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Special Article

Nuclear and isotopic techniques for addressing nutritional problems, with special reference to current applications in developing countries

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Abstract

Nuclear and isotopic techniques are valuable tools in human nutritional research studies. Isotopes, both radioactive and nonradioactive, enable detailed evaluations of nutrient intake, body composition, energy expenditure, status of micronutrients, and nutrient bioavailability. In recent times, isotopic methods have been widely used in a number of coordinated research projects and technical cooperation projects of the International Atomic Energy Agency's Nutrition Programme. The doubly labeled water technique combines the use of the stable isotopes oxygen-18 and hydrogen-2 (deuterium) to measure total energy expenditure in free-living human subjects, and to investigate the magnitude and causes of both undernutrition and the emergence of obesity in developing countries. The deuterium dilution technique is a reliable tool to measure breastmilk intake and thereby infant growth and development. In collaboration with the World Health Organization's Growth Monitoring Program, this technique is being used to generate new data on growth standards for children in developing countries. This technique is also used in the measurement of body composition by the estimation of lean body mass and fat mass in individuals. Stable isotopes of iron and zinc have been successfully used to assess the nutritional impact of several nationwide food supplementation-programs conducted on pregnant and lactating women and children in both industrialized and developing countries. Isotopic techniques are especially suitable for monitoring changes in body composition, energy metabolism, and mineral status (with particular reference to osteoporosis) in the elderly. Nuclear methods have also served to develop models for a physiological reference man in Asia in support of radiological health and safety issues, for establishing elemental composition of foods, and for measurement of pollutants in the environment.

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Global nutritional challenges

Hunger and undernutrition are among the most devastating problems facing the majority of the world's poor and needy. Several United Nations conferences on food and nutrition have highlighted this situation and the need to eliminate poverty and undernutrition, especially among women and children [1–3]. Each year 30 million infants in the developing world are born with intrauterine growth retardation, leading to low weight at birth. This represents about 24% of the births in these countries. Nearly 200 million children (more than 150 million in Asia and about 27 million in Africa) under five years of age are moderately to severely undernourished, while 70 million are severely undernourished. There are projections that about one billion children will be growing up by 2020 with impaired mental development [4, 5].

Around 243 million adults in developing countries are reportedly undernourished (body mass index of less than 18.5 kg/m^2), resulting in lowering of their work capacity and resistance to infection. Maternal anemia is pandemic, with a prevalence over 80% in some countries, and is associated with very high rates of maternal mortality. Evidence from both developing and industrialized countries links maternal and early childhood undernutrition to increased susceptibility to diabetes, heart disease, and hypertension in adult life. A fundamental link is emerging between maternal and childhood malnutrition and the child's subsequent marked sensitivity to abdominal obesity, diabetes, high blood pressure, and coronary heart disease [6]. Added to this is the burden of overnutrition and obesity that is rapidly emerging in the same developing countries, affecting both children and adults.

Since the early 1990s, there has been a shift in concern from overt clinical nutritional deficiencies (e.g., protein and energy malnutrition or extremely severe vitamin deficiencies) to so-called hidden or silent hunger or micronutrient malnutrition, a symbol of persistent undernutrition [7]). According to global estimates, some two billion people in more than 100 developing countries suffer from multiple micronutrient deficiencies, and more than 90% of pregnant women and preschool children in developing countries show signs of iron-deficiency anemia and other related disorders [8].

Nutritional disorders spanning the entire human life span

Malnutrition seriously affects individuals in all stages of human life. Combating nutrition-related disorders that span the entire life cycle will be the biggest task for scientists in the decades ahead (table 1). Malnutrition during pregnancy often results in intrauterine growth retardation of the fetus, resulting in low birthweight of the infant. This directly influences the survival and growth of young children. Poor nutritional status of the mother during lactation further compounds the already existing negative effects on the growing infant. These undernourished children in later years show poor performance at school.

Adolescent nutrition is an area that is just being recognized as one that requires nutritional monitoring. Children gain up to 50% of their adult weight, 20% of their adult height, and 50% of their adult skeletal mass during this crucial stage of adolescent life [6]. Energy, protein, calcium, and micronutrients, including iron, zinc, and folate, are required at maximum levels, and deficits in intake of nutrients could signal the start of nutrition-related disorders in adulthood. Malnourished adults have decreased overall resistance to disease and increased disability at work, eventually affecting the overall quality of life, especially as they join the ranks of the elderly.

Nutrition of the elderly is of special concern because of the high prevalence of osteoporosis in this age group. This serious bone disease of the elderly, characterized by low bone density leading to fractures (particularly in postmenopausal women), severely limits their quality of life. Aging is also associated with changes in body composition, such as a decline in lean body mass, and with an increase in the risks of disease and accidents. Thus, increasing attention to nutritional needs and care of the aged is key to reducing the risk of onset of osteoporosis and other degenerative diseases.

Nutrition–pollution interactions and related diseases

The severity of malnutrition in human subjects is further exacerbated by environmental pollution. Parasitic infestations and the spread of infections through communicable diseases form a major segment of the environmental component of nutritional disease. In Asia, Africa, and Latin America, the malnourished populations suffer from a host of other nutrient deficiencies and are more prone to parasitic infestations (hookworm and amebiasis) and malaria. The contrast in mortality between industrialized and developing countries, arising out of the differential load of infections, has been described in detail in a recent review [9]. Operating in synergism with diarrheal, respiratory, and other infections, poor diets in early childhood lead to growth failure, delayed motor and mental development, impaired immunocompetence, and higher risks of complications and deaths from infectious disease.

Environmental pollutants, such as lead and oxides of nitrogen, also have debilitating effects on already nutritionally compromised individuals. Pollution, in the larger context, encompasses both anthropogenic and nonanthropogenic factors, as shown in table 2.

In tandem with pressing environmental pollution issues, food safety issues are becoming critical to several aspects surrounding the nutrition-health-disease domain, with the study of nutritional toxicology becoming a global challenge. Interelement interactions between lead and iron (anemia), mercury and iron, arsenic and selenium, selenium and iodine, and cadmium and zinc are becoming an area of concern [10], as is placental transfer of nutrients and toxicants from the mother to the fetus. Children are more susceptible to the effects of lead, and a combination of iron deficiency and lead toxicity can have devastating effects for them [11, 12]. Children with iron-deficiency anemia may absorb more lead than those who are iron sufficient [13]. Besides heavy metals, nutrient interactions with pesticides, oxides of nitrogen, tobacco, and alcohol should be considered.

Nuclear and isotopic techniques for health-related investigations

Nuclear and isotopic techniques have an important role to play in the identification and monitoring of the nutrition and health issues described above. The International Atomic Energy Agency program in human nutrition is designed to assist developing countries in the application of isotopic techniques for assessment of nutrient intake, body composition, energy expenditure, status of micronutrients, and nutrient bioavailability in developing countries. The majority of the work was done through coordinated research projects of the Department of Nuclear Sciences and Applications. Among the numerous applications available, isotopic techniques are uniquely well suited to targeting and tracking progress in food and nutrition development programs. Nuclear and isotopic techniques commonly used in nutritional research are shown in figure 1. These are tools that help to evaluate the nutritional status of individuals and populations

TABLE 1. Malnutrition across the human life span

Life stage	Nutritional disorders	Main consequences	Applicable nuclear techniques
Embryo and fetus	IUGR, IDD, folate deficiency	Low birthweight Brain damage Neural tube defect Stillbirth	RIA (T_3, T_4, TSH, folate)
Neonate	Low birthweight, IDD	Growth retardation Developmental retardation Brain damage Continuing malnutrition	RIA (T_3, T_4, TSH, folate) Deuterium-labeled water (breastmilk intake) Stable isotopes (micronutrients) ^{13}C- and ^{15}N-labeled substrates (macronutrients)
Infant and young child	PEM, IDD, VAD, IDA	Developmental retardation Increased risk of infection High risk of death Blindness Anemia Growth retardation	RIA (ferritin, folate, T_3, T_4, TSH and other hormones) Deuterium-labeled water (breastmilk intake) Stable isotopes (micronutrients, e.g., ^{57}Fe, ^{67}Zn) ^{13}C-labeled substrates (macronutrients, *Helicobacter pylori*)
Adolescent	PEM, IDD, IDA, folate deficiency, calcium deficiency	Delayed growth spurt Stunted height Delayed or retarded intellectual development Goiter Increased risk of infection Blindness Anemia Inadequate bone mineralization	RIA (ferritin, folate, T_3, T_4, TSH and other hormones) Doubly labeled water (energy expenditure) Stable isotopes (micronutrients) ^{13}C-labeled substrates (macronutrients, *H. pylori*) DEXA (bone density, body composition)
Pregnant and lactating women	PEM, IDD, VAD, IDA, folate deficiency, calcium deficiency	Maternal anemia Maternal mortality Increased risk of infection Night-blindness Blindness Low birthweight or high risk of death for fetus	RIA (ferritin, folate, T_3, T_4, TSH and other hormones) Deuterium-labeled water (breastmilk intake) Stable isotopes (micronutrients) ^{13}C-labeled substrates (macronutrients, *H. pylori*) DEXA (bone density, body composition)
Adults	PEM, IDA, obesity, cancer	Thinness Lethargy Obesity Heart disease Diabetes Hypertension and stroke Anemia	RIA (ferritin, hormones, e.g., insulin) Doubly labeled water (energy expenditure) Stable isotopes (micronutrients) ^{13}C-labeled substrates (macronutrients, *H. pylori*) DEXA (body composition)
Elderly	PEM, IDA, obesity, cancer, osteoporosis	Thinness Obesity Spine and hip fractures and accidents Heart disease Diabetes	RIA (ferritin, hormones) Doubly labeled water (energy expenditure) Stable isotopes (micronutrients) ^{13}C-labeled substrates (macronutrients, *H. pylori*) DEXA (bone density, body composition) Deuterium-labeled water (body composition)

Source: modified from ref. 1.

