 mm internal diameter) that allowed separation of some *cis* and *trans* geometric isomers of linoleic and linolenic acids, identified by comparison to reference standards (Nu-Chek Prep, Elysian, Minn., USA). *Cis* and *trans* isomers of monenes coelute and cannot be quantified under these chromatographic parameters. Chromatography at the University of North Carolina-Chapel Hill was performed on a Perkin Elmer AutoSystem XL gas chromatograph with a 30 m × 0.25 mm inside diameter column, DB 225 (J&W Scientific, Folsom, Calif., USA). Fatty acids are reported as percentages of total fatty acids to the nearest 0.1%. Samples with fatty acid patterns (as identified by comparison with fatty acid databases [10]) that were discrepant from the labeling were retranslated and reanalyzed to confirm the initial results. The typical run-to-run variation for fatty acids in a single sample in our laboratory is less than 2% relative standard deviation. The comparative weight percent results for fatty acids generated by the two laboratories differed by no more than 10%.

Dietary intake data

China Health and Nutrition Survey

The China Health and Nutrition Survey (CHNS) is an ongoing longitudinal survey of households in nine provinces in China (Heilongjiang, Guangxi, Guizhou, Henan, Hubei, Hunan, Jiangsu, Liaoning, and Shandong). We draw on one round of data collected as part of the CHNS for 1997. The CHNS sample consists of 3,780 households from 188 villages plus urban neighborhoods. In 1997 we sampled more than 16,000 individuals. The sampling of the CHNS is described in more detail elsewhere [11].

Collection of dietary data

A detailed layout of the dietary intake data is presented elsewhere [2]. The results are based on three days of household intake of oil, measured directly before and after use, and three consecutive days of 24-hour recall from each individual.

Results

Dietary intake of edible oils

Thirteen kinds of oils were consumed in the CHNS sample households. Table 1 presents the mean intake per capita, the proportion of the sample who consumed the oils, and the mean intake among those who consumed oil for all individuals aged two years or older in 1997. The most frequently consumed edible oils were peanut, rapeseed, and soybean. During the three survey days, the proportions of people who consumed these three oils were 31.6%, 24.1%, and 11.7%, respectively. About 8.1% of urban residents consumed salad oil, which is more expensive than rapeseed oil. Most consumers do not know that salad oil is actually a kind of deodorized rapeseed oil.*

The proportions of people who consumed mixing oil and palm oil were not high, but the intakes of the two oils were very high among those who did consume them. Mixing oils usually contain rapeseed oil, palm oil, and a little bit of sesame oil, which gives the oil a pleasant smell. Only 0.1% of the sample population consumed mixing oil, but the average intake for those who did consume it was 58.3 g per day. This is notable, as palm oil (i.e., red palm oil) is rich in β-carotene.

In other research on this same topic, we show that higher-income individuals consume more edible oil than those with lower incomes. Furthermore, we have shown in longitudinal research that there is a very high income elasticity for edible oil intake [12, 13]. That is, for each percentage increase in income, there is a corresponding increase in edible oil intake.

* Please note that the lists of oils in the China food composition table and the oils noted in Table 1 are different from those actually sold and measured (and thus specified in Table 2).

Composition of edible oils

Table 2 shows the commercially available types of oil and the number of samples of each obtained from Beijing and seven provinces. Sesame, peanut, rapeseed, salad, and soybean oil together represented 81% of the samples. Samples of a number of less frequently consumed oils were also obtained and analyzed, including teaseed, cottonseed, maize, perilla, and fungi oil. The names of some oils (mixing, salad, and health oils) did not indicate their contents.

Most samples (85 of 126) had fatty acid profiles that corresponded closely with standard database values [10]. For 41 samples (32%) there was evidence of some deviation from the fatty acid pattern predicted by the label. Sesame oil is readily identified by the preponderance of oleic and linoleic acids; soybean by the ratios of oleic, linoleic, and α-linolenic acid; and peanut oil by the presence of C20, C22, and C24 saturated fatty acids. By regulatory definition, 5% to 60% of the fatty acids of rapeseed oil must be C22:1n9 (erucic acid), whereas low-erucic acid rapeseed oil (LEAR)(known also as canola oil in the United States) typically has less than 2% erucic acid, as permitted by the FDA. In Canada, edible oils may not contain more than 5% erucic acid, and infant formula in the European Community may not contain more than 1% erucic acid. Samples in which the proportion of C22:1n9 is between 2% and 35% are most likely contain some rapeseed oil, or they could represent a change in phenotype, or reversion, of the LEAR crop back to the native rape phenotype. Table 3 shows examples of fatty acid pat-

TABLE 1. Consumption of edible oils among all persons aged two years or older, China Health and Nutrition Survey, 1997[a]

	Mean daily intake per capita (g)			% of sample consuming the oil			Mean daily intake per consumer (g)		
Oil	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total
Peanut	11.2	12.2	11.5	31.5	31.8	31.6	32.4	34.4	33.0
Rapeseed	8.5	10.6	9.1	23.0	26.9	24.1	33.9	35.8	34.5
Soybean	5.1	4.5	4.9	12.5	9.9	11.7	37.6	41.3	38.5
Cottonseed	1.5	1.2	1.4	4.6	2.6	4.1	29.0	40.3	31.2
Salad	0.8	4.0	1.8	1.6	8.1	3.5	48.5	44.9	46.0
Sesame	0.2	0.3	0.2	2.1	3.4	2.5	8.5	7.4	8.0
Teaseed	0.2	0.3	0.3	0.8	0.9	0.8	25.5	31.2	27.4
Sunflower	0.2	0.1	0.1	0.5	0.4	0.4	30.0	23.3	28.3
Palm	0.2	0.1	0.1	0.3	0.2	0.3	46.1	39.4	44.7
Hempseed	0.0	0.1	0.1	0.1	0.4	0.2	34.7	31.2	32.2
Linseed	0.0	0.0	0.0	0.1	0.1	0.1	3.4	27.8	8.7
Mixing oil	0.0	0.2	0.1	0.0	0.3	0.1	0.0	58.3	58.3
Chili	0.0	0.0	0.0	0.1	0.0	0.0	20.3	0.0	20.3
Total	27.9	33.5	29.6	74.9	81.1	76.8	34.1	37.5	35.1

a. Based on three days of dietary intake and measurement of all edible oils used in the household.

terns for three oils that corresponded to database values and three samples that differed from the expected fatty acid pattern. When the sample patterns were compared with identifying patterns of fatty acids, some fatty acid patterns were observed that varied from the claims on the product label. The most common discrepancy occurred when rapeseed oil was present but not specified on the label, which occurred in 10 samples

TABLE 2. Samples of oil according to province and name on label

Label name	Beijing	Jiangsu	Guizhou	Hubei	Hunan	Henan	Guangxi	Shangdon	Total
Sesame	9	2		5	1	3		6	26
Peanut	2	2		1		1	10	7	23
Rapeseed		4	8	4	4	2	1		23
Salad	3	1	5	5	2	4			20
Soybean	1	5				3	1	1	11
Mixing	2	1			3	2			8
Maize	2				1			1	4
Teaseed					2		1		3
Safflower	2								2
Cottonseed				2					2
Sunflower	1								1
Perilla				1					1
Health oil					1				1
Fungi					1				1
Total	22	15	13	18	15	15	13	15	126

TABLE 3. Fatty acid patterns in oils (% of total fatty acids) according to the province from which the sample was collected and the name on the label

No. of carbons[a]	Hunan, rapeseed	Henan, rapeseed	Shangdong sesame	Hubei, sesame	Henan, soybean	Shangdong, soybean
C10	0.2	—	0.2	0.1	0.2	0.2
C14	—	0.1	—	0.1	0.1	0.1
C16	3.0	8.4	8.8	6.0	11.2	10.8
C16:1n7	0.2	0.2	0.1	0.2	0.1	0.1
C17	—	0.1	0.1	—	0.1	0.1
C17:1n7	—	—	—	—	0.1	0.1
C18	1.2	3.1	5.2	2.8	3.7	4.3
C18:1n9	19.3	26.1	37.6	28.9	22.9	20.3
C18:1n7	1.1	1.6	0.8	1.3	1.5	1.3
C18:2n6	12.7	37.7	45.4	28.1	50.8	51.0
18:2n6 c,t or t,c[b]	—	0.1	0.2	0.2	0.1	1.8
C18:3n3	7.9	7.9	0.3	5.5	6.9	4.1
C20	0.8	0.5	0.6	0.6	0.4	0.4
C20:1n9	8.3	2.9	0.1	4.8		0.2
C20:1n7	1.2	0.5	0.2	0.6	0.4	0.2
C20:2n6	0.5	0.2	0.1	0.3	0.1	
C22	0.7	0.5	0.1	0.4	0.1	0.4
C22:1n9	39.7	9.2	—	17.9	0.4	
C22:1n7	0.6	0.2		0.3	0.4	0.1
C22:2n6	0.6	0.2	—	0.3		0
22:3n3	0.1				—	
C24	0.3	0.2		0.2	0.2	0.2
Unknown	0.4	0.2	0.0	0.0	0.1	0.2

a. The number of carbons in the fatty acid backbone is indicated by the number following the letter C. After the colon, the number of unsaturated double bonds in the fatty acid backbone is indicated. The number following the omega (represented by the letter "n") indicates the number of carbons from the methyl end of the fatty acid to where the first double bond occurs.

b. c, *cis*; t, *trans*

(in table 3, the sample labeled Hubei contained sesame oil with nearly 18% of its fatty acids as erucic acid). The presence of soybean oil without its being specified on the label was also common and was evident when linolenic acid levels were elevated without elevated levels of oleic or erucic acid. Of 26 samples labeled as sesame oil, 4 had evidence of the presence of rapeseed oil (30%–60% of total fatty acids), 2 contained soybean oil (20% and 70% of total fatty acids), and 1 other may have contained LEAR. The apparent inclusion of rapeseed oil among otherwise labeled oils was common among specialty oils. One of the two samples labeled as cottonseed was approximately 75% rapeseed oil, although cottonseed is considered an inferior oil. The single sample of fungi oil had a profile identical to that of rapeseed oil. The single sample of peanut oil from Hubei had a fatty acid pattern characteristic of cottonseed oil.

Of 23 samples labeled as rapeseed, 4 had fatty acid patterns identical to that of LEAR, with less than 5% erucic acid, and two contained intermediate levels of erucic acid (5.9% and 8.4%), possibly suggesting a reversion of the LEAR oilseed to the native rapeseed. Two samples labeled as rapeseed appeared to contain soybean oil (60%–70%), and one had a fatty acid pattern that suggested it was 100% soybean oil. The samples consisting of LEAR labeled as rapeseed are not strictly mislabeled according to species, but the percentage of erucic acid is not correctly indicated. In 21 of 28 cases where the labels "oil mixture" and "salad" were used, the oils were identified as either rapeseed or LEAR oil. Oils labeled with ambiguous names like "vegetable," "salad," and "mixing" nearly always contained LEAR or rapeseed.

There were many samples (36 of the 126 samples, or 28%) that contained *trans* isomers of linoleic and α-linolenic acid, indicating partial hydrogenation or possible thermal damage to the oil (table 4). Among oils labeled as "salad oil" or "mixing oil," nearly all samples (16 of 20 and 7 of 8, respectively) contained α-linolenic acid isomers.

Many oils labeled as other than rapeseed oil actually contained significant amounts of erucic acid. In Shangdong and Guangxi, there were no samples with more than 5% of fatty acids as erucic acid, but in 1 of 22 in Beijing, 3 of 15 in Jiangsu, 4 of 15 in Henan, 12 of 18 in Hubei, 9 of 13 in Guizhoui, and 12 of 15 in Hunan, erucic acid constituted more than 5% of fatty acids.

In the sample labeled teaseed oil that did not contain significant C22:1n9, 78% of fatty acids were oleic acid, and only 7.7% and 0.4% were linoleic acid and α-linolenic acid, respectively.