IUGR, Intrauterine growth retardation; IDD, iodine-deficiency disorders; PEM, protein-energy malnutrition; VAD, vitamin A deficiency; IDA, iron-deficiency anemia; RIA, radioimmunoassay; T_3, triiodothyronine; T_4, thyroxine; TSH, thyroid-stimulating hormone; DEXA, dual-energy x-ray absorptiometry.

TABLE 2. Environmental determinants of pollution in broader context

Anthropogenic (industrial, cultural)	Nonanthropogenic (biological agents)
Lead Other heavy metals Arsenic Antimony Pesticides Oxides of nitrogen Tobacco Alcohol	Parasitic (industrial and hematological) Bacterial and viral (water- and vector-borne) Communicable (tuberculosis): overcrowding, poor sanitation Human immunodeficiency virus (HIV)

Source: ref. 9.

and to measure nutrient requirements and the uptake and bioavailability of vitamins and minerals. These efforts put forth by the International Atomic Energy Agency help to verify the nature of the nutrition problem and the efficacy of specific interventions; help implement nutrition intervention programs by monitoring effectiveness and reducing program costs; guide in the processing of local foods for optimal nutritional value; serve as early indicators of important long-term health improvements; and strengthen capacity building in developing countries.

Nuclear and stable isotopic techniques have several applications in the field of nutrition (table 3) and are very useful in carrying out health-related investigations. These include the following.

Assessment of nutritional status and nutrient requirements by measurement of body composition, breastmilk intake, total energy expenditure, and protein and other nutrient metabolism. These methods are particularly useful in assessing the nutritional status of infants, children, pregnant women, and nursing mothers.

Assessment of micronutrient malnutrition. Stable isotopes provide the only direct way to measure iron uptake and bioavailability and are regarded as the "gold standard" for iron studies in humans and other studies of nutrient bioavailability (e.g., iron, zinc, and vitamin A).

Analysis of foods by neutron activation analysis (radiochemical and instrumental) is very effective because of the exceptional sensitivity of the technique and the possibility of simultaneous determination of several trace elements. Inductively coupled plasma mass spectrometry (ICP-MS) also offers multielement determinations [14]. Application of neutron activation analysis–related methods is particularly attractive for developing countries, since many research reactors are

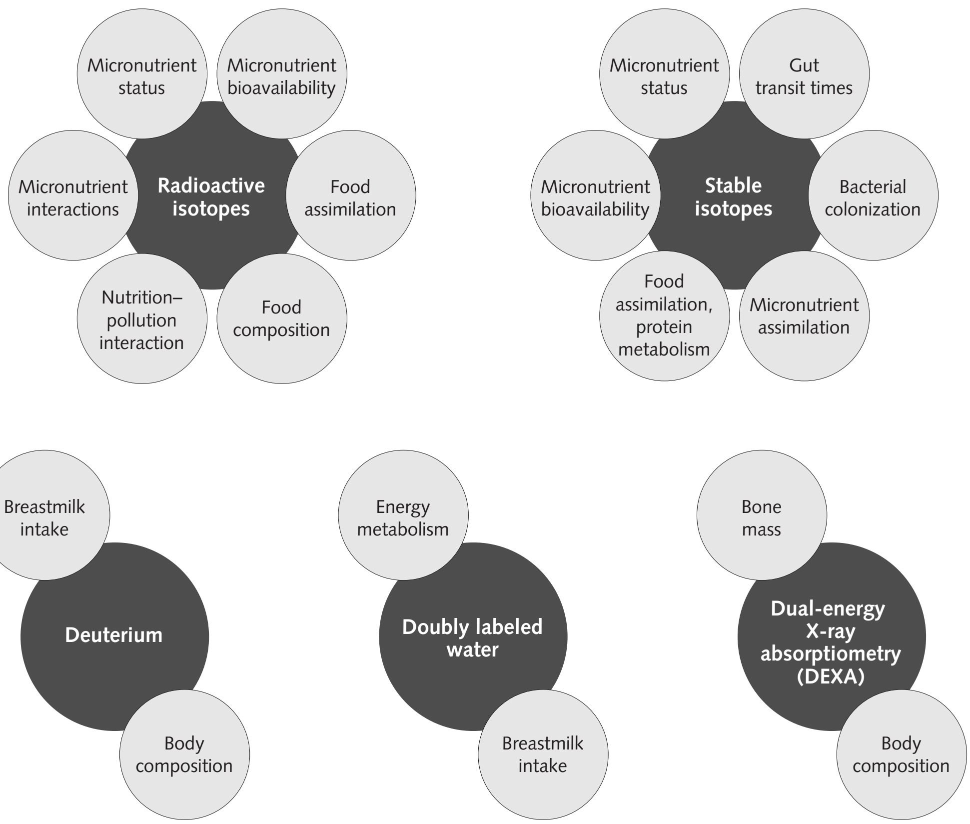

FIG. 1. Nuclear methods in nutrition

TABLE 3. Overview of selected isotopic techniques in human nutrition studies

Technique	Applications
Radioisotopic tracer study	Body composition (tritium-labeled water) *In vivo* study of iron uptake and bioavailability ($^{59}Fe/^{55}Fe$) *In vitro* study of iron dialyzability (^{59}Fe)
Radioimmunoassay	Iron status (serum ferritin), iodine status (T_3, T_4, TSH)
Nuclear analytical techniques	Trace element content of foods, diets, and human tissues Body composition (DEXA)
Whole-body counting	Body composition (lean body mass)(^{40}K) Uptake and bioavailability of essential micronutrients (^{59}Fe and ^{65}Zn)
In vivo neutron activation analysis	Body composition (total body nitrogen, calcium, etc.)
Stable isotopic tracer study	Body composition and breastmilk intake (deuterium-labeled water) Substrate metabolism (^{13}C- and ^{15}N-labeled amino acids, fat) Energy expenditure (deuterium- and ^{18}O-labeled water) Uptake and bioavailability of essential micronutrients (Fe, Zn, and vitamin A using appropriate stable isotopes) Bacterial colonization (^{13}C-urea breath test)

available to provide the needed neutron source.

Clinical applications. Isotopes are used in the detection of *Helicobacter pylori* infection, measurement of gastric emptying, and measurement of macronutrient assimilation in many laboratories around the world.

Measuring pollutants in air has become a matter of global concern, particularly in some of the world's largest cities. Nuclear and related analytical techniques are uniquely suited for conducting nondestructive multielement analyses of air particulate matter collected on filters. Commonly used techniques include neutron activation analysis, particle-induced x-ray emission (PIXE), particle-induced gamma-ray emission (PIGME), energy dispersive x-ray fluorescence analysis (EDXRF), total reflection x-ray fluorescence (TXRF), and ICP-MS [15].

Stable isotopes in nutritional studies supported by the International Atomic Energy Agency

Measurements of breastmilk intake, energy expenditure, micronutrient status, macronutrient utilization, body composition, and many more indicators are important in assessing the nutritional status of infants, children, pregnant women, and nursing mothers, as well as that of individuals who subsist on marginal food supplies. Stable isotopic tracers are completely safe and noninvasive and can be used in free-living humans. They emit no externally measurable radiation, and their presence in excess of natural levels is detectable only by changes in the ratio of minor isotope to major isotope. The ratio is measured by an isotope ratio mass spectrometer in which heavy and light forms of the same molecule undergo separation and quantification. The required technique can be obtained from the resources available [16].

Cost of analysis is indeed a cause for concern, since the instrumentation and expertise required are not available in many countries. However, stable isotopes for the studies supported by the International Atomic Energy Agency are made available under the project, and in some cases assistance is provided for analysis in an International Atomic Energy Agency–recognized laboratory. The underlying idea is that these studies would encourage strengthening of the infrastructure of national facilities for subsequent investigations. The cost of the equipment for carbon-13 breath tests used for infection studies is not very high and can be within the reach of many developing countries.

The major isotopes (hydrogen-1, carbon-12, nitrogen-14, and oxygen-18) are always accompanied by a constant proportion of minor heavier isotopes whose individual abundances range from 0.02% to 1.11%. An inventory of the human body shows that a 50-kg person has a total of 225 g of hydrogen-2, carbon-13, nitrogen-15, oxygen-17, and oxygen-18 [17]. Although there are variations in the proportions of ^{1}H to ^{2}H, ^{13}C to ^{12}C, ^{14}N to ^{15}N, and ^{16}O to ^{18}O, each has a characteristic baseline abundance to which tracer measurements are referred. The enriched form (e.g., $^{2}H_2O$ or $H_2{}^{18}O$) may be used directly, $^{13}CO_2$ may be incorporated into plants by biosynthetic procedures, or the isotope may be transformed through organic syntheses into labeled fats, carbohydrates, or amino acids. These stable isotopes can be administered orally, and the metabolic products into which they enter (e.g., body water, respiratory carbon dioxide, and urea) can be sampled in breath, saliva, milk, urine, and stool.

^{13}C-urea breath tests are used to examine bacterial colonization in the stomach by *Helicobacter pylori.*

The test measures the production rate of $^{13}CO_2$ in expired air, followed by oral ingestion of ^{13}C-labeled urea. Breath tests for *H. pylori* using stable isotopes are reliable and noninvasive tools that can be safely applied in children from developing areas, where high rates of infection and malnutrition are observed.

Isotope dilution methods are used in the assessment of vitamin A status. The principle relies on labeled carotenoid conversions to vitamin A, which can be traced with ^{13}C carotenoids. Vitamin A pool sizes are measured by the dilution of an oral ingested tracer into the different body pools. This technique has potential applications in measuring the effectiveness of vitamin A and carotenoid supplementation and fortification regimes in nutrition studies.

Another powerful use for stable isotopes is in the assessment of bioavailability and pool sizes of trace elements such as iron (^{57}Fe and ^{58}Fe) and zinc (^{67}Zn and ^{70}Zn). The uptake of these labeled micronutrients can be traced *in vivo* and which has been used widely as a valuable tool for measuring the effectiveness of supplementation or fortification trials in several developing countries.

Estimation of total energy expenditure

The doubly labeled water ($^2H_2{}^{18}O$) method is the only technique that can accurately determine the energy needs of people in their own environments and is one of the most reliable methods for determining food energy intake. This method is gaining wider acceptance because it is inexpensive and accurate, and can be applied under field conditions. When doubly labeled water is administered to a subject, both isotopes mix with the body water and are eliminated in the body fluids over a period of days. The turnover of body water can be estimated from the daily measurements of ^{2}H concentration in urine or saliva samples. When the samples are analyzed for ^{18}O, the values will reflect a more rapid excretion rate than that for ^{2}H (deuterium), because the ^{18}O is also incorporated into exhaled carbon dioxide. The difference in excretion rates between ^{18}O and ^{2}H tracers thus reflects the volume of carbon dioxide produced over the period of observation. This value can be used to calculate the total energy expenditure of a subject.

Determination of lean body mass

A tracer dose of water labeled with ^{2}H or ^{18}O is administered and allowed to equilibrate for 4 to 6 hours. The isotope concentration in saliva or urine will reflect the dilution undergone by the isotope. When the lean body mass is calculated, the difference in body weight is the amount of adipose (fatty) tissue.

Measurement of overall nitrogen flux

The nitrogen flux balance stumbles in periods of stress, and then the catabolic processes predominate over synthetic processes and a negative balance is the result. Whole-body protein turnover is measured by administration of a single oral dose of an amino acid, or preferably a protein, labeled with ^{15}N [e.g., yeast grown in medium containing ($^{15}NH_4$)SO_4]. Urine is collected for 9 to 12 hours and the amounts of tracer nitrogen in urinary NH_3 and in the urea are determined. These two values provide a reliable estimation of whole-body protein turnover that is insensitive to changes in nonprotein-nitrogen metabolism.

Nutrient absorption and utilization after diarrhea

Weaning infants often have periods of infection leading to diarrhea. During these periods, nutrient intake is insufficient to maintain infant growth, and regeneration of small-intestinal capacity is essential. When rice labeled with ^{13}C (by exposure to $^{13}CO_2$ during periods of photosynthesis) is cooked (rice water for rehydration) and consumed, digestion and absorption of the starch can be detected from the appearance of labeled $^{13}CO_2$ in breath samples. The degree of malabsorption can be estimated from the recovery of tracer carbon in total stool carbon [17].

Isotopic techniques in support of preventive measures

Preventive measures are based on the knowledge that a clean environment and a healthy lifestyle are essential for a productive existence. From the public health perspective, preventive health care begins with the newborn and extends across the entire life span. Isotopic tools for strengthening health and nutrition monitoring are being used extensively in industrialized countries to analyze human energy requirements, body composition, and the metabolism of important nutrients such as protein, fat, vitamins, and minerals. The information acquired has led directly to many improvements in nutrition and health. These tools are thus well suited for determining the success of food-supplementation programs and other interventions aimed at combating the many forms of malnutrition. Several strategic applications of isotopic techniques are supported by the International Atomic Energy Agency (table 3).

The International Atomic Energy Agency, through coordinated research projects and technical cooperation projects in the areas of health, nutrition, and environment, is eminently positioned to provide the technical underpinnings to international efforts for improving the quality of life [18]. To date, isotopic strategies evolved through International Atomic Energy Agency efforts to measure energy metabolism, resistance to insulin, rate of synthesis of fat, changes in protein synthesis, lactation performance, bone mineral density, food composition, efficacy of nutrient fortification, nutrient utilization, and prevalence of infection are practiced in more than 50 of its member states. A few examples are cited below.

The Regional Latin America (RLA/7/008) project, with five participating countries (Argentina, Brazil, Chile, Cuba, and Mexico), used isotopes to evaluate nutrition-intervention programs. A technical cooperation project in Chile completed a study on isotope techniques to measure iron bioavailability in fortified milk of the National Complementary Food Program (PNAC), bioavailability of zinc and body composition in children, and body composition and energy expenditure in preschool children using doubly labeled water. Similarly, the first phase of the Regional East Asia and Pacific (RAS/7/010) study measuring the effectiveness of multinutrient supplementation using stable isotopic techniques to assess zinc and iron bioavailability in seven participant countries (People's Republic of China, Indonesia, Malaysia, Pakistan, Philippines, Thailand and Vietnam) has been completed.

A coordinated research project (People's Republic of China) on osteoporosis examined differences in bone mineral density of young adults across a range of races in 3,752 subjects recruited at 11 centers in nine countries. There were highly significant differences in mean weight, height, and bone mineral density between countries ($p < .001$). After adjustment for age, weight, and height, differences between centers in bone mineral density persisted for both men and women. Significant differences existed in young adult bone mass, which, if persisting into old age, may contribute to a two- to threefold difference in fracture risk.

A coordinated research project on the Reference Asian Man with the participation of several Asian countries (RAS project) generated reliable data sets for dietary intake for all participating countries (and in tissues by some) that will enhance their ability to resolve national problems of radiological protection, as well as facilitating the development of the characteristics of a Reference Asian Man, the primary goal of this Regional Project. Improved reference values have been derived for a number of additional elements and reference material matrices that will also strengthen the capability to address issues of nutritional interest.

Refined isotopic techniques resulting from a coordinated research project on the isotopic evaluations of maternal and child nutrition to help prevent stunting have been extensively used in Latin America and Pakistan in field studies and in an ongoing coordinated research project on isotopic evaluations in infant growth monitoring, in collaboration with the World Health Organization (WHO) Growth Monitoring Program.

According to 1993 statistics, persistent diarrhea accounted for over 60% of infant diarrheal deaths in Brazil, 47% in India, 36% in Senegal, and 26% in Bangladesh [19]. Stable isotopic techniques have been recognized as the best and cost-effective modes of diagnosis of *H. pylori* infection through a simple breath test using ^{13}C-enriched substrates and measurement of labeled CO_2. A number of countries in Africa, Asia, and Latin America that joined a coordinated research project on *H. pylori* infection and malnutrition, particularly addressing public health problems in the young population, have made significant progress with fieldwork. Isotopic techniques using ^{13}C-labeled substrate breath tests for bacterial colonization and digestion and absorption of nutrients (lactose, amino acids, and triglycerides), which are sensitive tools to examine the significance of *H. pylori* and its consequences for poor nutrient assimilation in young children, have been successfully used for breath-sample analyses in these countries.

To target malnutrition, the International Atomic Energy Agency has been developing noninvasive isotopic tracer techniques for measuring whole-body vitamin A under conditions of supplementation (Ghana, Peru), food fortification (Peru, Israel), and dietary improvement (China, Thailand, Philippines, India) to address problems of vitamin A nutrition in children and pregnant or lactating women. Similarly, assessment of iron absorption from diets to evaluate its bioavailability is an important nutritional need.

Future prospects

A consultants' meeting called by the International Atomic Energy Agency in December 2000 [20] offered insights into the future applications of stable isotopes in nutrition research. Novel applications were identified by improving existing techniques to extend the usefulness of stable isotopic techniques in mineral and trace element nutrition research and to allow their use more routinely. Several examples are listed below:

- Recent investigations have shown that calcium in the skeleton can be labeled with stable, long-lived radionuclide calcium-41. This offers the unique opportunity to look at calcium losses and balance in bone directly via urinary excretion of the isotopic label.
- Based on the simultaneous excretion of an oral and an intravenously administered label, the urinary monitoring technique has been validated for determination of true calcium absorption; attempts are being made to validate this technique for urinary monitoring of zinc and magnesium.

» Stable isotopic techniques are used routinely to assess the absorption of iron, copper, zinc, selenium, calcium, and magnesium from test meals. It is possible to extend the range of application to other elements, such as molybdenum, nickel, vanadium, tin, and boron, to better understand their biological functions. Semistable, very long-lived radionuclides (aluminum-26, manganese-53, and iodine-129) can be used for monoisotopic elements.
» Use of stable isotopic techniques for absorption studies is not limited to those elements that are essential to the human body. They can also be used for toxicological studies of lead, cadmium, mercury, and chromium. For heavy metals, stable isotopic techniques have been used in humans to study cadmium absorption.
» Impressive progress has been seen in the instrumentation of isotope ratio mass spectrometry (IRMS) incorporating a gas-chromatographic interface. This improvement facilitates the conversion of specific compounds to carbon dioxide, hydrogen, or nitrogen, yielding compounds specific to isotope ratio measurements. This is expected to open new and exciting applications in nutritional sciences.

Conclusions

Isotopic techniques have been used extensively in industrialized countries to analyze human energy requirements, human body composition, and the metabolism of important nutrients, such as protein, fat, vitamins, and minerals. The information acquired has led directly to many improvements in nutrition and health. These techniques have only begun to be applied in developing countries, where they can not only benefit millions through improved nutrition, but also serve as specific indicators of broader social and economic advances. Stable isotopes provide the only direct way to measure iron uptake and bioavailability and are regarded the "gold standard" for iron studies in humans. Isotopic methods are unique for measuring the absorption of zinc from foods and breastmilk intake by infants.