Discussion

Edible oil represents a major source of energy in all transitional countries. In China there has been a rapid rise in consumption of edible oil, with the intake more than doubling in the past decade [14]. The increase in dietary fat is related to improved income; total dietary fat has increased even more among higher socioeconomic subsets of the population [13]. This suggests that as income in China continues to rise, the level of dietary fat will continue to increase. This increase in total fat consumption is one reason that our findings are relevant. Adverse health outcomes related to dietary fat are generally only observed when total dietary fat is high; thus, our findings identify potential adverse outcomes related to particular fatty acids that may be revealed as total dietary fat increases.

This rapid rise in the consumption of edible oils in China may be linked with a number of potentially adverse health effects. One dimension rarely examined is the potential adverse health effects of the fatty acid composition of many of these oils [3]. The optimal balance of omega-6 and omega-3 fatty acids, for instance, has been related to a number of chronic diseases in the West, such as atherosclerosis, hypertension, and inflammatory diseases [7, 15]. Similarly, high levels of *trans* fatty acids and erucic acid are of concern [5, 6, 9, 16–18].

Using individual fatty acid percentages to identify oils depends on each oil's having a stable but unique fatty acid pattern and accurate labeling borne out

TABLE 4. Linoleic and α-linolenic acid *trans* isomers in oil samples

	Type of oil						
Location	Soybean	Sesame	Mixing	Salad	Rapeseed	Cottonseed	Teaseed
Beijing	1		2	3			
Jiangsu			1	1	1		
Guizhiou				2	1		
Hubei		1		5	1	1	
Hunan			3	2			1
Henan	1	1	1	4			
Guangxi	1				1		
Shangdong	1						

by analysis. We did not set quantitative criteria for identification of the presence of a nonlabeled oil, so there may be some misclassification in our tables. Similarly, the sampling plan was rather comprehensive and unbiased with respect to the possible presence of mislabeled product, but it was not intended to provide a representative sample of food oil consumption in China. Consequently, our results should be viewed qualitatively. At the same time, the differences from expected fatty acid patterns were sometimes pronounced, so we are confident that there are mislabeled oils in the Chinese marketplace, more frequently in the South than in the North.

This research definitively shows that many Chinese are unknowingly consuming a variety of types and amounts of fatty acids considered unhealthful as hidden components in edible oil. Hidden rapeseed oil may increase the intake of erucic acid, since we found that about 15% of all samples in the current study contained more than 5% of fatty acids as erucic acid. The literature remains inconclusive about the possible harm from high intakes of erucic acid. Young animals have been disposed to develop cardiolipidosis [8] and reduced proliferation of platelets [5], but there is no direct evidence of harm in young humans. The erucic acid intake among Chinese women appears to be greater than among women from eight other countries (Chile, Philippines, United States, Mexico, United Kingdom, Australia, Canada, and Japan), based on erucic acid levels in the breastmilk of Chinese women (1.2% of fatty acids, nearly 10 times the percentage in breastmilk of women from other countries; Yuhas R, Wyeth Nutrition, unpublished data). Unintentional maternal consumption of erucic acid from mislabeled oils may contribute to milk erucic acid, thus increasing the exposure of breastfed infants to erucic acid. Our data may be useful for the design of subsequent studies of the effects of erucic acid consumption in China, especially in southern China, where we found the most frequent occurrence of mislabeling.

The biological effects of erucic acid that have been discovered since the affirmation of LEAR as generally recognized as safe (GRAS) suggest new reasons for caution about the consumption of high levels (more than 2% of total fatty acid by FDA regulatory definition) of erucic acid in dietary fats. Similarly, there is a proposal before the *Codex Alimentarius* and another before the Chinese Government to limit the content of erucic acid in infants' diets.

Reversion of LEAR to the native plant can occur in field conditions. Variants of rape that have been specifically bred to contain extremely high erucic acid for industrial applications [19] may need to be segregated from other varieties intended to enter the human food supply.

Other plant oils contain lipid substances that may have physiological effects. For example, cottonseed oil contains gossypol, which affects the reproductive system and has been investigated as a male contraceptive agent [20]. Thermal processing may also affect the fatty acid composition of oils, producing *trans* geometric isomers of linoleic and α-linolenic acids [21]. The effects of dietary *trans* fatty acids have been studied mainly with respect to changes in blood lipoprotein levels, especially low-density lipoprotein (LDL) cholesterol. Consequently, the health effects of the increase in oil consumption during the shift to energy-dense diets in transitional countries may be compounded by increased consumption of unhealthful fatty acids.

Some oils in China are labeled not according to plant origin, but simply as "health oil." The high added value of oils promoted for health purposes, or expensive oils used for flavoring, may make them susceptible to mislabeling by addition of undeclared, less costly oils.

It is apparent from our results that there is little distinction in labeling between rapeseed oil and its LEAR counterpart. The unlabeled inclusion of rapeseed oil in unusual oils used for flavor, or represented as healthful, appears to occur with about the same frequency as its admixture with common edible oils in China, so there is no obvious association of mislabeling with the cost, availability, or use of oils. Our results also indicate that when oils are ambiguously labeled, it is likely they have also been subjected to thermal abuse. It is unlikely that consumers understand the consequences of consuming low-grade oil for their intake of isomers of fatty acids, including *trans* fatty acids. Perhaps manufacturers refine cottonseed oil and label it peanut or rapeseed oil to avoid a poor image associated with cottonseed oil.

By analyzing the pattern of fatty acids in food oils, we have obtained evidence that oils in China are often incompletely and incorrectly labeled. The presence of unlabeled oils may have health consequences by increasing the exposure to erucic acid or by adding isomers of fatty acids that may adversely affect health. The improved understanding of the consequences of consumption of rapeseed oil for the maternal diet similarly suggests that unlabeled oils consumed during lactation could contribute to the exposure of infants to higher than expected levels of erucic acid [7]. Estimates of the types of dietary fat consumed in China should consider the possibility that dietary survey data may misrepresent actual fatty acid intake.

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Progress in salt iodization and improved iodine nutrition in China, 1995–99

Jinkou Zhao and Frits van der Haar

Abstract

In 1993, the State Council of China announced the policy to virtually eliminate iodine-deficiency disorders (IDD) by 2000 and adopted universal salt iodization (USI) as the national strategy. Biennial province-based monitoring from 1995 onward aimed at capturing the use and iodine content of household salt, along with urinary iodine concentrations among schoolchildren from the same households. This paper reports on the progress made in China toward the goal of virtually eliminating iodine-deficiency disorders on the basis of 85 population-representative surveys in China's provinces during 1995–99. The percentage of households using adequately iodized salt (iodine ≥ 20 mg/kg) increased from 43.1% in 1995, to 82.2% in 1997, to 89.0% in 1999. In 1999, at least 90% of the households in 15 (48%) of the 31 provinces used adequately iodized salt, and a median urinary iodine concentration of less than 100 µg/L in children was reported in only one province. Across provinces, the median urinary iodine concentrations in children were positively correlated in each survey year with the median household salt iodine contents (combined $r_s = 0.74$, $p < .001$) *and with the proportions of households using adequately iodized salt (combined* $r_s = 0.81$, $p < .001$)*. Also in each survey year, the percentage of children with urinary iodine concentrations of at least 300 µg/L was correlated (combined* $r_s = 0.69$, $p < .001$) *with the proportion of households using salt with iodine content of at least 40 mg/kg. The median urinary iodine concentration in children had reached 300 µg/L or more in 13 provinces (42%) by 1999. In a little more than five years, then, China has achieved outstanding progress toward the goal of virtual elimination of IDD through USI. Policy recommendations include improvement of quality assurance by salt manufacturers, along with a modest reduction in the mandated salt iodization levels.*

Key words: China, IDD, iodine-deficiency disorders, iodine nutrition, policy analysis, universal salt iodization

Introduction

Universal salt iodization (USI) is agreed upon [1] as the recommended strategy to eliminate iodine-deficiency disorders (IDD) in a population. USI is defined as the iodization of all food-grade salt [2] for consumption by humans and livestock. USI can ensure optimal population iodine nutrition and thereby protect each generation of newborns from brain damage due to iodine deficiency [3]. When USI has been practiced for 5 to 10 years, the recommended core standards to ascertain that the goal of sustained elimination of iodine-deficiency disorders is reached include the use of adequately iodized salt by at least 90% of households, along with an associated median urinary iodine concentration in the population in the range of 100 to 299 µg/L [4].

The elimination of IDD gained prominence among global development priorities during the last 15 years, and much progress has been made worldwide [5, 6]. National survey data consolidated at UNICEF show that nearly 70% of the world's households were using iodized salt by the end of the twentieth century, although more recent trends indicate a likelihood of some backsliding. Nevertheless, the goal of virtual elimination of IDD by the year 2000 was reached in a number of countries, together with evidence of conditions considered critical for sustainability [4, 5].

In China, the IDD problem was acknowledged as a

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public health threat early during the 1990s [7]. The Chinese Academy of Preventive Medicine had estimated that about 450 million people lived in iodine-deficient areas, with more than 30% of the population considered at risk [8]. In 1993, the State Council of China committed itself to the virtual elimination of iodine-deficiency disorders by the year 2000 and introduced USI as the national strategy [9]. Until that time, iodized table salt was directed to areas where goiter was regarded as an endemic public health problem, combined with provision of iodized oil capsules through schools.

Following the decision by the high-level political leadership, the Ministry of Light Industry and the Ministry of Health jointly publicized the outlines for accomplishment of the USI strategy, and in August 1994 the State Council enacted the national specifications for salt iodization to eliminate health hazards due to iodine deficiency in China [10]. Legal supervision of the quality of iodized salt became authorized as part of the food inspection mandate of the health administration department, while the salt administrative department was made responsible for manufacturing and marketing of iodized salt. Potassium iodate (KIO3) had already replaced potassium iodide (KI) as the iodating agent of salt in China by 1990. The new national regulations called for salt iodine contents in households to be at levels no less than 20 mg/kg. To reach this desired consumption level, the level of salt iodization during manufacturing was set at 50 mg/kg to ensure a level of not less than 40 mg/kg in the manufacturer's supply outlets. In the spirit of the solid political commitments by the State Council, a comprehensive national effort began, mobilizing many sectors and institutions. The China National Salt Industry Corporation undertook drastic industry reform and modernized its production and marketing operations, and the Ministry of Health increased enforcement measures to stop the leakage of unauthorized raw salt into consumer markets [10].

Between 1993 and 1995, a national monitoring system was also devised to track trends in goiter prevalence among schoolchildren, household use of iodized salt, and the iodine nutrition status of schoolchildren, based on provincial prevalence surveys conducted every two years and county-based household salt iodine testing conducted every month. Because of the well-known delay in the decrease in the prevalence of goiter after improved iodine nutrition [11, 12], the earlier evidence of adequate population iodine nutrition rested on trends in the use of iodized salt in households, along with trends in urinary iodine excretion among members of these households.

The present report uses the biennial province-based survey data collected in China between 1995 and 1999 to describe changes in the above indicators over time and to determine the relationships between iodine nutrition indicators of household salt and urinary iodine excretion of school-aged children from these households. The objective is to assess the practical functioning and outcomes of the USI strategy in China and suggest ways of improving its effectiveness to ensure the optimal iodine status of the population.

Methods

Survey design

In each provincial survey, a multistage, probability proportionate to population size (PPS) cluster sample was obtained. The county served as the primary sampling unit, and 30 counties (clusters) were selected systematically in each province from a county population list. In each province, in each survey year, a list of all counties was used to select 30 counties at random without putting the name of the county back on the list after its selection.

In each selected county, a school was then sampled at random. Schoolchildren aged 8 to 10 years served as the index population. For each cluster, 40 children were selected at random from the enrolment list. All children were examined for thyroid size by palpation and/or ultrasound, and the iodine content of a salt sample brought by the child from home was determined by titration. From among the 40 children in our sample, a subsample of at least 12 children was randomly selected to provide a urine sample for iodine concentration analysis. A uniform survey protocol, including sample selection, questionnaires, and record sheets, was designed and used nationally for all the provincial surveys in 1995, 1997, and 1999. The provincial surveys in 1995 were conducted between March and June, before all the previously manufactured noniodized salt had disappeared from the salt delivery channels [13].