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Palm oil: A healthful and cost-effective dietary component

A. S. H. Ong and S. H. Goh

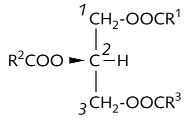
Abstract

Palm oil is an excellent choice for food manufacturers because of its nutritional benefits and versatility. The oil is highly structured to contain predominantly oleic acid at the sn2-position in the major triacylglycerols to account for the beneficial effects described in numerous nutritional studies. Oil quality and nutritional benefits have been assured for the variety of foods that can be manufactured from the oil directly or from blends with other oils while remaining trans-free. The oxidative stability coupled with the cost-effectiveness is unparalleled among cholesterol-free oils, and these values can be extended to blends of polyunsaturated oils to provide long shelf-life. Presently the supply of genetic-modification-free palm oil is assured at economic prices, since the oil palm is a perennial crop with unparalleled productivity. Numerous studies have confirmed the nutritional value of palm oil as a result of the high monounsaturation at the crucial 2-position of the oil's triacylglycerols, making the oil as healthful as olive oil. It is now recognized that the contribution of dietary fats to blood lipids and cholesterol modulation is a consequence of the digestion, absorption, and metabolism of the fats. Lipolytic hydrolysis of palm oil glycerides containing predominantly oleic acid at the 2 position and palmitic and stearic acids at the 1 and 3 positions allows for the ready absorption of the 2-monoacylglycerols while the saturated free fatty acids remain poorly absorbed. Dietary palm oil in balanced diets generally reduce blood cholesterol, low-density lipoprotein (LDL) cholesterol, and triglycerides while raising the high-density lipoprotein (HDL) cholesterol. Improved lipoprotein(a) and apo-A1 levels were also demonstrated from palm oil diets; an important benefit also comes from the lowering of blood triglycerides (or reduced fat storage) as compared with those from polyunsaturated fat diets. Virgin palm oil also provides carotenes apart from tocotrienols and tocopherols that have been shown to be powerful antioxidants and potential mediators of cellular functions. These compounds can be antithrombotic, cause an increase of the prostacyclin/thromboxane ratio, reduce restenosis, and inhibit HMG-CoA-reductase (thus reducing) cholesterol biosynthesis). Red palm oil is a rich source of β-carotene as well as of α-tocopherol and tocotrienols.

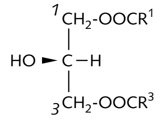
Introduction

Oils and fats are macronutrients for humans, who need to consume about 20 to 25 kg per capita per year, as recommended by the World Health Organization (WHO). People in some countries consume excessive amounts of oils and fats—about 40 to 50 kg per capita—with adverse effects on health; in contrast, a number of the most populous countries in the world consume only about 8 to 9 kg per capita per year, which is inadequate. For good health, one needs a balanced diet, including oils and fats that supply energy and essential fatty acids. There are many sources of oils and fats, but soybean oil, palm oil, sunflower seed oil, and rapeseed oil contribute 60% to 70% of the world's production.

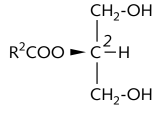
All oils and fats have the triacylglycerol or triglyceride structures shown below. Their differences lie in the types of fatty acids (RCOOH) attached to the glycerol backbone in positions 1, 2, and 3.



Triacylglycerol (TAG) or Triglyceride



1,3-Diacylglycerol (DAG)



2-Monoacylglycerol (MAG)

Fats and oils are classified simply as saturated, monounsaturated, and polyunsaturated depending on

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which fatty acids are dominant, but with many newly developed crop oils, the three classifications may be less clearly defined.

There are a number of well-known facts about vegetable oils:

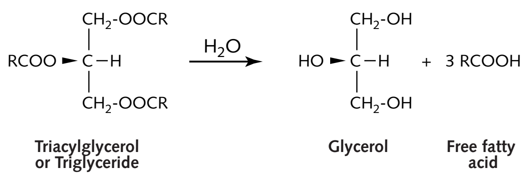
» Fatty acids from plant oils are mainly unsaturated at the 2 position of the glyceride structure. Cocoa butter and palm oil can be considered highly structured, having the 2-positional fatty acids mainly unsaturated and the 1,3-fatty acids mainly saturated.
» Vegetable oils and fats, in contrast to animal fats, are cholesterol-free.

Food manufacturers use oils and fats in their different forms for specific products. Their choice of oils and fats depends on quality and technical performance.

Quality

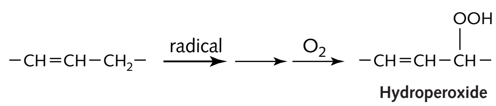
The quality of oils is dependent on their resistance to two major chemical reactions:

Hydrolysis



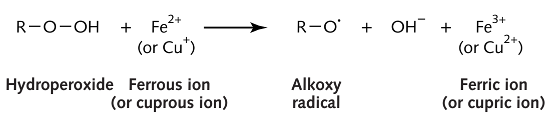
The hydrolysis reaction occurs slowly in the presence of water but is catalyzed by lipase enzymes as well as acid.

Oxidation



Oxidation is mediated by initiating free radicals to produce more radicals from fat molecules, which then readily combine with oxygen, a diradical (˙O–O˙), of air to give hydroperoxy radicals and then hydroperoxides. In special circumstances oxygen can be in the singlet state, $^1O_2$; singlet oxygen is in the excited state and is more reactive. The oxidized products usually proceed to generate more radicals, which will cause the destruction of more oil molecules.

For example:



Breakdown products of oxidation cause rancid odors, and furthermore the consumption of oxidized oils is highly suspected to cause undesirable biochemical reactions. Oxidative stability is therefore an important factor in the formulation and processing of foods. A summary of the role of free radicals in nutrition, health, and disease can be obtained from several reviews [1, 2].

The quality of the oil also takes into account its nutritional attributes, in particular its effects on cardiovascular diseases and possibly cancer. The role of fats in health and nutrition should be evaluated in the context of the digestion, absorption, and metabolism of lipids. Triacylglycerols with long-chain fatty acids are mainly hydrolyzed by the pancreatic lipase to 2-monoacylglycerols or 2-monoglycerides (see structures above) and free fatty acids from positions –1 and –3 of the triglycerides (shown in fig. 1). The ease or difficulty of absorption of these components will affect their subsequent metabolism and finally their role, if any, in cardiovascular diseases [3, 4].

It is the 2-monoacylglycerols that are readily absorbed in the intestine to be re-esterified again to triacylglycerols. The rate of absorption of the free fatty acids depends on the nature of the acids and the emulsifying medium in the intestine. Long-chain saturated fatty acids are poorly soluble and form insoluble calcium and magnesium salts. These acids require greater concentrations of bile than the unsaturated fatty acids for absorption. In the case of palm oil, the fatty acids in the 2-monoacylglycerols are mainly unsaturated (87%), although overall 50% of the fatty acids in the three positions of triacylglycerols are saturated, a consequence of having the 1- and 3-positional fatty acids more highly saturated. There are two very important dietary consequences. First, the absorbed fatty acids are mainly mono- and diunsaturated (87% for palm oil and up to 96% for palm olein), despite the relatively high saturation in the total glycerides (see tables 1–3) [4–9]. Second, the relatively high content of saturated free fatty acids in digested palm oil in comparison to other highly unsaturated oils and fats,

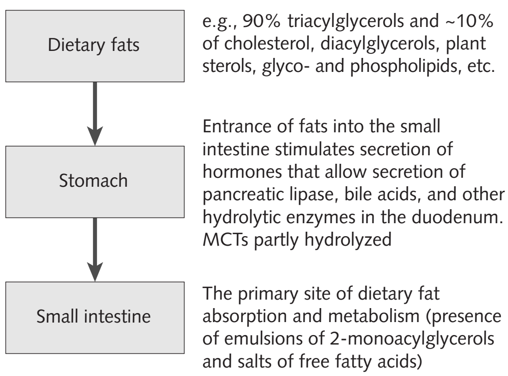


FIG. 1. Digestion, absorption, and metabolism of fats

will be less absorbed and therefore contribute less to caloric intake and serum triacylglycerols. Assuming that all the unsaturated fatty acids at the 1- and 3-positions in palm oil are preferentially absorbed while the saturated fatty acids from these same positions are excreted as salts, then only 8% of saturated fatty acids from the 2-position will be absorbed, an ideal situation to enhance the nutritional attribute of palm oil. Studies indicate that the fatty acids in the 2-position of the triacylglycerols have been highly conserved in the digestive process [10–13]. Research has also suggested that dietary cholesterol needs to be re-esterified with unsaturated fatty acids before it is incorporated into chylomicrons and transported by intestinal lymph. Therefore, palm oil fatty acids will be expected to contribute less to the absorption of dietary cholesterol already in the bloodstream.