Determination of iodine concentration in urine and salt

Urinary iodine concentration was analyzed using an acid-digestion method modified from the method of Dunn et al. [14]. The iodine content in salt samples was determined by iodometric titration [15]. All chemical analyses were conducted in provincial laboratories, accredited by the national iodine-deficiency disorders reference laboratory in Beijing. The results of urine or salt iodine analyses from field collection were not accepted unless the criteria for accreditation of a provincial laboratory were met. These criteria required that the accuracy and precision from analyzing external quality specimens provided by the reference laboratory be less than 5% of the specimen target.

Data entry and analyses

Public health professionals from each province entered the data for analysis using Epi Info 6.04b (Centers for Disease Control and Prevention, Atlanta, Georgia, USA). A training course on survey methods, sample analyses, and Epi Info was held in Beijing every year with participants from each province before the survey and data entry. During data entry, an Epi Info check-file was used to minimize errors. After entry, the raw data were cleaned in each province and then sent to the National Institute of Iodine-Deficiency Disorders in Harbin, where a further data check was performed.

Each of the datasets collected by provinces in 1995, 1997, and 1999 was handled as a separate cohort. Therefore, the provinces were the primary units for the present analysis. Distributions of salt iodine contents were available for the categories < 5 (noniodized salt), 5–19.9, 20–39.9, and ≥ 40 mg/kg; and urinary iodine concentrations for the categories < 100, 100–199, 200–299, ≥ 300, and ≥ 500 µg/L. For urinary iodine data analysis, individuals who reported the use of oral iodized oil within one year prior to the survey were excluded. Medians and 95% confidence intervals (CIs) were calculated by standard statistical methods. Because the iodine contents of salt and urine were not normally distributed, nonparametric Spearman rank correlation was used to examine associations between the various iodized salt indices and urinary iodine parameters [16]. Confidence intervals were calculated as described by Altman et al. [17].

Results

Description of dataset

In 1995, complete surveys were reported from 23 provinces; in 1997 and 1999, all 31 provinces of China provided complete data. Thus, the present dataset is composed of results from 85 province-based surveys.

The sample sizes for salt iodine by province ranged from 1,200 to 2,400 (mean, 1,259) in 1995, from 1,197 to 1,246 (mean 1,204) in 1997, and from 1,161 to 1,324 (mean 1,213) in 1999. For the urinary iodine assays, the sample sizes by province ranged from 90 to 1,190 (mean, 457) in 1995, from 36 to 1,195 (mean, 319) in 1997, and from 278 to 1,291 (mean, 442) in 1999. The present dataset therefore contains data from 103,891 salt iodine and 34,573 urinary iodine determinations, arranged as 85 cohorts from three survey rounds over six years.

The percentage of children reported to have received an oral iodized oil supplement within one year prior to urine collection was close to 50% in 1995 and 1997, but in 1999 none of the selected schoolchildren reported having received oral iodized oil in the previous year.

TABLE 1. Iodine content and use of iodized salt in households in provinces of China, 1995–99

		Salt iodine content (mg/kg)			Use of iodized salt (% of households)								
					Any iodized salt			Adequately iodized salt (≥ 20 mg/kg)			Salt with iodine ≥ 40 mg/kg		
Year	No. of provinces	Median	95% CI	Range	Median	95% CI	Range	Median	95% CI	Range	Median	95% CI	Range
1995	23	18.4	14.8–21.7	0.0–29.8	77.2	57.8–86.0	3.2–95.3	43.1	32.1–54.3	3.1–77.1	6.4	5.2–13.3	1.5–32.8
1997	31	38.1	35.0–41.3	4.2–50.8	91.0	87.7–93.6	44.5–98.7	82.2	74.0–85.7	8.7–92.3	46.3	38.0–52.6	3.8–70.7
1999	31	43.4	40.5–45.5	5.3–50.0	94.3	90.3–97.1	51.7–99.7	89.0	83.6–92.1	27.6–96.5	63.0	52.1–67.7	3.0–78.9

CI, Confidence interval of provincial pooled medians.

Household salt iodine content and use of iodized salt

From 1995 through 1999, the median household salt iodine content and the percentage of households using iodized salt (table 1) showed a steady increase with each survey year. In 1999, the percentage of households using adequately iodized salt (iodine content ≥ 20 mg/kg) reached 89.0% (95% CI, 83.6–92.1), and the median iodine content of household salt reached 43.4 mg/kg (95% CI, 40.5–45.5); these were more than twice the levels seen in 1995. In 1995, none of the 23 participating provinces reported that 90% or more of households used adequately iodized salt; however, in 1999, 15 (48%) of the 31 provinces reported that 90% or more of households used adequately iodized salt. During the same period, the percentage of household samples with iodine content of at least 40 mg/kg increased, so that by 1999, 63% of the samples brought from households had an iodine content of at least 40 mg/kg (95% CI, 52.1–67.7).

Urinary iodine concentration

As shown in table 2, the national median urinary iodine concentration in schoolchildren progressed from 160 µg/L in 1995 (95% CI, 138–188) to 300 µg/L (95% CI, 237–326) in 1997 and 282 µg/L (95% CI, 246–345) in 1999. The median varied considerably among provinces, however, and particularly in 1997, the lowest and highest provincial medians of child urinary iodine concentrations differed by more than fivefold. For the country, the proportion of children with urinary iodine levels less than 100 µg/L decreased by 50% to 60%, while the proportion with urinary iodine levels of 300 µg/L or higher increased by a similar extent during the six-year observation period. In 1999, the median urinary iodine concentration in children was below 100 µg/L in only one province of China, while in 13 provinces the median had surpassed 300 µg/L.

Relationships between salt iodine content and use of iodized salt, and urinary iodine concentration

The median iodine content of household salt and the median urinary iodine concentration in children were positively correlated during each year of the survey (fig. 1). For the combined dataset of 1995–99, r_s = 0.74 ($p < .001$), and significant positive correlations were also obtained within each year. A positive correlation was also apparent (fig. 2) within each survey year between the percentage of households using adequately iodized salt (iodine content ≥ 20 mg/kg) and the median urinary iodine concentration among children from these households (combined r_s = 0.81, $p < .001$). Figure 3 shows that over the survey years, the

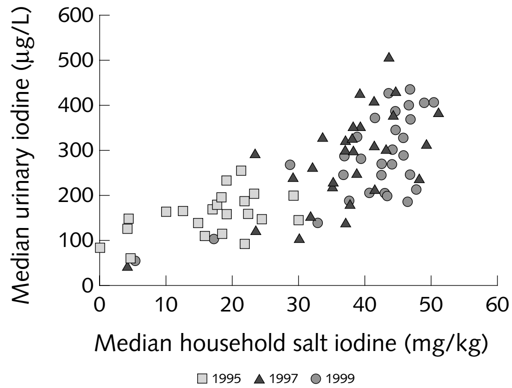

FIG. 1. Median household salt iodine content and median urinary iodine concentration in school-aged children in China, 1995–99. Nonparametric Spearman rank correlations: 1995: $r_s = 0.43, p < .05$; 1997: $r_s = 0.61, p < .001$; 1999: $r_s = 0.56, p < .01$

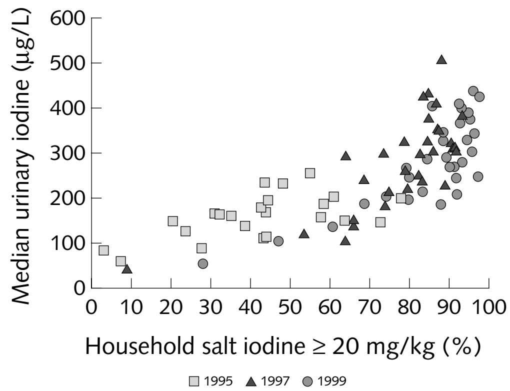

FIG. 2. Percentage of households using adequately iodized salt (iodine content ≥ 20 mg/kg) and median urinary iodine concentration in school-aged children in China, 1995–99. Nonparametric Spearman rank correlations: 1995: $r_s = 0.56, p < .01$; 1997: $r_s = 0.72, p < .001$; 1999: $r_s = 0.72, p < .001$

TABLE 2. Urinary iodine concentration among schoolchildren in provinces of China, 1995–99

Year	No. of provinces	Urinary iodine (µg/L)			% of children with urinary iodine < 100 µg/L			% of children with urinary iodine ≥ 300 µg/L		
		Median	95% CI	Range	Median	95% CI	Range	Median	95% CI	Range
1995	23	160	138–188	60.6–256.4	29.0	25.0–40.0	13.9–63.8	19.5	11.7–24.1	0.0–41.6
1997	31	300	237–326	41.2–506.9	9.5	6.1–18.4	2.6–78.3	50.5	33.6–57.7	4.7–72.1
1999	31	282	246–345	54.8–437.7	10.8	8.1–15.0	1.6–73.6	46.4	36.3–56.4	2.6–76.6

CI, Confidence interval of provincial pooled medians.

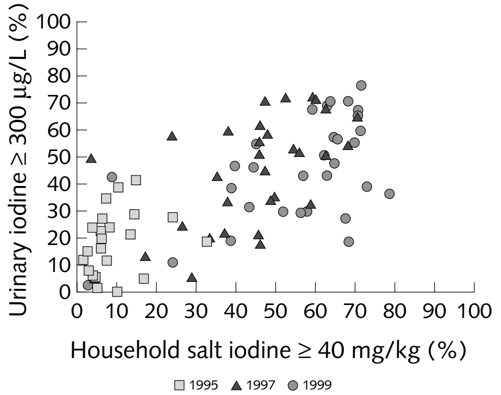

FIG. 3. Proportion of households using iodized salt with iodine content ≥ 40 mg/kg and proportion of school-aged children in China with urinary iodine concentrations ≥ 300 μg/L, 1995–99. Nonparametric Spearman rank correlations: 1995: $r_s = 0.38$, $p < .05$; 1997: $r_s = 0.57$, $p < .01$; 1999: $r_s = 0.48$, $p < .01$

proportion of children with urinary iodine concentrations of at least 300 μg/L increased with an increase in the proportion of households using salt with iodine content of at least 40 mg/kg (combined $r_s = 0.69$, $p < .001$).

Discussion

Starting out from a strategy focused on delivering iodized salt combined with iodized oil supplements in selected populations, the State Council of China in 1993 decided on a national policy to virtually eliminate iodine-deficiency disorders by 2000 and adopted USI as the strategy [9]. The results of representative monitoring of the iodine content of household salt and urinary iodine excretion in children from 1995 through 1999 show the solid progress made in China toward the implementation of USI and elimination of iodine-deficiency disorders. By the end of the six-year period in 1999, half of the provinces of China had met the target level of use of adequately iodized salt by at least 90% of households recommended by the World Health Organization/UNICEF/International Council for the Control of Iodine Deficiency Disorders (WHO/UNICEF/ICCIDD) expert consultation [4]. Also in 1999, the national median of this key iodine nutrition supply indicator had shifted closer to 90%. Measurements of the iodine content of household salt over time show a concurrent increase in salt iodine levels at consumption. In 1999, the national median salt iodine content had reached more than double the median content observed in a subsample of provinces in 1995.

The biennial provincial monitoring system was designed to collect data on urinary iodine concentrations among those schoolchildren selected to bring the salt used in their households. The distributions of urinary iodine concentrations in children may therefore be expected to reflect the iodine content of the salt used in the households where these children resided. From 1995 to 1999, during the period when both the national median salt iodine content and the proportion of households using iodized salt were seen to increase twofold, the median urinary iodine concentration in children increased from 160 to 282 μg/L, and the proportion of children with urinary iodine concentrations under 100 μg/L decreased by 50% to 60%. The consistent positive correlations found between provincial median household salt iodine contents and median urinary iodine concentrations in children lend further credibility to the implicit relationships between, on the one hand, household salt iodine content and its level of use, and on the other, urinary iodine concentrations in children. Along with improvements in the adequacy of salt iodization and increases in the use of iodized salt in households (fig. 2), an upward shift can be seen in the distribution of urinary iodine concentrations among schoolchildren. Thus, the progress in population iodine nutrition in China during 1995–99 can be attributed to both an improvement in the quality of the iodized salt supply and an increase in its use in households. Separating the proportional contributions of these two factors was not possible from the present dataset, however.