Technical performance

Quality must also be considered in the performance of the oil during processing. For example, during frying at 180°C, polyunsaturated oil undergoes extensive oxidation, giving rise to oxidized products and dimeric/oligomeric compounds. Similarly, ready biological oxidation of polyunsaturated molecules leads to reactive free oxy-radicals, which are harmful to human cells and genetic material. Although the polyunsaturated oil can be stabilized by hydrogenation to produce more saturated material, partial hydrogenation inevitably produces *trans* fatty acids, which have been shown to cause two undesirable effects: raising the "bad" low-density-lipoprotein (LDL) cholesterol and lowering the "good" high-density lipoprotein (HDL) cholesterol, both effects being considered harmful to the heart in the long term. Therefore, an oil with high oxidative stability, such as palm oil, which does not require hydrogenation in the majority of applications, would be the preferred choice over other vegetable oils. Furthermore, refined palm oil provides an organoleptic bland flavor ideally suited to enhance the various flavors of foods. A wide range of solid fat products, e.g., margarine and shortenings, are also needed in the marketplace, and this requirement means that polyunsaturated oils need to be partially

TABLE 1. Positional distribution of fatty acids in triacylglycerols in oils and fats

Oil	Positions	Fatty acid (mol%)											Major triacyl-glycerols[a]
		16:0	16:1	18:0	18:1	18:2	18:3	20:0	20:1	22:0	22:1	24:0	
Virgin palm oil	1, 2, 3	44.3		4.6	39	10.5							POP, POO
	2	11.0		2.0	65.0	22.0	—	—	—	—	—	—	PLO, PLP[b]
Palm olein	2	4.3			65.9	29.8							
Olive oil	1	13.1	0.9	2.6	71.8	9.8	0.6	—	—	—	—	—	OOO, OOP
	2	1.4	0.7	—	82.9	14.0	0.8	—	—	—	—	—	OLO
	3	16.9	0.8	4.2	73.9	5.1	1.3	—	—	—	—	—	
Soybean	1	13.8	—	5.9	22.9	48.4	9.1	—	—	—	—	—	LLL, LLO
	2	0.9	—	0.3	21.5	69.7	7.1	—	—	—	—	—	LLP
	3	13.1	—	5.6	28.0	45.2	8.4	—	—	—	—	—	
Rapeseed	1	4.1	0.3	2.2	23.1	11.1	6.4	—	16.4	1.4	34.9	—	
	2	0.6	0.2	—	37.3	36.1	20.3	—	2.0	—	3.6	—	
	3	4.3	0.3	3.0	16.6	4.0	2.6	—	17.3	1.2	51.0	—	
Corn	1	17.9	0.3	3.2	27.5	49.8	1.2	—	—	—	—	—	LLL, LOL
	2	2.3	0.1	0.2	26.5	70.3	0.7	—	—	—	—	—	LLP
	3	13.5	0.1	2.8	30.6	51.6	1.0	—	—	—	—	—	
Peanut	1	13.6	0.3	4.6	59.2	18.5	—	0.7	1.1[c]	1.3	—	0.7	OOL, POL
	2	1.6	0.1	0.3	58.5	38.6	—	—	0.3[c]	0.2	—	0.5	OLL
	3	11.0	0.3	5.1	57.3	10.0	—	4.0	2.7[c]	5.7	—	2.8	
Cocoa butter	1	34.0	0.6	50.4	12.3	1.3	—	1.0	—	—	—	—	POS, SOS
	2	1.7	0.2	2.1	87.4	8.6	—	—	—	—	—	—	SPO
	3	36.5	0.3	52.8	8.6	0.4	—	2.3	—	—	—	—	
Linseed	1	10.1	0.2	5.6	15.3	15.6	53.2	—	—	—	—	—	
	2	1.6	0.1	0.7	16.3	21.3	59.8	—	—	—	—	—	
	3	6.0	0.3	4.0	17.0	13.2	59.4	—	—	—	—	—	

Source: refs. 4–11.

a. L denotes 18:2, O 18:1, P 16:0, and S 18:0.

b. Major triacylglycerols are the same for virgin palm oil; approximately 5% diacylglycerols are also present.

c. Together with 18:3 *n*-3.

TABLE 2. Fatty acid (mol %) and triacylglycerol composition of some oils

Fatty acid	Butter (wt%)	Milk fat			Lard			Cocoa butter			Cod liver oil			Virgin palm oil	
		sn-1	*sn*-2	*sn*-3	*sn*-1	*sn*-2	*sn*-3	*sn*-1	*sn*-2	*sn*-3	*sn*-1	*sn*-2	*sn*-3	*sn*-1,-2 and -3	*sn*-2
4:0	4	5	2.9	43.3											
6:0	2	3.0	4.8	10.8											
8:0	1	0.9	2.3	2.2											
10:0	2	2.5	6.1	3.6											
12:0	3	3.1	6.0	3.5										0.2	
14:0	13	10.5	20.4	7.1	1	4	—				2	5	2	1.1	
16:0	26	35.9	32.8	10.1	10	72	7	34	2	37	12	14	6	44.3	11
18:0	13	14.7	6.4	4.0	30	2	73	50	2	53	5	1	1	4.6	2
18:1	28.5	20.6	13.7	14.9	51	13	18	12	87	9	35	9	25	39.0	65
18:2	3	1.2	2.5	0.5	6	3	—	1	9	—	1	1	1	10.5	22
18:3	0.5										—	—	—	[a]	
20:1											14	8	18		
22:0											3	11	11	[a]	
22:2											12	8	11		
22:6											1	3	1		
24:0											3	2	2		
Major triacylglycerols[b]	PPB, PPC				SPO, OPL, OPO			POS, SOS, SPO						POP, POO, POL, PLP	

Source: refs. 4–11.
a. 0.3% of 16:1, 18:3 *n*-3 and 20:0; *sn*-1, -2, and -3 = all 1, 2, and 3 positions, values averaged.
b. B denotes 4:0, C 10:0, L 18:2, O-18:1, P 16:0, and S 18:0.

TABLE 3. Saturated, monounsaturated, and polyunsaturated fatty acids in some oils and fats

Oil	Saturated (S)	Monounsaturated (M)	Polyunsaturated (P)	P/S ratio	U/S ratio	P2/S2 ratio	U2/S2 ratio
Rapeseed	5.0	71.0	24.0	4.8	19	95	166
Canola	7.0	61.0	32	4.67	13.3	155	330
Sunflower	11.7	18.0	68.6	5.9	7.4		
Olive	13.0	79.1	7.9	0.6	6.7	10.6	73
Corn	13.3	28.4	58.3	4.4	6.5	28	39
Soybean	16.0	23.5	60.5	3.8	5.3	64	85
Groundnut	20.0	38.7	41.3	2.1	4.0	14.8	38
Cottonseed	27.7	19.8	52.5	1.9	2.6	6.32	8.8
Lard	43.0	47.0	10.0	0.2	1.3	0.04	0.2
Palm olein	46.8	41.5	12.0	0.3	1.1	6.9	22
Palm	49.5	40.3	9.6	0.2	1.0	1.7	6.7
Cocoa butter	60.1	36.5	3.4	0.2	0.7	2.3	24
Butter	63.4	32.5	4.5	0.1	0.6	0.03	0.2
Hydrogenated soybean[a]	64.0 + *trans*	26.0	4.0	0.1	0.5		
Palm kernel	84.0	14.0	2.0	0.02	0.2		
Coconut	92.2	6.2	1.6	0.02	0.1	0.02	0.05

Source: refs. 7–9.
P/S and U/S: polyunsaturated/saturated and (monounsaturated + polyunsaturated)/saturated fatty acid ratios, respectively. P2, S2, U2: polyunsaturated, saturated, and total unsaturated fatty acids, respectively, from position-2 of the triglycerides.
a. Typical sample, saturated 22%, *trans* fatty acids 42%.

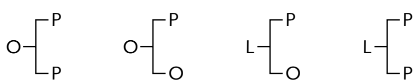
hydrogenated. This has been widely practiced for a long time (e.g., soybean oil), although it was known that the formation of *trans* fatty acids via partial hydrogenation is not desirable. To avoid this problem, a formulation of polyunsaturated oil blended with palm oil can be used to provide healthful *trans*-free products, and the additional benefit provided is the formation of the desirable polymorphic crystals, giving the food the appropriate texture. Also, in recent years, many consumers have been concerned about the consumption of genetically modified foods and these are now widespread in many oilseed crops. However, palm oil at the present time is assured to be 100% free of genetic modification.

Techno-economic considerations for palm oil

Manufacturers are always likely to choose raw materials that are in constant supply at economic prices. The oil palm is a perennial crop, and its high oil yield per planted hectare (8 to 10 times higher than that of any other oil) provides sufficient and reliable supplies. The world has been assured of good-quality palm oil for several decades. Information is available covering formulation, handling, storage, and transportation of palm oil and its products [14, 15].

Palm oil is the main oil from the oil palm and is derived from the mesocarp or flesh of the palm fruit. Being a fruit oil, it is like olive oil. The nut of the palm fruit contains the palm kernel from which a different oil (palm kernel oil) and palm kernel cake are obtained. Thus, from the oil palm fruit two types of oils are produced, which have totally different chemical and physical properties and different applications. Palm oil is mainly used for food, but palm kernel oil is mainly for the oleochemical industry. The differences need to be emphasized because they have caused confusion to those less acquainted with the oil palm crop. The distinctly different chemical compositions and physical properties that determine their varied applications are given in tables 1 to 3. Palm oil and palm olein (liquid fraction) have similar compositions to monounsaturated oil. However, palm kernel oil, with a high content of lauric acid, is practically interchangeable with coconut oil, and both oils have many applications, such as for surfactants, soap, and specialty fats. On the other hand, palm oil has a wide spectrum of applications in the food industry described below, and its potential is yet to be fully exploited.

The chemical composition of virgin palm oil (crude palm oil) shows that it contains mainly triacylglycerols (more than 95%), diacylglycerols, and free fatty acids (approximately 3.5%) and minor components (approximately 1%). There are more than 33 triacylglycerols with the major triglyceride as the symmetrical POP, POO, POL, and PLP glycerides (tables 1 and 2). The presence of the symmetrical triglycerides POP and PLP makes it possible to fractionate for cocoa butter equivalents for the manufacture of chocolates and confectioneries.



POP POO PLO PLP

P = palmitic; O = oleic; L = linoleic acid

The minor components of virgin palm oil contain a range of important, well-researched compounds, including tocotrienols (powerful antioxidants), carotenoids, phytosterols, squalene, diacylglycerols, etc. These compounds play a significant role in stabilizing palm oil as well as in the refinability of the oil. Extraction of some of these high-value compounds has provided several nutraceutical products [16–20].

The average Malaysian virgin palm oil does not contain more than 3.5% free fatty acids, and these are readily removed by physical refining to produce refined, bleached, and deodorized (RBD) palm oil. Dry fractionation of this oil yields palm olein (liquid fraction) and palm stearin (solid fraction). From these the refining industry produces 14 processed palm oils for various applications based on physical processes without the use of solvents, in contrast to seed oils such as soybean oil.