The mandated iodization levels of food-grade salt in China aimed at an addition of at least 100 μg iodine per day to the diet of the average individual [8]. From the present dataset, an accurate estimate of the national baseline urinary iodine concentration cannot be obtained, because the data obtained in 1995 were collected after USI had already been launched, although it had not yet taken hold in the salt supply channels everywhere [8]. The data points in figure 1 for provinces with a median salt iodine content of less than 10 mg/kg would suggest, however, that the national baseline child urinary iodine concentration may have started out at a median near or below 100 μg/L. For the 15 provinces (with 5,047 determinations of urinary iodine) in which, during any survey year, at least 90% of households reported using adequately iodized salt *and* the median iodine content of household salt was between 20 and 39.9 mg/kg, a median urinary iodine concentration of 245 μg/L was reported in children. Thus, it would seem from this simple comparison that the additional iodine consumption provided through the mandated policy was higher in practice than what the national policy had aimed for. At the same time, however, it is notable that under conditions considered optimal in USI practice, the observed urinary iodine concentration among children in China fell within the range recommended internationally [4].

The present dataset shows that by 1999 USI practice in China had progressed to the extent that the median household salt iodine content in the majority of provinces (22 of 31, or 71%) had reached levels considerably above what the policy aimed for. Figure 3 shows that the proportion of households using salt with an iodine content of 40 mg/kg or more was strongly associated with the proportion of children with a urinary iodine concentration of at least 300 µg/L. In 1999, the median urinary iodine concentration was 333 µg/L and the median household salt iodine content was 43.7 mg/kg in the 15 provinces (with 5,369 determinations of urinary iodine) reporting that at least 90% of households were using adequately iodized salt. Based on these observations, a reduction of the legislated salt iodization levels would be justifiable.

Although the practice of salt iodization in China improved overall, considerable variation remained in the measured iodine content of household salt. As table 1 shows, the more than 10-fold range between provinces in median salt iodine content observed in 1997 remained in 1999. Although the median household salt iodine content increased over time, along with a sizable reduction in the proportion of households using salt with an iodine content of less than 20 mg/kg, the proportion of household salt samples with iodine contents between 20 and 39.9 mg/kg remained rather constant in each province, at about one-third of samples. These observations show that the national salt industry in China still faced a challenge to improve performance enough to ensure a narrower range of iodine content during the production of iodized salt.

These considerations of USI outcomes in China were among the factors that led to a decision in October 2000 to revise the nationally mandated salt iodine levels to 35 ± 15 mg/kg at production. The monitoring results in 2002 should confirm whether this adjustment, in tandem with continuous improvements in quality assurance procedures by salt manufacturers, has prompted further improvement and optimization of the iodine nutrition situation in China.

In conclusion, following the high-level political decision in China in 1993 to virtually eliminate iodine-deficiency disorders by 2000 through the national practice of USI, steady improvements took place in the iodine content of salt and the proportion of households using iodized salt, as well as in the urinary iodine concentrations of children from these households. By 1999, China had basically achieved the goal of USI: almost half of the provinces had reached USI, and in only one province was the urinary iodine concentration in children still below the recommended range. Biennial data collection from 1995 to 1999 based on representative household salt samples and urine samples from children in China's provinces shows an intrinsic relationship between these indicators of iodine supply and nutrition. At the same time, however, it became apparent that the salt iodization practice in China had resulted in iodine consumption among schoolchildren in 1999 above the desired level. In addition, the variation in household salt iodine content remained considerable over the period of observation.

The data from 1999 show that China was tantalizingly close to achieving the national policy goal of virtual elimination of iodine-deficiency disorders set in 1993. The adjustment in 2000 of the mandatory levels of salt iodization at production, in combination with stronger efforts by the Chinese salt industry to ensure a narrower range of iodine contents in iodized salt, strengthens the expectation that the progress made toward optimum iodine nutrition of the population in China will continue.

Acknowledgments

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Advancing human nutrition without degrading land resources through modeling cropping systems in the Ethiopian Highlands

Tilahun Amede, Ann Stroud, and Jens Aune

Abstract

*Food shortage in sub-Saharan Africa is generally considered a function of limited access to food, with little thought to nutritional quality. Analyzing household production of nutrients across farming systems could be valuable in guiding the improvement of those systems. An optimization model was employed to analyze the scenario of human nutrition and cropland allocation in enset (*Enset ventricosum*)/root crop-based and cereal-based systems of the Ethiopian Highlands. The type and amount of nutrients produced in each system were analyzed, and an optimization model was used to analyze which cropping strategies might improve the nutritional quality of the household using existing resources. Both production systems were in food deficit, in terms of quantity and quality of nutrients, except for iron. The energy supply of resource-poor households in the enset/root crop-based system was only 75% of the recommended daily dietary allowance (RDA) of the World Health Organization (WHO), whereas resource-rich farmers were able to meet their energy, protein, zinc, and thiamine demands. Extremely high deficiency was found in zinc, calcium, vitamin A, and vitamin C, which provided only 26.5%, 34%, 1.78%, and 12%, of the RDA, respectively. The RDA could be satisfied if the land area occupied by enset, kale, and beans were expanded by about 20%, 10%, and 40%, respectively, at the expense of maize and sweet potato. The cereal-based system also had critical nutrient deficits in calcium, vitamin A, and vitamin C, which provided 30%, 2.5%, and 2% of the RDA, respectively. In the cereal system, the RDA could be fully satisfied by reducing cropland allocated to barley by about 50% and expanding the land area occupied by faba beans, kale, and enset. A shift from the cereal/root crop-dominated system to a perennial-enset dominated system would decrease soil erosion by improving the crop factor by about 45%. This shift would also have a very strong positive impact on soil fertility management. However, any policy suggestions for change in cropland allocation should be done through negotiations with households, communities, and district stakeholders.*

Key words: C-factor, cropping systems, human nutrition, modeling, land allocation

Introduction

The food situation in sub-Saharan Africa is continuing to deteriorate as a consequence of multiple calamities such as drought, occasional flooding, decline in soil fertility, increasing pests and diseases, land scarcity, and poor market access, coupled with discouraging policy environments. The effect is visible as recurring food shortage, malnutrition, and poverty. Food shortage in sub-Saharan Africa is generally regarded as a function of limited access to food, with little thought given to nutritional quality [1]. Malnutrition in the most vulnerable groups (children and women) could occur even in good crop harvest years because of nonbalanced food intake. Studies in Ethiopia showed that about 45% of the children were stunted and about 42% were underweight, in association with zinc, iron, and vitamin A deficiencies [2]. The most important documented forms of malnutrition countrywide in Ethiopia were protein-energy malnutrition and vitamin A, iodine, and zinc deficiencies [2, 3]. A recent survey showed that 53% of boys and 26% of girls aged between 6 and 72 months had night-blindness or Bitot's spots, with the highest prevalence in those between 36 and 72 months [2].

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Analyzing household production of nutrients across farming systems may be valuable for guiding the improvement of those systems, particularly in situations where markets are less important than securing subsistence. For instance, in Papua New Guinea, communities farming in flat wetland areas had significantly higher energy and protein intakes than those in the drier hills [4]. In Uganda, both banana-based and cereal-based systems failed to satisfy a range of nutritional needs, with calcium and zinc being the most deficient [5]. However, there is scant information on the interaction of enset/root crop-based and cereal-based systems of the Ethiopian Highlands in relation to household nutrition and human health. Enset (*Enset ventricosum,* known also as false banana) is a carbohydrate-rich perennial crop with a strong pseudostem and edible bulbs and corms [6], which is a staple of millions of households in the Ethiopian Highlands.

The nutritional quality of food may be improved by various practices, such as application of fertilizers and soil fertility improvement, selection of varieties with high micronutrient content, use of indigenous high-nutrient-value crops, and genetic modification of plants to improve micronutrient supplies [1, 7]. However, the application of these methods to address malnutrition depends upon the availability of technological and policy interventions that are commonly not within the reach of small-scale farmers. It may also be possible to supplement the diet with animal products where livestock is an integral part of the system, but animal products are rarely consumed by rural households, because they are scarce sources of cash [3]. Dietary supplements are also rarely available to the rural poor.

One option to minimize the risk of malnutrition is reallocation of cropland in favor of crops with high contents of the nutrients in deficit. Once the nutrient budget of these systems has been quantified and the type of the nutrient in deficit or excess has been identified, the nutritional balance may be improved by reallocation of cropland and by increasing the land area allocated to crops rich in the requisite nutrients [5]. Modeling the cropping system, by considering the adaptability of the crop to the environment in question, could offer a better and faster method of reversing malnutrition. However, the possible acceptance or rejection of the model depends largely on the compatibility of the new crop adjustment with cultural values, food habits, labor, input demands, and soil fertility management options.

Ethiopia is one of the most severely affected countries in sub-Saharan Africa in terms of land degradation, having lost about 17% of its potential gross domestic product (GDP) because of physical and biological soil degradation [8, 9]. Land degradation may be the major cause of recurrent crop failure, i.e., food insecurity. Hence, any attempt to efficiently exploit the potentials of land resources to produce more food should be integrated with strategies to rehabilitate depleted land resources [10]. Changing the plot size of one crop and reallocating it to another crop may have significant implications on soil erosion [11] because the change in crop type, which may be characterized by different leaf area, root density, and vegetative cover index, would affect the interception of rain by the vegetative cover. This is presented as a "crop factor" (C-factor) in the universal soil loss equation (USLE) [12]. The relationship between relative erosion and crop cover of the soil surface is strongly parabolic: a 25% increase in cover would yield a 50% reduction in erosion [10]. A shift from a cereal-dominated system to a perennial-dominated system may improve the C-factor, whereas the reverse may cause more erosion and land degradation. Therefore, altering crop allotment to improve human nutrition should take soil fertility, conservation, and management into account.

The objective of this study was to estimate the type and amount of nutrients that enset/root crop-based or cereal-based systems furnish, in terms of protein, energy, zinc, calcium, iron, thiamine, vitamin A, and vitamin C, to model cropping strategies that may improve the nutritional quality of the household using the existing resources, and to estimate the effect of reallocation of crops on land management and soil erosion.

Methods

Site description

The research was conducted in two contrasting farming systems of the Ethiopian Highlands: Areka and Ginchi. Areka is characterized by a multiple cropping system, with strong perennial components of enset and coffee, accompanied by sweet potato, taro, maize, wheat, and many others (table 1). The population pressure is high (> 400 inhabitants per square kilometer), with average landholdings of less than 0.5 ha per household. The elevation ranges from 1,880 to 1,960 m above sea level, with a mean annual rainfall of about 1,300 mm and an average temperature of 19.5°C. Rainfall is bimodal, with a short rainy season from March to June and the main rainy season from July to October. The dominant soils are eutric nitisols, which are characterized by high water-holding capacity, moderately acidic pH, low levels of nitrogen, and high phosphorus fixation.

Ginchi is an example of a mountainous Ethiopian plateau with an elevation of 2,700 to 3,000 m. The area has a weak annual bimodal rainfall of 1,200 mm and an average temperature of 15°C. The farming system is dominated by barley-fallow-barley rotation and livestock, which are grazed according to a communal management system. Crop diversity is restricted by

TABLE 1. Crop yield and nutrient composition of major crops grown in Areka and Ginchi

Crop	Yield (dry) (qt/ha)	Nutrient content/kg edible yield Energy (kcal)	Protein (g)	Zinc (mg)	Iron (mg)	Calcium (mg)	Thiamine (mg)	Vitamin A (μg)	Ascorbic acid (mg)
Enset (*kocho*)[a]	119.08	2,111	6	6	37	320	0.3	0.2	0
Taro	29.66	1,038	13	1.4	20	550	0.4	0	90
Pumpkin	6.78	249	11	1.9	9	400	0.3	0	40
Kale[a]	18.75	401	25	8.6	22	50	0.4	112.5	13.2
Sweet potato	39.35	1,370	0.7	2	7	130	0.2	0	14.2
Irish potato[a]	14.46	840	15	4	36	184	0.1	0.4	2.83
Maize	14.84	2,234	41	13.3	20	80	0.2	0	0
Teff	4.09	1,620	41	11	115	690	0.3	0.03	0
Wheat[a]	8.93	2,220	68	2	27	270	2.1	0.8	0
Barley[a]	5.81	2,020	44	15.8	35	160	2.1	0	0
Pea	6.97	2,071	109	24.6	31	450	2.4	10.5	0
Faba bean[a]	6.77	2,759	164	13.8	43	870	1.9	1	0
Common bean	6.52	1,700	91	3	33	560	2.6	0.6	0
Sorghum	8.31	2,360	50	4.9	49	150	2.2	1.1	0

a. Crops grown both in Ginchi and Areka.

low average temperature. Population pressure on the land is exerted by humans (100/km^2) and livestock, with an average farm size of 3 ha. About 24% of the farmers own more than 4 ha. On the upper side of the watershed, the system is predominantly barley-fallow-barley accompanied by wheat, potato, and enset. The soils in the Ginchi plateau are litisols, which are acidic and low in organic matter, nitrogen, and phosphorus. The fertility of the soil is so low that it does not currently support continuous cropping.

Data collection

A household survey was conducted over two years (2000–01) in the two communities of the enset/root crop-based and cereal-based systems. Farmers from two wealth categories (relatively rich and poor) were considered for the study in Areka (n = 24) and Ginchi (n = 31). A participatory wealth-ranking exercise, which was undertaken by the African Highlands Initiative Program, grouped households into three wealth categories based on the size of landholdings, number of livestock, perennial crops grown, and sources of income, was used in this study [8]. During the household surveys, the researchers were able to observe and quantify over a period of two years. The major parameters considered for the analysis were farm and household size, household family composition by age and sex, cropland allocation, household food items available over seasons, household food allocation or distribution among family members, crop yield on the farm, and crop purchase or sales over seasons. Household food consumption was monitored in each household on a weekly basis by interviewing the women. The consumption unit (CU) of each household was calculated by adding the CU of each household member using Food and Agriculture Organization (FAO) designations [13]. Secondary data were also collected on average crop yield in the district [14], nutritional composition of each crop [15] (table 1), and other relevant factors. For crops for which reliable data were not available, measurement of yield, moisture content, and estimation of edible components was done on the farm at harvest. The survey was composed of a stratified questionnaire, household group discussion, and direct measurement of crop yields during harvest, and was administered by a technical assistant residing in a nearby village. Continual follow-up was made at all levels.

Since the bimodal rainfall supports at least two crops per year at Areka, land size per household was calculated as the sum of land used for growing crops in both seasons per year. Hence, the farm size presented here is larger than the actual land size. In the process, intercropping and relay cropping practices complicated the establishment of land area and yield per individual crop. However, for the purpose of this exercise, we followed a procedure similar to that used by McIntyre et al. [5], whereby the dominant crop is assumed to occupy the entire area if the populations of the crop mixtures are sparsely grown. The area occupied by the companion crop was calculated from the current plant population density and the optimal plant population density. In situations where none of the crops grown in the crop mixture comprised the highest ratio, crop area was calculated based on the proportional areas they occupied.

The nutrient yields of annuals were determined by measuring the edible yield per area, analyzing the nutrient content of the produce, and converting it to household nutrient supply as the sum of all consumable crop products of the household in the respective systems. Besides annuals, the system comprises perennial crops (e.g., *Enset ventricosum*) of various ages. The nutrient yield of perennial crops *in situ* was determined by estimating crop yield per plant from measurements of corm height and the circumference of plants, as described earlier [16], supplemented by sample weighing, and multiplied by the nutrient content of the product [15] and the number of plants to be harvested per year.

Alterations in crop area and crop species may affect erosion by changing the vegetative cover. Therefore, the relative farm erosivity index (FEI) was calculated by considering the C-factor in terms of cover effect on soil erosion [10] and by considering the cropland size allocated to each crop at present and after optimization of the cropping system for optimum human nutrition, as follows:

$$\text{FEI} = \frac{\sum \text{CF} \times \text{optimized cropland area}}{\sum \text{CF} \times \text{current cropland area}}$$

where

FEI = cumulative farm erosivity index
CF = C-factor of respective crop species

The model

An optimization model was developed using the Solver in Microsoft Excel and employed to analyze the scenario of human nutrition and cropland allocation. After the land size allocated per crop, yield data, percent edible yield, moisture content, and nutrient composition of each crop had been assembled, an annual nutrient budget and household consumption unit was calculated. The recommended dietary nutritional allowance defined by the World Health Organization (WHO) [17] was used to establish optimal nutrient balances.

The objective function used in the model was energy availability per consumption unit and day:

$$\frac{\sum_{i=j}^{N} LS_j \times EY_j \times DM_j \times NC_j}{CU \times 365}$$

where

LS = land allocated to crop *i*
EY = edible yield of crop *i*
DM = dry matter yield of crop *i*
NC = nutrient content of crop *i*
CU = number of consumption units in the household (number of people eating in the house)

Farm land size and daily nutritional requirements for protein, zinc, calcium, iron, thiamine, vitamin A, and vitamin C were used as constraints in the model (see list of constraints below). The constraints differ between the locations because the farming systems were different. The constraints were set to ensure that the households would continue to cultivate, at least partly, their current staple crops. The staple crops in Areka are enset, sweet potato, and maize, whereas those in Ginchi are barley, faba beans, and kale.

Constraints for Areka communities:

Total farm land ≤ 1,659 m^2/CU
Land size of enset ≥ 100 m^2/CU
Land size of sweet potato ≥ 100 m^2/CU
Land size of maize ≥ 100 m^2/CU
Protein ≥ 35 g/day/CU
Vitamin C ≥ 25 mg/day/CU
Zinc ≥ 15 mg/day/CU

Constraints for Ginchi communities:

Total farm land ≤ 4,081 m^2/CU
Land size of barley ≥ 1,000 m^2/Cu
Land size of faba bean ≥ 80 m^2/CU
Land size of kale ≥ 50 m^2/CU
Protein ≥ 35 g/day/CU
Calcium ≥ 500 mg/day/CU
Vitamin A ≥ 25 μg/day/CU
Zinc ≥ 15 mg/day/CU

The decision variables in the model are land allocation for different crops, energy availability per consumption unit, and day, subject to the constraints given above.

Results

Although the average family size is equal in the two regions, the land size per consumption unit is much higher in the cereal-based system (Ginchi) than in the enset/root crop-based system (Areka) (table 2). The difference in land size would be even higher if the fallow land in Ginchi were considered as a potential area for expansion of current crop fields. Both systems are considered nutrient deficient, especially in drought years; the Ginchi farmers have a better ability to cope with drought by selling small ruminants, whereas the Areka system includes very few animals.

Enset/root crop-based systems

The population density in Areka is relatively high (> 400/km^2), and the landholdings are relatively small, about 816.8 m^2/CU. More than 50% of the land is allocated to root/corm crops, in particular sweet

TABLE 2. Characteristics of an average household in enset/root crop-based (Areka) and cereal-based (Ginchi) systems in Ethiopia

Characteristic	Areka	Ginchi
Household size		
Males	3.2	3.1
Females	3.1	3.3
Total	6.3	6.4
Mean CU	4.59	4.65
Actual cropland/ household (m^2)	3,749.7 (± 511)*	17,499.7 (± 1,149)
Cropland used/ household (m^2)	5,218.7 (± 679)	10,402 (± 709)
Actual cropland/ CU (m^2)	817	3,764
Cropland used/ CU (m^2)	1,137	2,237
Land used for cash crops (%)	6	0

CU, Consumption unit. Numbers in parentheses indicate standard deviation.
* Mean (±SD).

potato, Irish potato, enset, and taro, with land areas of 25.8%, 16.2%, 10.1%, and 2.75%, respectively (figs. 1 and 2). Most of these crops are grown in the homestead or the mid-field, which is halfway between their home and the end of their farm. Another 45% of the land is allocated to cereals, with maize as the dominant grain crop in the system. The total land allocated to legumes and vegetable crops is less than 5%.

The current enset/root crop-based system was found to be in deficit for most of the nutritional components, regardless of household wealth status. Except for iron, the system failed to cover the needs for macro- and micronutrients (table 3). The daily energy supply of resource-poor households was only 75% of that recommended by WHO [17]. Extremely high deficits were found of zinc, calcium, vitamin A, and vitamin C, at 26.5%, 34%, 1.78%, and 12% of the required levels, respectively (table 3). The situation was similar even for relatively resource-rich farmers, except for energy, which was higher.

Cereal-based systems

The average landholdings are much larger in the cereal-based system (4 ha per household) than in the enset/root crop-based system. However, in the cereal-based system the farmers leave about 40% of their land fallow, due to declines in soil fertility and lack of grazing land for keeping livestock. Crop diversification at Ginchi is very low, with only six crop species. The greatest proportion of land is allocated to barley (63.5%), followed by wheat and Irish potato (fig. 3). Similar to the situation in Areka, the amount of land allocated to legumes and vegetables in Ginchi is relatively small. Hence, it is predominantly a barley-fallow-barley system.

The current production system is unable to satisfy the human requirements for most nutrients. The system is able to deliver relatively high amounts of iron and thiamine. The resource-rich farmers can satisfy their energy, protein, zinc, iron, and thiamine

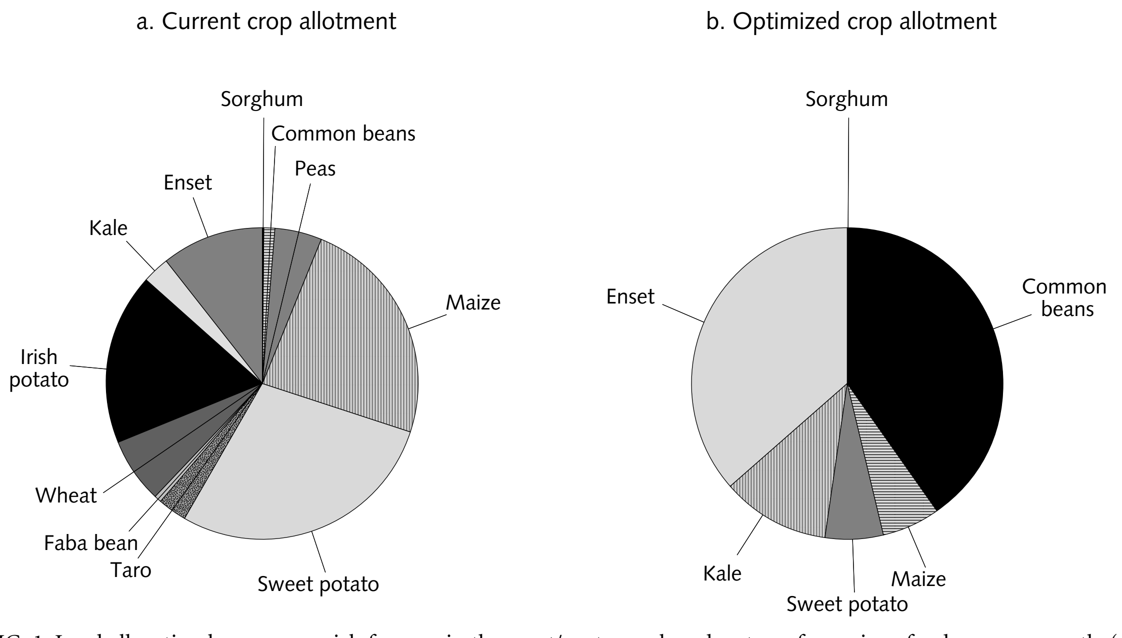

FIG. 1. Land allocation by resource-rich farmers in the enset/root crop-based systems for various food crops, currently (a) and after optimization for improved human nutrition (b)