The specifications of processed palm oils have been published [14, 15]. The main processed products are RBD palm oil, RBD palm olein, and RBD palm stearin. The multiple applications of these products in the food industry are summarized in table 4, making palm oil a perfect partner in the food industry. Higher-value products of fractionation include superolein, top olein, and fractions for cocoa butter equivalents. Superolein, a relatively polyunsaturated fraction, and red palm oil, a carotene-enriched oil, are also readily available.

In addition to those in table 4, palm oil-based applications can be extended to the following:

Trans-free margarine formulation
Expanded and extruded snacks
Reduced fat spreads
Nuts (fried)
Bakery fat
Doughnuts
Cocoa butter replacers and equivalents
Milk with palm fat replacing milk fat
Manufacture of food emulsifiers
Palm-based processed cheese
Pastry
Yogurt with palm fat replacing milk fat
Flour confectionery
Soup mixes
Sugar confectionery
Salad dressing
Peanut butter
Cooking sauces
Frying chips (french fries)
Ready-made meals

Two applications in particular will be elaborated below. These are palm oil for frying and palm oil for margarines, shortenings, and vanaspati (a vegetable ghee).

TABLE 4. Food uses of some palm oil products[a]

Product	Palm oil	Palm olein	Palm stearin (soft)	Palm stearin (hard)	Hardened palm oil	Double fractionated palm olein	Palm mid-fraction	Palm kernel oil
Shortenings	xxx	xxx	xxx	xx	xxx	—	x	x
Margarines	xx	xxx	xxx	x	xxx	—	x	xxx
Frying fats	xxx	xxx	xx	—	xx	xxx	x	—
Cooking oil (warm climate)	—	xx	—	—	—	xxx	—	—
Fats and coating	—	—	xxx	—	—	—	x	xxx
Ice cream	xxx	—	—	—	xx	—	—	xxx
Biscuits	xxx	x	xx	x	xx	—	—	xx
Cookies	xxx	—	xx	x	xx	—	—	—
Crackers	xxx	x	xx	x	x	—	—	xxx
Cake mix	xxx	—	xx	x	x	—	—	—
Icings	xx	—	x	—	x	—	xx	—
Instant noodles	xxx	xxx	xx	—	xxx	—	—	—
Nondairy creamer	x	—	x	—	x	—	—	xxx

Source: refs. 14 and 15.
a. xxx, Major use; xx, moderate use; x, minor or specialized use.

Palm oil for frying

For deep-fat frying the conditions are severe, with temperatures at about 180°C under atmospheric oxygen. A host of reactions takes place, based mainly on free-radical oxidation and hydrolysis. The nature of the oil will be modified to produce derivatives of the original molecules known as polar compounds. For frying, palm olein is an excellent choice, and its superior frying quality may be compared with that of other oils. For example, after four days of frying with soybean, corn, and palm oils, the amounts of polar gums obtained were 3.4%, 3.1%, and 1.9%, respectively [21]. The stability of palm olein to free radical oxidation is due to its relatively high content of monounsaturated (oleic) and saturated fatty acids and to the presence of natural antioxidants such as tocotrienols. The performance of polyunsaturated oils such as soybean and sunflower seed oils is very poor, since they are easily oxidized, isomerized, and polymerized. Potato chips have less oil retention when fried in palm olein than when fried in polyunsaturated oils. To impart oxidative stability to the latter oils, they are hydrogenated. However, hydrogenation produces *trans* fatty acids, which have been demonstrated to be unhealthful (discussed in more detail below) because they raise “bad” LDL and lower “good” HDL cholesterol as well as participating in other biochemical reactions. Thus, palm olein is the preferred choice for industrial frying of potato chips, snacks, instant noodles, etc.

For home cooking, palm olein is suitable for shallow pan frying as well as deep frying (e.g., of potato chips). The oil can be reused several times. Consumers in temperate countries may observe cloudiness in the oil when the temperature drops below 20°C. This crystallization is purely a physical phenomenon and happens to all oils, but occurs at lower temperatures for polyunsaturated oils. Solid oils can be returned to their liquid state by warming them. This aesthetically undesirable aspect of the oil can be overcome by blending palm olein with other liquid oils. Blending will enable producers to market oils with the recommended ratios of saturates:monounsaturates:polyunsaturates as specified by various countries, usually in the range 1:1–1.7:0.6–1 [22]. The percentage of monounsaturates in the recommendations has been gradually increased at the expense of the polyunsaturates

Palm oil for margarines, shortenings, and vanaspati

Approximately 55% of the world’s population consume liquid vegetable cooking oil, and the remaining 45% consume solid cooking fats. The latter group is used to consuming butter and ghee, which come from animal sources and are high in cholesterol and cholesterol oxide, which are perceived to have negative effects on the heart. As a result, many vegetable oils have been modified to resemble butter and ghee products. The main modification process is hydrogenation of liquid oils such as soybean, rapeseed, and sunflower oils. However, hydrogenation gives rise to unhealthful *trans* fatty acids. The natural solid-fat fractions of palm oil containing palmitic fatty acid render palm oil a suitable *trans*-free main ingredient in margarines, shortenings, and vanaspati. Furthermore, palm-based blends provide the desirable polymorphic crystal forms for the required textures and melting characteristics in a variety of margarines.

Nutrition

Some quarters have raised concern about the high content of saturated fatty acids and their implications for cardiovascular diseases. This simplistic inference needs correction. A person consuming oils and fats does not take in only the fatty acids; rather, it is the chemical nature of the triacylglycerols (see triacylglycerol formulas above), particularly the position of attachment of the fatty acids, that determines the final absorption and metabolism in the body. In the digestion and absorption of triacylglycerols, not only are the nature and chain length of the fatty acids important, but also the position of attachment (*sn* 1, 2, or 3) to the glycerol backbone plays a role in determining absorption and subsequently the levels of blood triacylglycerols and cholesterol. Minor components, such as tocotrienols, also play a role (e.g., by modulating the thromboxane/prostacyclin ratio) in reducing the aggregation of blood platelets, thus reducing the tendency of blood to clot. The most compelling evidence that palm oil does not cause harm to the heart is found in recent human experiments whose results have been published and are summarized below.

Recently increasing attention has been focused on triacylglycerol metabolism and uptake of the fatty acids at the three positions of the triacylglycerol molecules [3, 4, 12, 13, 23]. It is the 2-positional fatty acids that will play the most important role in the absorption of the fat, whereas the 1- and 3-positional fatty acids will be less absorbed, especially if they are long-chain saturated fatty acids. The phenomenon is being made use of in various nutraceutical foods with designed structured fats. For instance, infant formulas can contain triacylglycerols with 2-positional palmitic acid, with oleic acid occupying the other two positions. Apart from this, it may be noted that saturated acids such as palmitic acid are an important requirement in nutrition; for example, 1,2-dipalmitoyl-phospholipids are required for healthy lungs.

The problems of obesity and excessive intake of calories have been recent concerns, and to alleviate these, oils with suitably structured triacylglycerols need to be looked for or designed. The appearance of diacylglycerol oils and fats also tries to address these problems, since diacylglycerols are in the thermodynamically stable 1,3-diacylglycerol forms and do not provide 2-monoacylglycerols for absorption and re-esterification to blood triacyglycerols. In a way the industry is moving away from looking at fats and oils as just organoleptic enhancers, flavor and vitamin carriers, or emulsifiers. Instead, their roles in health, disease prevention, neural development, and memory functioning are being explored in the development of new nutraceuticals or supplements.

There have been two recent reviews on dietary fat and prevention of cardiovascular disease [24, 25]. The conclusions from almost 50 years of studies indicate that modification or reduction of dietary fat intake has little effect on total mortality, and eating a low-fat diet does not increase longevity. Only the most stringent diets achieve plasma cholesterol reductions that are smaller than those available from the use of statin drug therapy. Reduction or modification of dietary fat intake in trials of long duration shows only a small reduction in cardiovascular risk.

Palm oil and coronary heart disease

Dietary palm oil lowers the total blood cholesterol and "bad" LDL cholesterol but increases the "good" HDL cholesterol, effects that are accepted to be beneficial against cardiovascular diseases. Thus palm oil does not behave like a saturated fat, although it contains almost equal proportions of saturated and unsaturated fatty acids. All the nutritional data show that palm oil behaves like an unsaturated fat. Apart from differences in unsaturation, there is a considerable difference between palm oil and coconut oil (a well-known saturated fat) in the detailed molecular composition of the glycerides (tables 1–3). Furthermore, the main saturated fatty acid in palm oil, palmitic acid, is very different from myristic acid, which is present in butter (13%), coconut oil (18%), and palm kernel oil (16%) but is practically negligible (1%) in palm oil. The saturated fatty acids of palm oil consist of palmitic acid (44%) and stearic acid (5%), and the unsaturated fatty acids are oleic acid (39%) (monounsaturated) and linoleic acid (10%) (polyunsaturated). Notably, the monounsaturated and polyunsaturated acids constitute 87% of the total fatty acids at the 2-position, which condition enables only these fatty acids to be easily absorbed. As a result, dietary palm oil behaves like a monounsaturated oil, and nutritional studies have consistently confirmed this. There is now a paradigm shift to consider important differences in absorption of fatty acids and 2-monoacylglycerols resulting from the action of digestive enzymes on the triacylglycerols and not just the overall fatty acid composition of the fat. In contrast to palm oil, it is evident that the largely saturated 2-positional fatty acids in coconut and many animal fats account for their hypercholesterolemic properties.

A number of pre-1990 human feeding studies reported that palm oil diets produced a reduction of blood cholesterol values ranging from 7% to 38% [26–30]. Many later nutritional studies, specifically designed to evaluate palm oil, confirmed that the effects of palm oil on blood cholesterol and lipoprotein profiles are beneficial.

- A comparative study in young Australian adults showed that the total blood cholesterol, triglyceride, and LDL-cholesterol levels of those fed palm oil (palm olein) and olive oil were lower than those fed the usual Australian diet [31]. Young Australian adults fed palm oil diets had the same total blood cholesterol, triglycerides, and "good" HDL-cholesterol levels as those fed olive oil.
- A double-blind crossover study [32] showed that a palm olein-rich diet was identical to an oleic acid-rich diet. A *trans*-fatty acid-rich diet elevated total cholesterol, "bad" LDL-cholesterol, and lipoprotein (a) and depressed "good" HDL-cholesterol relative to diets rich in oleic, stearic, lauric, and myristic acids.
- A study on 51 Pakistani adults showed that those given palm oil-rich diets performed better than those given sunflower oil. Palm oil increased HDL-cholesterol and Apo-A1 levels. Hydrogenated cottonseed oil raised blood triglyceride and lipoprotein levels [33].
- A study by the Institute of Nutrition and Food Hygiene, Beijing, China compared the effects of palm oil, soybean oil, peanut oil, and animal lard [34]. Palm oil decreased total blood cholesterol and "bad" LDL cholesterol while increasing the level of "good" HDL cholesterol. Soybean oil and peanut oil had no effect on blood cholesterol, but lard increased cholesterol levels. Among hypercholesterolemic subjects, palm oil diets lowered the cholesterol levels.
- A study conducted on healthy Indian subjects [35] showed that palm olein and groundnut oil had comparable effects. Neither oil induced hypercholesterolemia. In the same project, plasma lipoprotein (a) was also measured. There was a highly significant 10% decrease in lipoprotein (a) during consumption of the palm oil-rich diet. Lipoprotein (a) is a reliable indicator of the risk of cardiovascular disease, and a 10% decrease is therefore positive.
- A Malaysian study [36] compared the effects of diets containing palm oil (olein), corn oil, and coconut oil on serum cholesterol. Coconut oil raised serum total cholesterol by more than 10%, whereas corn and palm oil diets reduced total cholesterol by 36% and 19%, respectively.
- A crossover feeding study showed that the blood levels of cholesterol, triglycerides, HDL cholesterol, and LDL cholesterol of subjects consuming palm olein and olive oil diets were comparable [37].
- The effects of palm olein and canola oil on plasma lipids were examined in double-blind experiments in healthy Australian adults. Palm oil performed better than canola oil in raising the "good" HDL cholesterol [38].
- A similar cholesterol-lowering effect of palm oil was observed in 110 students in Malaysia [39]. The study compared the effect of palm oil with that of soybean oil. Volunteers fed palm oil (olein) and soybean oil for five weeks, with a washout period in the sixth week, had comparable blood cholesterol levels. However, the blood triglycerides increased by 28% on the soybean oil diet, implying that soybean oil provides more calories than palm olein. This is in agreement with the discussion above that there the uptake of free polyunsaturated fatty acids is better than that of the long-chain saturated ones. In an animal study palm olein fed rats showed a depression of fat storage as compared to soybean oil or tallow, a consequence of differences in uptake of the dietary fats [40].

All existing evidence discussed above indicates that the impact of palm oil on blood lipids is more like that of a monounsaturated rather than a saturated oil, making palm oil resemble olive oil. There appear to be a number of explanations.

Hayes and coworkers [41] demonstrated, in monkeys, that dietary myristic acid (14:0) and palmitic acid (16:0) have very different effects on cholesterol metabolism, myristic acid being strongly cholesterolemic (table 5). This effect was first noted in humans in 1965 but was subsequently largely ignored. Hayes and Khosla [42] advanced a hypothesis to explain the differing effects of dietary fatty acids on plasma total cholesterol reported in the literature over three decades. It was proposed that linoleic acid (18:2 *n*-6) up-regulates LDL receptors (i.e., permits full activity), allowing lipoprotein cholesterol to be cleared from plasma, whereas myristic acid (14:0) down-regulates the receptors (i.e., lowers receptor activity), resulting in a rise in LDL cholesterol; and that lauric acid (12:0) and palmitic acid (16:0) are equal and neutral in normocholesterolemic individuals and the requirement for 18:2 depends on the amount of 14:0 present. In diets that provide more than 5% to 6% of their energy as 18:2, fatty acids of any kind (except 14:0) have minimal effects. In diets that provide between 3% and 6.5% of their energy as 18:2, 14:0 is the only fatty acid to increase plasma LDL cholesterol, whereas in diets that provide less than 3% of their energy as 18:2,

TABLE 5. Fatty acid composition of palm oil and its effects on blood cholesterol[a]

Fatty acid	Composition (%)	Effects on blood cholesterol
Lauric (12:0)	0.2	Negative or neutral
Myristic (14:0)	1.1	Negative
Palmitic (16:0)	44.3	Neutral or slightly negative
Stearic (18:0)	4.6	Neutral
Oleic (18:1)	39.0	Positive
Linoleic (18:2)	10.5	Positive
Others (16:1,18:3)	0.3	Positive
Total in palm oil	100.0	Positive

a. Palm oil and palm olein contain very insignificant amounts of cholesterol-elevating saturated fatty acids (12:0 and 14:0); negative means cholesterol-raising.

myristic acid (14:0) is highly hypercholesterolemic but palmitic acid only moderately so. These interactions may be further modified by the quantity of cholesterol in the diet (at increasing levels, the sensitivity to saturated fatty acid may be greater) and by the initial concentration of plasma total cholesterol. Subjects who are already hypercholesterolemic may be more sensitive because their LDL receptors are saturated or down-regulated. If we derive as much as 30% of our energy from palm oil, the energy from linoleic acid should be more than 3%. Therefore, the effects of the main saturated fatty acid, palmitic acid, from palm oil would be almost neutral, and this was offered as an explanation of the cholesterol-lowering effects of palm oil, as discussed above. The benefits of having a *trans*-free fat cannot be overemphasized, as sufficient data have documented the dangers of *trans* fatty acids from partially hydrogenated fats [43–47].

As discussed in earlier sections, because of the specific action of pancreatic lipase enzymes, the position of the saturated and unsaturated fatty acid chains in a triacylglycerol backbone of the fat molecule determines which fatty acids are preferentially absorbed and subsequently their elevating or reducing effects on the cholesterol level in the blood [3, 4, 6, 10–13, 23, 48]. The highly structured triacylglycerols of palm oil with predominant unsaturation at the 2 position lead to these “unexpected” good properties. In palm oil, 87% of the fatty acids found in position 2 of the triglyceride molecule are unsaturated [4–9], whereas the saturated acids mainly occupy positions 1 and 3 (tables 1 and 2). This is the likely explanation why palm oil is not cholesterol elevating and possesses other associated beneficial properties.

There are also many beneficial properties of dietary palm oil. Blood clotting can be induced by injury to the blood vessel wall and the alteration (by diet) in the aggregating properties of blood platelets. Several studies are summarized below:

» Hornstra [49] in the Netherlands first demonstrated that palm oil has an anti-clotting effect, and is as antithrombotic as the highly unsaturated sunflower seed oil.
» A human study [50, 51] showed that tocotrienols (from palm oil) supplementation can reduce restenosis of patients with carotid atherosclerosis.
» Tocopherol and its relative, tocotrienol in palm oil, inhibit human platelets from “sticking” to each other. Evidence [52–54] showed that a palm oil diet either increases the production of prostacyclin which inhibits blood-clotting or decreases the formation of thromboxane which induces blood-clotting. Thus, scientific evidence indicates that the palm oil diet is no less antithrombotic than a diet based on polyunsaturated oil.

Palm oil does not promote the formation of plaques in the arteries. By feeding diets high in cholesterol along with certain saturated fats, such as milk fat, tallow, and coconut oil, atherosclerosis can be produced in rabbits, quail, pigs, and monkeys. Studies were conducted on rabbits to test the effect of palm oil on atherosclerosis [49, 55]. After the rabbits had been fed for 18 months, palm oil and sunflower oil diets caused the lowest degree of atherosclerosis in comparison with fish oil, linseed oil, and olive oil. Using the rabbit model, the effects of palm oil were compared with those of hydrogenated coconut oil, cottonseed oil, hydrogenated cottonseed oil, and an American experimental fat blend containing a mixture of butterfat, tallow, lard, shortening, salad oil, peanut oil, and corn oil. Rabbits fed coconut oil had the most atherosclerotic lesions, whereas in rabbits fed palm oil the number of lesions was no different from that in rabbits fed other oils.

Tocopherols, tocotrienols, and carotenoids

Refined palm oil, as used in foods, is a rich source of vitamin E and related compounds, such as tocotrienols. Mildly refined palm oil is also a rich source of these compounds, as well as of carotenoids. Tocopherols and tocotrienols are natural antioxidants [1, 2, 56–58] and protect the oil from oxidation. Being lipid soluble, they also have a protective role in vivo, especially to retard the oxidation of polyunsaturated acids. Animal experiments have shown that tocotrienols inhibit the enzyme HMGCoA reductase and consequently the synthesis of cholesterol [59, 60].

The tocopherols and tocotrienols capture and destroy damaging oxy free radicals that have been suggested to play a role in cellular aging, atherosclerosis, and cancer [50, 61–63]. Laboratory experiments on isolated rat hearts have shown that a tocopherol/tocotrienol concentrate from palm oil is more efficient than α-tocopherol in protecting the heart against the oxidative injury usually associated with postsurgical flow of fresh blood into the affected organ [64–67]. When the same tocopherol/tocotrienol concentrate was used in a controlled clinical trial to treat patients with vascular disorders that limited the flow of blood, the test subjects showed a significant increase in walking distance before onset of pain, as compared with the groups given aspirin or a placebo. A measure of oxidation of their blood lipids also showed significant reduction. The natural antioxidants protect LDLs from oxidation. LDLs are involved in the formation of atherosclerotic lesions, which may be exacerbated when the unsaturated fatty acid components in LDL have become oxidized.