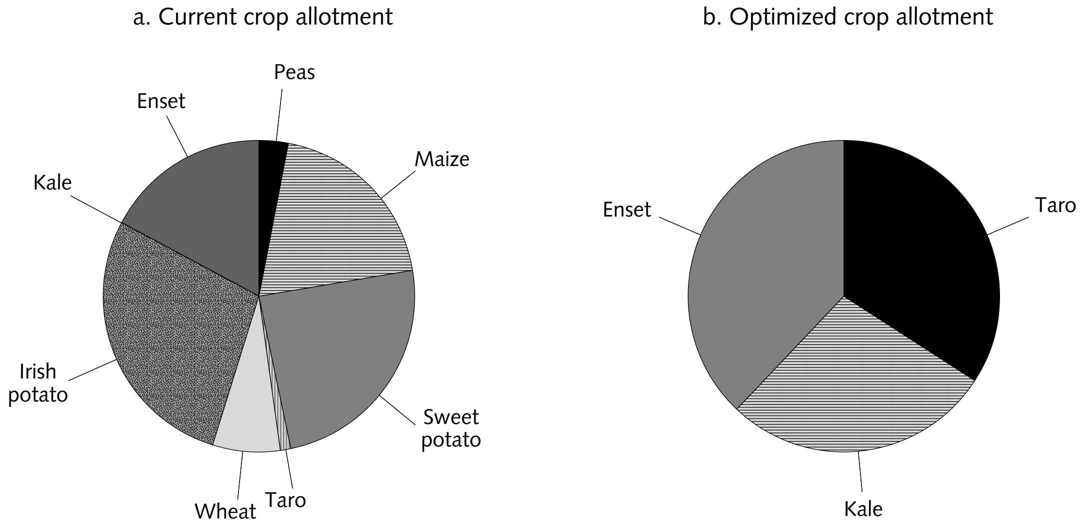

FIG. 2. Land allocation by resource-poor farmers in the enset/root crop-based systems for various food crops, currently (a) and after optimization for improved human nutrition (b)

requirements. However, they can provide only 30%, 2.5%, and 2% of the RDA for calcium, vitamin A, and vitamin C, respectively [17] (table 3).

Modeling results

The modeling was run by taking system constraints into account, including household food habits, the adaptability of crops, and the effects of pests and diseases. In Areka enset and sweet potato are the major components of household nutrition, whereas in Ginchi barley is currently the major staple crop. Thus, we ran a simulation model that included barley in Ginchi and enset and sweet potato in Areka.

In Areka, the major constraint affecting the model was the extremely low landholdings of the majority of community members, who were regarded as resource-poor in the analysis. When the whole system was considered in modeling, it was not possible to improve the system with regard to most nutrients, except in terms of energy. However, when the simulation was run separately for the relatively resource-rich households, the energy supply became much higher than the recommended levels, while the demand for all other nutrients was fully covered (table 3). This finding recommends a significant shift from cereals and root crops to an enset-bean dominant system. There needs to be a shift in land allocation, from about 10% to 36% and from 0.1% to 40% for enset and the common bean, respectively (figs. 1 and 2).

At Ginchi, there was a better possibility for the model to improve the nutritional quality of the household by increasing the amount of cropland per consumer unit, if the land was not compromised by a decline in soil fertility and a shortage of livestock feed. The existing cropland, at 2,237 m^2/CU, is enough to provide bal-

TABLE 3. Nutrient budget of households in enset/root crop-based and cereal-based systems of Areka and Ginchi, at current cropping systems and after the system was optimized for improved human nutrition.

		Areka				Ginchi			
		Resource-poor		Resource-rich		Resource-poor		Resource-rich	
Nutrients	RDA	Current	Optimized	Current	Optimized	Current	Optimized	Current	Optimized
Energy (kcal)	2,000.00	1,293.66	2,000.00	2,284.18	4,758.4	1,397.5	3,329.00	2,081.50	3,695.60
Protein (g/kg)	37.53	7.82	9.31	17.39	35.98	32.39	40.00	42.40	42.75
Zinc (mg/kg)	15.00	3.98	6.09	7.38	15.00	7.39	15.33	19.75	20.80
Iron (mg/kg)	7.61	21.48	36.63	35.68	81.664	26.41	78.00	33.55	68.56
Calcium (mg/kg)	528.00	178.76	362.42	310.00	758.70	163.25	694.00	194.50	547.04
Thiamine (mg/kg)	0.92	0.21	0.35	0.41	0.89	1.17	1.08	1.52	1.30
Vitamin A (μg/kg)	10.00	0.18	10.00	2.54	10.00	0.25	12.51	1.45	20.80
Vitamin C (mg/kg)	25.42	2.98	14.95	9.08	2.41	0.54	1.62	0.01	2.61

RDA, Recommended dietary allowance [17].

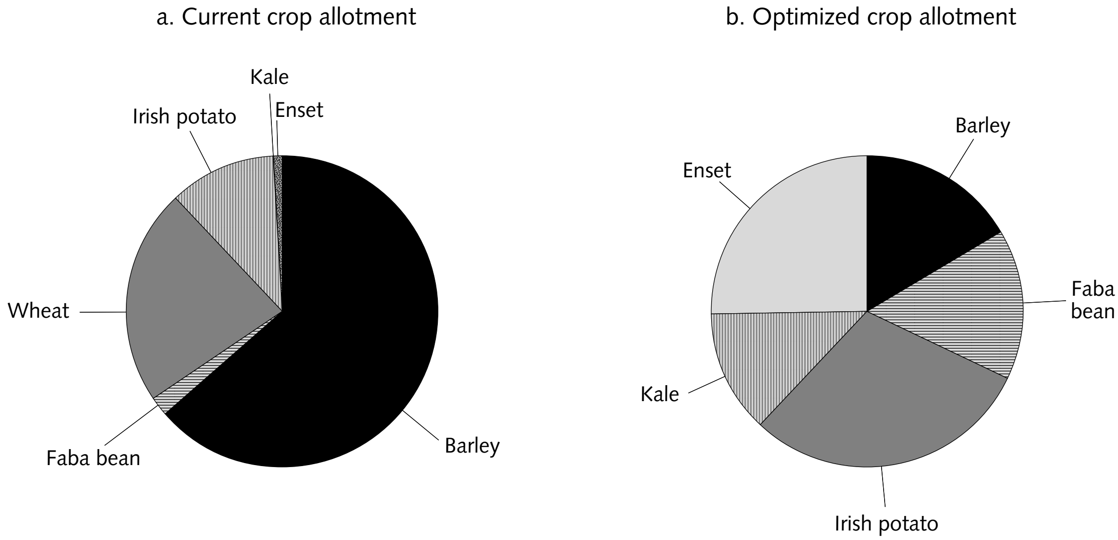

FIG. 3. Land allocation in the cereal-based systems for various food crops, currently (a) and after optimization for improved human nutrition (b)

anced nutrition with a moderate change in the cropping system. The suggested shift was intended to reduce the area occupied by barley by about 50% and expand the land area available for enset, kale, and faba bean to 25.3%, 17.7%, and 15.6%, respectively (fig. 3). By doing so, the requirements for the nutrients of interest were fully satisfied, except for vitamin C. In this case, vitamin C supplements could be used, or a new vegetable crop could be introduced into the system.

Implications of crop reallocation for soil erosion

A shift from one cropping system to another may have a considerable effect on soil loss and nutrient management [10]. In the enset/root crop-based system, a shift from the enset-root crop mix to an enset-bean system improved the C-factor at the farm level by 42%, indicating that soil erosion could be significantly minimized. The same applies to the cereal-based system, in which FEI was improved by 45% (table 4). This has a very strong implication for soil-fertility management, since the enset system traditionally attracts more organic matter into the system [6, 8, 18] because it does not grow in soils with low organic matter content.

Discussion

Integrating human nutrition with sustainable land management

An attempt to address food security cannot be complete without a thorough consideration of the relationship between land degradation and nutritional availability. Initiatives and policies directed toward food security should integrate strategies to turn the negative chain reactions between productivity and land use into positive balances.

Crop reallocation with human nutrition as the sole criterion could affect land management in at least two ways. First, the system may demand intensified soil fertility management because of the expansion of perennials. Traditionally, farmers have divided their farms into three categories, homestead, mid-field, and outfield, based on fertility status, type of soil management, and type of crops grown. About 80% of a farm's available organic fertilizer is applied to the homestead area, where enset is traditionally grown [6, 8]. Hence, it is the most fertile corner of the farm because of the addition of manure, crop residues, and household wastes [6, 8]. Farmers even export crop residues from the outfield to the enset field because the local wisdom considers enset a mulch-loving crop. The expansion of enset at the expense of cereals may, therefore, improve the nutrient budget of the system by encouraging farmers to intensify soil fertility management options, such as composting, better manure management, and fair distribution of resources across soil fertility gradients. Fertilizing the expanding enset fields may have a strong effect on labor and the availability of organic resources. In this case, farmers would be encouraged to practice better organic resource production and management. Second, a shift from a cereal-dominant system to an enset-dominant system may minimize erosion effects by improving vegetative cover, thus reducing the erosivity power by about 45%.

Implications for human nutrition

Malnutrition is common in the farming communities

TABLE 4. Effect of crop reallocation on soil erosion at Areka and Ginchi[a]

Crop	C-factor	Cumulative C-factor			
		Areka		Ginchi	
		Current	Optimized	Current	Optimized
Enset	0.04	6.48	24.20	0.88	24.56
Taro	0.35	16.17	np	np	np
Kale	0.26	11.17	48.47	0.73	80.32
Sweet potato	0.23	99.45	23.00	np	np
Potato	0.22	59.73	np	59.21	159.98
Maize	0.35	127.67	35.00	np	np
Sorghum	0.40	0.94	np	np	np
Teff	0.40	58.84	np	np	np
Wheat	0.42	43.39	np	228.89	np
Barley	0.42	np	np	648.48	167.96
Faba beans	0.24	4.16	np	11.61	91.00
Common beans	0.19	2.132	126.83	np	np
Pea	0.15	11.21	np	np	np
∑C-factor	0.28	441.35	257.51	949.82	523.81
FEI (%)		100	58.3	100	55.1

np, Not planted; FEI, farm erosivity index.

a. Data show the effects of current and suggested (optimized) cropping on C-factor as a component of the universal soil loss equation (USLE).

of the Ethiopian Highlands [2, 3]. This study suggests that one affordable remedy may be reallocation of cropland in favor of perennial crops with a high content of the nutrients that are in deficit. This could be done by considering community food habits, the adaptability of crops to the environment under consideration, and the potential effect of reallocation on the health of the agro-ecosystem.

The conventional wisdom was that enset/root crop-based systems may produce sufficient amounts of carbohydrates and vitamins to cover the household's nutrient requirements, but may be deficient in protein and micronutrients. Our results, however, showed that the system was deficient in most of the required micronutrients, especially vitamin A, vitamin C, zinc, and calcium (table 3). Even the available energy and protein for the resource-poor families was only 75% of the recommended amounts. This was confirmed by the fact that the system has relied heavily on food aid for at least three months a year for the last decade. This was partly the consequence of small landholdings (817 m^2/CU cropland) and very low crop yield caused by low soil fertility, use of low-yield varieties, and occasional drought. Malnutrition was severe in the resource-poor households (table 3), because resource-poor farmers concentrate on annual crops whereas resource-rich farmers allocate large plots to enset [6, 8], in agreement with our findings. Resource-poor farmers would have to allocate about 38% of their land to enset, an increase of 20% from the current system, to increase crop yield by about 20% and thus be able to partially cover the nutritional demands of the household (table 3). As it stands now, unless external supplementation is considered, the resource-poor households will remain deficient in most of the micronutrients.

The constraints on the cereal-based systems were similar to those on the enset/root crop systems except for the severe deficiency of vitamins. Malnutrition in Ginchi could be even more severe in the resource-poor families, because the crop yield is much lower there than in Areka, mainly because of the low temperatures in the mountains. Yet, there is more opportunity to expand cropland and increase productivity by improving the existing fallow-barley system through integration of soil fertility management options and high-yield varieties. Malnutrition was aggravated by limited diversification of crops, and even reallocation of the existing crops would not be enough to fulfill the requirement for vitamin C. Introduction of frost-resistant vegetable crops to be grown under a layer of expanded enset fields may satisfy the vitamin requirements (fig. 3). Households occasionally buy green peppers and citrus fruits (crops high in vitamin C) from the nearby markets in the valley bottoms. Earlier reports also showed that the lowest rates of vitamin A deficiency in Ethiopia were found in predominantly enset/root crop-based systems [3].

Nutrient deficiencies (e.g., protein and calcium) in the two systems could have been alleviated by livestock products. However, 93% of the interviewed households in both systems sold livestock products to cover household cash needs. Hence, livestock contributes little to household nutrition.

Our results indicate that if food security and environmental health are to be achieved in the Ethiopian Highlands in the short term, there is an urgent need to shift from a cereal-dominant to an enset-legume-dominant system. Expansion of the land area allocated to beans in Areka and to faba beans in Ginchi is vital to alleviate protein malnutrition. Enset is already supporting 7 to 10 million people as a staple or costaple with cereals and root crops [8, 18], and increasing its land allocation is expected to be an attractive option. The shift would have a positive impact on food security, not only because of the high energy yield of enset, but also because of its protective functions for the land, its greater ability to provide food at any time of the year, and its potential for being drought-resistant.

This approach differs from biofortification in that it does not require the introduction of nutrient-extracting crops or varieties with higher nutrient concentrations. Farmers may adopt the recommendations to reallocate their existing crop fields without the problems in adopting a new crop, i.e., one with a different color and/or different cooking quality. Biofortified varieties could also aggressively consume soil nutrients and might lead to unsustainable production unless the system is continuously supplemented by external inputs.

Implications for policy

The current policy of the Ethiopian Government gives great attention to food security, with limited emphasis on natural resource management. On the other hand, the continual quest for food, pasture land, and fuel for mere survival and to meet basic community needs has forced the increased cultivation of marginal lands, regardless of ecological soundness. The current model favors the expansion of perennial crops to address household food security and environmental degradation, while the current system of land tenure, in a situation where the government owns the land, may not encourage farmers to expand their perennial crops and practice sustainable land use.

Integration of the suggested cropping system will need strong policy support in many ways. First, an expansion of enset fields would have a strong impact on labor, mainly that of women, who are commonly responsible for managing enset fields. The most labor-intensive operation is the processing of enset into *kocho* (the bulk of the fermented starch obtained from the mixtures of the decorticated leaf sheath and grated corm) and *bulla* (a white powder produced from squeezing the liquid containing starch from the corm), which is currently estimated to take about seven hours to process one single enset plant. Hence, integration of more enset into the system should be accompanied by the integration of processing implements at affordable prices to minimize pressure on household labor. Second, the expansion of perennials calls for an immediate policy decision on land tenure and guarantees. Third, initial policy support, in terms of credit, would be needed, because the expansion of enset may demand more input of organic and mineral fertilizer into the system to establish and grow the crop in the less fertile outfields. However, the farmers' choices of livelihood strategies substantially influence cropping choice decisions and welfare and resource outcomes. Hence, any policy suggestion for change in cropland allocation should be done through bottom-up negotiations at the levels of the individual farmer, the community, and the district. Increasing awareness of nutritional deficiencies inherent to the current system and their implications for health, and of the benefits that could accrue from modification of the current production system, may lead to an early adoption.

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Influence of socioeconomic status on the prevalence of stunted growth and obesity in prepubertal Indonesian children

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Abstract

This cross-sectional study assesses the prevalence of stunting, overweight, and obesity in prepubertal children from different socioeconomic groups in Indonesia. Children from rural, poor urban, and nonpoor urban communities were studied (n = 3,010)*. The prevalences of stunting, wasting, overweight, and obesity were 19.3%, 5.0%, 2.7%, and 0.8%, respectively. The odds ratios (OR) for stunting, as compared with nonpoor urban children, were higher among rural children (2.92; 95% confidence interval [CI], 2.37–3.59) than among poor urban children (1.58; 95% CI, 1.18–2.13). The prevalence of wasting was not influenced by socioeconomic status. Both rural and poor urban children were significantly less likely to be overweight than were nonpoor urban children: in comparison with nonpoor urban children, the OR values were 0.19 (95% CI, 0.10–0.36) for rural and 0.13 (95% CI, 0.04–0.43) for poor urban children. Boys were more likely to be stunted or obese than girls: OR for stunting, 1.75 (95% CI, 1.44–2.12); OR for obesity, 4.07 (95% CI, 1.40–11.8). Stunted children were less likely than non-stunted children to be overweight: OR, 0.10 (95% CI, 0.03–0.43). In Indonesia, undernutrition is still related to poverty, whereas obesity is more related to prosperity.*

Key words: obesity, overweight, socioeconomic status, stunted growth

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Introduction

Stunted growth affects 32% of children under five years of age in the developing world [1]. The process of becoming stunted due to chronic undernutrition begins at birth, or even before, and continues during the first three years of life. The stunting that occurs during these early years cannot be restored thereafter [2]. Unfortunately, when energy intake is adequate, these stunted children are at higher risk of overweight [3]. Besides being a risk factor for adult obesity, childhood obesity is associated with chronic diseases in later life, such as hyperinsulinemia, hypertension, hyperlipidemia, type 2 diabetes mellitus, and atherosclerotic cardiovascular disease [4, 5]. Increasing levels of these chronic diseases will pose a particular burden for developing countries. They will face the double burden of infectious and poverty-related diseases (e.g., malaria, chronic undernutrition), and the emerging concerns of chronic diseases related to early malnutrition, e.g., stunting and a related likelihood of being overweight.

Indonesia, a developing country with a total population of approximately 200 million, underwent a significant improvement in standard of living (defined by higher income and improved nutrition and health care) from 1960 to 1998. The infant mortality rate decreased from 128 to 40 per 1,000 live births, while the mortality rate among children under five years of age decreased from 216 to 58 per 1,000 live births [6]. However, this new prosperity was not evenly distributed. In 1999, 27% of the population was still living below the national poverty line [7]. With a documented increase in the prevalence of obesity among urban adults in Indonesia from 4.9% in 1988 to 7.6% in 1993 [8], it is important to know the prevalence of under- and overnutrition among children from different socioeconomic levels in Indonesia.

The aim of this study was to assess the prevalence of stunting, overweight, and obesity in school-aged prepubertal children from different socioeconomic levels (rural, poor urban, and nonpoor urban) in Indonesia. The study was also intended to investigate the association between stunting and overweight or obesity in relation to socioeconomic status.

Subjects and methods

Study population and design

The study was performed in two adjacent areas in Central Java. Yogyakarta, an urban area, was a city with approximately 487,115 inhabitants at the time of the study. Gunung Kidul, a rural area located about 20 to 40 km from Yogyakarta, had approximately 710,691 inhabitants [9]. We chose these two study areas because of the relatively homogeneous ethnicity of their populations. Most of the people in both areas are of Javanese descent. The altitude of both study areas is less than 500 m above sea level [9].

A cross-sectional study was conducted in school-aged prepubertal children in both areas. We randomly selected 33 of 509 public primary schools in the rural area and 37 of 172 public primary schools in the urban area. In Indonesia, it is obligatory for children to enter primary school at the age of six or seven years. Prepubertal children (under eight years old for girls and under nine years old for boys) from the first- and second-year class of every school were included. The ages of the children finally studied ranged from 6 to 7.9 years for girls and from 6 to 8.9 years for boys. This study selected prepubertal children because puberty, which normally occurs after the age of eight in girls and nine in boys, may interfere with the interpretation of measurements due to changes in body composition and differences between children in the timing of the adolescent growth spurt.

We excluded children with prominent chronic diseases, such as congenital heart disease or major thalassemia. Also excluded were children who had physical handicaps that might interfere with the measurements.

The study was performed from February to May 1999 and was approved by the ethical committee of Gadjah Mada University, Yogyakarta, Indonesia.

Data collection

Anthropometric data were collected by health professionals. Heights and weights were measured using the standard techniques described by the World Health Organization (WHO) [10]. Training for standardization of the measurements, followed by field practice and testing, was performed prior to data collection. All measurements were performed between 8 and 10 a.m. The children, wearing light clothing, were weighed to the nearest 0.1 kg with a Seca digital scale (Germany). Height was measured to the nearest 0.1 cm with a portable stadiometer. Height was measured with the child standing facing the fieldworker, without shoes.

Birth dates were verified by a copy of the child's birth certificate filed at the school. Definitions of rural and urban populations were based on agricultural activities and population densities. Yogyakarta had a population density of 14,988/km^2, while Gunung Kidul had a population density of 498/km^2 [9]. In the urban area, the socioeconomic status of each child was individually deduced from his or her living environment. Children living in the urban slum area were considered poor, and those not living in this area were considered to be not poor.

Data on height-for-age and weight-for-height were converted to z-scores of the WHO/National Center for Health Statistics (NCHS) reference population using the EPINUT component of the Epi Info 6.04 package (Centers for Disease Control and Prevention, Atlanta, Ga., USA). Biologically implausible values, such as z-scores below –6.00 or above +6.00, were excluded from the analysis. Values that were most likely to represent errors, i.e., those that were 4 z-score units (standard deviations) outside the observed mean for every age in one full year, were also excluded (flexible exclusion range) [11].

Children were classified as stunted if they had height-for-age z-scores (HAZ) below -2.00, and as not stunted if they had HAZ of –2.00 or more. Children were classified as overweight if they had weight-for-height z-scores (WHZ) based on WHO-NCHS references above +2.00. Wasting or thinness was defined by weight-for-height z-scores (WHZ) below –2.00 [11].

The body-mass index (BMI) was calculated by dividing the weight in kilograms by the square of the height in meters (kg/m^2). The BMI reference proposed in 2000 by the International Obesity Task Force (IOTF) was used to classify children as overweight or not overweight and as obese or not obese. According to the IOTF cutoffs for persons 18 years of age, overweight is defined by a BMI above 25 kg/m^2 and obesity by a BMI above 30 kg/m.^{2} The cutoff points were tabulated at the exact half-year of ages. The cutoff points for overweight ranged from BMIs of 17.34 to 18.35 in 6- to 8-year-old girls and from 17.55 to 19.10 in 6- to 9-year-old boys. For obesity, the cutoff points ranged from 19.65 to 21.57 in 6- to 8-year-old girls and from 19.78 to 22.77 in 6- to 9-year-old boys [12]. Seven classes of age at midyear in our study population were defined as follows: 6 years old (6 to < 6.25 years), 6.5 years old (6.25 to < 6.75 years), 7 years old (6.75 to < 7.25 years), 7.5 years old (7.25 to < 7.75 years), 8 years old (7.75 to < 8.25 years), 8.5 years old (8.25 to < 8.75 years), and 9 years old (8.75 years or older). The maximum ages were 8 years for girls and 9 years for boys.

Data entry and analysis

Data were entered and analyzed using SPSS for

Windows (Version 9, SPSS, Chicago, Illinois, USA). The odds ratios for stunting, wasting, overweight, and obesity within socioeconomic and sex groupings were compared by χ^2 tests. Odds ratios are presented with 95% confidence intervals (95% CI). Quantitative data, i.e., data on height-for-age z-scores (HAZ) and weight-for-height z-scores (WHZ) and BMI, were analyzed by *t*-tests and Pearson's correlation.

Results

We visited 70 schools to examine a total of 3,689 prepubertal children who were listed as first- and second-year students. We excluded 674 children because they were not in the required age range. Of the remaining 3015 children, four missed the measurement session and one had a HAZ and a WHZ in the flexible exclusion range.

Of the 3,010 children for whom complete data were available, 1,218 were from the rural area and 1,792 were from the urban area. The children from the urban area were then subdivided into 440 poor (from the urban slum area) and 1,352 nonpoor children. The total population studied consisted of 1,738 boys (57.7%) and 1,272 girls (42.3%).

In our sample, the prevalence of stunting was 19.3% (HAZ < –2.00, 580 children). The prevalence of wasting was 5.0% (WHZ < –2.00,152 children), while the prevalence of overweight was 2.3% (WHZ > +2.00, 70 children). However, when the BMI reference was taken, the prevalence of overweight was 2.7% (80 children). The level of agreement between these two cutoffs for overweight was good ($\kappa = 0.89$, $p < .001$, Fisher's exact test). The prevalence of obesity based on the BMI reference proposed by IOTF was 0.8% (25 children). Details on the odds ratios for stunting, wasting, overweight, and obesity based on socioeconomic status are given in table 1.

Urban children, whether they were poor or nonpoor, were on average taller than rural children ($p < .001$), with mean (95% CI) differences in HAZ of 0.61 (0.54–0.68) and 0.20 (0.11–0.30), respectively. Nonpoor urban children were heavier than rural children ($p < .001$), with mean (95% CI) differences in weight-for-height z-scores (WHZ) and BMI of 0.24 (0.16–0.32) and 0.46 (0.32–0.59), respectively. There were no significant differences in WHZ and BMI between poor urban and rural children ($p > .05$).

The odds ratios for stunting (OR, 1.75; 95% CI, 1.44–2.12; $p < .001$) and obesity (OR, 4.07; 95% CI, 1.40–11.8; $p = .005$) were higher in boys than in girls. Details on the odds ratios and prevalences of stunting, wasting, overweight, and obesity in boys and girls are presented in table 2. The differences between boys and girls in the odds ratios for stunting were observed in both the rural and the urban areas (table 3).

Stunted children had lower odds ratios for over-

TABLE 1. Socioeconomic differences in the prevalence and odds ratio of stunting, wasting, overweight, and obesity

Characteristic	Socioeconomic status	*n*	Prevalence (%)	Odds ratio (95% CI)	*p*[a]
Stunted[b]	Rural	1,218	28.2	2.92 (2.37–3.59)	< .001
	Poor urban	440	17.5	1.58 (1.18–2.13)	.002
	Nonpoor urban	1,352	11.8	1.00 (reference)	—
Wasted[c]	Rural	1,218	4.8	0.97 (0.68–1.40)	0.89
	Poor urban	440	6.4	1.32 (0.84–2.09)	0.23
	Nonpoor urban	1,352	4.9	1.00 (reference)	—
Overweight based on IOTF[d]	Rural	1,218	1.0	0.19 (0.10–0.36)	< .001
	Poor urban	440	0.7	0.13 (0.04–0.43)	< .001
	Nonpoor urban	1,352	4.9	1.00 (reference)	—
Overweight based on NCHS/WHO[e]	Rural	1,218	1.0	0.23 (0.12–0.43)	< .001
	Poor urban	440	0.5	0.11 (0.03–0.44)	< .001
	Nonpoor urban	1,352	4.1	1.00 (reference)	—
Obese based on IOTF[f]	Rural	1,218	0.2	0.09 (0.02–0.39)	< .001[g]
	Poor urban	440	0.0	Not calculated	.005[g]
	Nonpoor urban	1,352	1.8	1.00 (reference)	—

CI, Confidence interval; IOTF, International Obesity Task Force; NCHS, National Center for Health Statistics; WHO, World Health Organization; BMI, body-mass index.

a. χ^2.
b. Height-for-age z-score (HAZ) < –2.00.
c. Weight-for-height z-score (WHZ) < –2.00.
d. Percentiles passing BMI of 25 kg/m^2 (IOTF); see Subjects and Methods section for detailed information.
e. Weight-for-height z-score (WHZ) > +2.00.
f. Percentiles passing BMI of 30 kg/m^2 (IOTF); see Subjects and Methods section for detailed information.
g. Fisher exact test.

weight (OR, 0.10; 95% CI, 0.03–0.43; $p < .001$). Overall, the mean WHZ and BMI of stunted children were lower than those of nonstunted children. The differences were statistically significant for the rural, poor urban, and nonpoor urban children (table 4). There were significant positive correlations between HAZ and WHZ ($\rho = 0.24$, $p < .001$) and between HAZ and BMI ($\rho = 0.30$, $p < .001$).

Discussion

The overall prevalence of stunting in rural children was almost three times higher than in nonpoor urban children. To a lesser degree, poor urban children also had significantly higher ($p = 0.002$, table 1) odds ratios for stunting than the nonpoor urban children. A similar study comparing the prevalence of stunting in slightly older (seven to nine years) urban and rural children in Malaysia found comparable results [13]. Two studies on urban schoolchildren in Jakarta and Manila also found higher prevalences of stunting in children of lower socioeconomic status. These two studies used attendance at public or private schools as a proxy for socioeconomic status, whereas in our study we used the child's area of residence as a proxy for socioeconomic status [14, 15]. Characteristics such as family income or parental education would be better indicators of socioeconomic status, but in these populations these were not always easy to assess. Many families had multiple irregular incomes, and extended families with multiple breadwinners and child caregivers were common. Our study and the other three studies mentioned above seem to suggest that, at least in these three Asian

TABLE 2. Sex differences in the prevalence and odds ratio of stunting, wasting, overweight, and obesity

Characteristic	Sex	*n*	Prevalence (%)	Odds ratio (95% CI)	p^a
Stunted[b]	M	1,738	22.8	1.75 (1.44–2.12)	< .001
	F	1,272	14.5	1.00 (reference)	—
Wasted[c]	M	1,738	5.5	1.24 (0.76–2.03)	0.22
	F	1,272	4.5	1.00 (reference)	—
Overweight based on IOTF[d]	M	1,738	3.0	1.40 (0.88–2.24)	0.15
	F	1,272	2.0	1.00 (reference)	—
Overweight based on NCHS/WHO[e]	M	1,738	2.5	1.25 (0.76–2.03)	0.38
	F	1,272	2.0	1.00 (reference)	—
Obese based on IOTF[f]	M	1,738	1.3	4.07 (1.40–11.8)	.005
	F	1,272	0.3	1.00 (reference)	—

CI, Confidence interval; IOTF, International Obesity Task Force; NCHS, National Center for Health Statistics; WHO, World Health Organization; BMI, body mass index.
a. χ^2.
b. Height-for-age z-score (HAZ) < -2.00.
c. Weight-for-height z-score (WHZ) < –2.00.
d. Percentiles passing BMI of 25 kg/m^2 (IOTF); see Subjects and Methods section for detailed information.
e. Weight-for-height z-score (WHZ) > +2.00.
f. Percentiles passing BMI of 30 kg/m^2 (IOTF); see Subjects and Methods section for detailed information.

TABLE 3. Odds ratios for stunting and obesity among boys relative to girls in rural and urban areas

Characteristic	Socioeconomic status	Prevalence (%)		Odds ratio (95% CI)	p^a
		Boys	Girls		
Stunted[b]	Rural	31.8	22.9	1.57 (1.21–2.04)	.001
	Poor urban	22.3	10.9	2.35 (1.36–4.07)	.002
	Nonpoor urban	14.4	8.6	1.79 (1.26–2.54)	.001
Obese based on IOTF[c]	Rural	0.3	0.0	Not calculated	0.24
	Poor urban	0.0	0.0	Not calculated	—
	Nonpoor urban	2.6	0.7	4.00 (1.36–11.8)	.007

CI, Confidence interval; IOTF, International Obesity Task Force; BMI, body mass index.
a. χ^2.
b. Height-for-age z-score (HAZ) < -2.00.
c. Percentiles passing BMI of 30 kg/m^2 (IOTF); see Subjects and Methods section for detailed information.

TABLE 4. Mean weight-for-height z-score (WHZ) and body mass index (BMI) of stunted compared with nonstunted children

Characteristic	Socioeconomic status	Stunted[a]	Nonstunted[b]	p[c]
Mean weight for height z-score (WHZ)	Overall	–0.85 (0.77)	–0.56 (1.07)	< .001
	Rural	–0.86 (0.66)	–0.66 (0.91)	< .001
	Poor urban	–0.97 (0.77)	–0.72 (0.86)	.02
	Nonpoor urban	–0.78 (0.96)	–0.44 (1.22)	< .001
Mean BMI (SD)	Overall	14.20 (1.06)	14.70 (1.73)	< .001
	Rural	14.18 (0.90)	14.49 (1.37)	< .001
	Poor urban	14.06 (1.03)	14.41 (1.25)	.02
	Nonpoor urban	14.31 (1.35)	14.93 (2.03)	< .001

a. Height-for-age z-score (HAZ) < –2.00.
b. Height-for-age z-score (HAZ) ≥ –2.00.
c. *t*-test.

countries, stunted growth is still strongly associated with poverty.

Boys in our study had a higher odds ratio for stunting than girls. For reasons that are unclear, similar findings have been reported from Kuala Lumpur, Jakarta, Manila, and South Africa [13–16]. This difference in prevalence persisted after the data had been stratified into the three socioeconomic levels, suggesting the relative independence of the difference from socioeconomic status. Our previous study in children under two years of age in another area of Indonesia showed that beginning at the age of seven months, the difference in mean length-for-age between the Indonesian children and the NCHS/WHO reference population was larger in boys than in girls [17]. Another study from Indonesia showed that the size of this difference between boys and girls increased up to the age of 35 months [18]. It is still not known whether this greater difference persists until the final height has been attained, or whether there will still be a catch-up growth in adolescence.

The overall prevalence of wasting was almost one-quarter that of stunting. Unlike stunting, there was no significant difference in the prevalence of wasting between children of different socioeconomic status. Studies from other areas yielded variable findings [13–15]. Stunting, which occurs mostly in the first three years of life, reflects long-term undernutrition and poor health, whereas wasting is more a reflection of recent energy imbalance. Our study seems to suggest that the problems of undernutrition are important in the poorer segment of the population, especially in the early years of life [2, 3, 11].

The prevalence of overweight, based on either the IOTF or the WHO-NCHS references, was, on average, four to five times higher in nonpoor urban children than in rural children or poor urban children, as was the prevalence of obesity. A higher prevalence of obesity in the higher socioeconomic portion of the population has been found in other studies in developing countries [13–15]. A study of schoolchildren in Manila found that children from higher socioeconomic groups tended to consume more food, including animal food, fats and oils, and beverages, resulting in higher intake of calories. Moreover, children from high socioeconomic groups were apparently less physically active, were more likely to be driven to school instead of walking, and were more likely to prefer television and computer games over outdoor games [19].

In industrialized countries, and increasingly in developing countries, wealth has been associated with diets high in fat in combination with a sedentary lifestyle. But as global income rises and luxuries become affordable to most people in developed and middle-income countries, the pattern is changing [20]. In most developed countries, obesity is now associated with low income and social class [21–24]. Studies in developed countries have shown that children from lower-income families consume more energy-dense but inexpensive foods than those from higher-income families. These children also engage in less physical activity either because there is no safe place to play outdoors or because there is no money to pay for safe indoor facilities [25–27].

Nonpoor urban boys had significantly higher odds ratios for obesity than nonpoor urban girls. Similar findings were reported from the cities of Jakarta, Manila, and Kuala Lumpur [13–15]. Two studies in the United States found a higher prevalence of obesity in younger school-aged boys compared with girls, followed by an increasingly higher prevalence in girls compared with boys, as they approached adolescence [25, 28]. Other studies in similar age groups in South Africa, France, Russia, and China produced variable results in the prevalence of obesity between boys and girls in different age groups. [3, 16, 29, 30].

There is no clear explanation for this gender difference in susceptibility to obesity across race and age groups. The difference may be due to the variability of age range between studies, which, combined with the variability of the timing of maturation and body composition across race and gender, may lead to apparent differences in the prevalence of obesity. This assumption needs further study to be verified.

Unlike the study by Popkin et al. [3], our study did not indicate any association between stunting and overweight or obesity. Stunted children had a significantly lower mean BMI and WHZ, irrespective of socioeconomic status. It is possible that short children were at higher risk for later obesity during adolescence or adulthood, but further investigation is needed to determine whether this is the case.

In summary, our study indicates that poorer segments of the population in Indonesia still face the problem of undernutrition and will benefit from intervention to improve the quantity and quality of their food intake, especially in the early years of life. This study also shows that children from higher socioeconomic groups will benefit from programs to reduce the risk of obesity, such as public health campaigns on healthful food and encouragement to increase physical activity. However, one of the limitations of our study is that it did not assess some important predictors of height and obesity, such as parental height and obesity status, as well as lifestyle factors, such as diet and physical activity [22, 24, 31, 32].

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