In a recent cross-cultural epidemiologic study, the amount of vitamin E in plasma showed a strong inverse correlation with age-specific mortality from coronary heart disease. The plasma level of vitamin

E appeared to be more important than total plasma cholesterol in explaining cross-cultural differences in mortality from coronary heart disease [68]. In a paper on lipid peroxidation in skeletal muscle induced by exercise, the authors concluded that there was substantial protection against protein oxidation induced during resting as well as during exercise, by supplementing with various isomers, such as α-tocopherol and α-, β-, γ-, and δ-tocotrienols [69].

Among the tocotrienols that consist of α-, β-, γ-, and δ-analogues, δ-tocotrienol is the most potent antioxidant [56, 58]. It has been shown to be effective in inhibiting breast and liver cancer cells [56, 70–72]. Furthermore, this antioxidant has been proven to prevent oxidation of protein and lipids after strenuous bouts of exercise, making it useful for athletes, joggers, and bodybuilders. Unlike α-tocopherol, tocotrienols are not accumulated in the liver and appear to benefit the epidermis or skin [73, 74].

In parts of West Africa and Brazil, unrefined palm oil containing carotenoids is a traditional food that is recognized for its healthful aspects, including use as an ointment. However, unrefined palm oil is not widely available as a commercial product elsewhere. The main component of its carotenoids is β-carotene, which is a precursor of vitamin A. Presently mildly refined red palm oil is commercially available [17, 18, 20, 23].

Conclusions

Palm oil should be the preferred choice of food manufacturers and consumers for the following reasons.

Palm oil provides desirable oxidative stability, texture, and flavor characteristics. Because it is very stable toward free radical-induced oxidation, the formation of harmful oxidized products during processing and cooking is negligible as compared with that of polyunsaturated oils. Products incorporating naturally *trans*-free palm oil directly or as blends will have a long shelf life and other desirable properties.

The supply of genetic modification-free palm oil will be assured for a long time at economic prices because oil palm is a perennial crop with unparalleled productivity.

The belief that palm oil should be classified nutritionally with saturated fats is untrue. The fact is that palm oil behaves like an unsaturated oil such as olive oil. As a naturally structured oil, the 2-positional fatty acids which are easily absorbed are mainly monounsaturated but only 13% saturated. Furthermore, the saturated fatty acids consist of palmitic acid and stearic acid, which have been shown to have a relatively neutral effect on blood cholesterol elevation. Palm oil is as good as if not better than olive oil, especially with regard to the reduced tendency of blood to clot and the lower uptake of fatty acids. The lower uptake of palm fatty acids in comparison to those from polyunsaturated oils allows for the reduction of blood triacylglycerols and adipose deposits.

There are many nutritional qualities and benefits of the food use of palm oil. The dual LDL cholesterol-lowering and HDL cholesterol-raising effects are beneficial to the heart. Palm oil diets also improve levels of lipoprotein (a) and apo-A1. Mild processing of virgin palm oil provides oils with high carotenes, antioxidant tocopherols, and tocotrienols. These compounds have also been shown to be powerful antioxidants and potential mediators of cellular functions. They can be antithrombotic, cause an increase in the prostacyclin/thromboxane ratio, reduce restenosis, and inhibit HMG-CoA-reductase (thus reducing cholesterol biosynthesis).

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Introduction to three regional studies of the nutritional status of urban primary schoolchildren

The next three papers have the common objective of providing information on the nutritional status of 8- to 10-year-old children in urban centers of three South Asian countries that are beginning the demographic and health transition. They are Manila, Philippines; West Jakarta and Bogor, Indonesia; and Kuala Lumpur, Malaysia. All three studies measured height and weight in both public and private schoolchildren and calculated indices of stunting, wasting, underweight, and obesity. Not surprisingly the private schoolchildren had less undernutrition and a higher prevalence of overweight and obesity. Nevertheless, by current Western trends overweight and obesity are still low but rising.

The prevalence rates of urban wasting, stunting, and underweight are decreasing and relatively low compared with those of populations in the cities of South Asia and some countries of Africa and Latin America. The authors and their sponsor, International Life Sciences Institute Southeast Asia (ILSISEA), are to be commended for paying attention to the growing urban populations in their countries with a common approach that makes possible comparisons among them. Public school students in the Philippines are the worst off, and overweight and obesity is beginning to be a significant public health problem among private school students in all three studies.

All three studies encountered the problem that weight-for-height Z scores could not be calculated for some of the 10 year old girls because the National Center for Health Statistics (NCHS) reference standards in the Statistical Package for the Social Sciences (SPSS) Anthro program did not include a sufficient height range. This needs to be corrected.

Regional study of nutritional status of urban primary schoolchildren. 1. Manila, Philippines

Rodolfo F. Florentino, Gracia M. Villavieja, and Ruby D. Laña

Abstract

This multicity study sought to provide baseline information on the nutritional status of urban schoolchildren in order to examine the emerging problem of overweight and obesity in this age group. The study included 1,208 children 8 to 10 years old who were randomly selected from all public and private schools in Manila for weight and height measurements. Nutritional status was assessed by weight-for-age and height-for-age Z scores and BMI percentile cutoff points. On the average, private schoolchildren were taller and heavier and had higher body mass index (BMI) values than public schoolchildren, resulting in a much lower prevalence of undernutrition and a much higher prevalence of overnutrition. These results have important programmatic implications. However, using the World Health Organization (WHO)-recommended cutoff points to define under- and overnutrition gave contrasting results when weight-for-height and BMI were used. There appears to be a need to validate the anthropometric reference standards and cutoff points in children and adolescents to better define nutritional status and ascertain the influence of ethnicity.

Introduction

Developing countries in Southeast Asia are in a state of socioeconomic transition in which undernutrition coexists with overnutrition. In some countries undernutrition among children predominates, but in other countries the rising prevalence of obesity among children is of greater concern.

In the Philippines, the national nutrition surveys conducted by the Food and Nutrition Research Institute (FNRI) over the last decade have shown that the nutritional status of schoolchildren, particularly those 6 to 10 years old, generally has improved slightly over the years. The 1989–1990 survey showed that in this age group, the prevalence of underweight (< –2 SD of weight-for-age) was 34.2% [1]. In the latest survey in 1998, the prevalence of underweight was 30.2% [2]. On the other hand, the problem of overnutrition has caught the attention of nutrition planners because of the increasing prevalence among adults of the so-called lifestyle diseases, such as diabetes mellitus, cardiovascular disease, hypertension, and obesity, as shown from recent health statistics.

Although the nationwide prevalence of overweight using World Health Organization (WHO)/NCHS standards among schoolchildren appears to be negligible, the proportion of overweight 6- to 10-year-old children according to local reference standards [3] was 7.3% (above the 95th percentile of weight-for-age) in the 1998 survey. However, the prevalence of overweight among the higher-income group has not been ascertained. Thus, in order to examine the extent of an emerging problem of overweight and obesity among children in urban areas particularly in the higher-income group, a study of the nutritional status of children attending public and private urban schools was conducted.

This study was part of a coordinated multicountry research project on the nutritional status and dietary and physical activity patterns of urban schoolchildren organized by the International Life Sciences Institute Southeast Asia (ILSI SEA). Similar studies were conducted at about the same time in Kuala Lumpur, Malaysia, and in Jakarta and Bogor, Indonesia. The ultimate aim of the study was to gather data that will assist authorities in planning and implementing nutrition education programs for improvement of nutrition among schoolchildren.

This report focuses on the anthropometric part of the project conducted in Manila. The rest of the study (dietary and physical activity pattern) will be covered in subsequent reports.

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Methods

The study was conducted in Manila, the most populous of the 17 cities and municipalities in Metro Manila. The subjects were schoolchildren 8 to 10 years old who were selected by using a two-stage stratified sampling design. Stratification was based on the type of school (public or private) and the age and sex of the children. The first stage involved selection of the schools and the second selection of the subjects. Fourteen schools were selected by systematic sampling, with the private and public schools represented by seven schools each. The schools were selected from a list of all schools in Manila (69 public and 72 private) that was provided by the Department of Education, Culture and Sports. From each of the schools sampled, a complete list of children was obtained, from which subjects were then selected by stratified random sampling.

Data collection

Interviews were conducted by trained interviewers using pretested survey forms to solicit information on dietary patterns through a three-day food record, activity patterns, and nutrition knowledge, attitude, and practice of both the child and the parents. Each subject was weighed and measured by the standard techniques described by Jelliffe [4]. Weight was measured to the nearest 0.1 kg with a calibrated beam balance scale (platform type). Standing height was measured to the nearest 0.1 cm. with a "microtoise" attached to a smooth straight wall.

The data collected were edited both in the field and in the office, after which, master databases were produced. Analysis of anthropometric data compared actual height and weight data with the NCHS reference standards using the ANTHRO Software of the Centers for Disease Control, Atlanta, Ga., USA. Children were considered underweight and stunted if their weight and height Z scores were less than –2 SD of the NCHS median for weight and height, respectively.

Since not all children could be analyzed for their weight-for-height because the heights of 10% of the children were beyond the limits of the NCHS Reference, body mass index (BMI)-for-age was used as the indicator to assess thinness and overweight. The table of BMI proposed by Must et al. [5], which gives the smoothed values for the 5th, 15th, 50th, 85th, and 95th percentiles derived from NHANES I for 6 to 74 years of age, was used as a reference. Thinness was defined by BMI less than the 5th percentile, whereas those with BMI values at or above the 85th percentile were considered "at risk of overweight" as recommended by WHO [6]. In addition, the 95th percentile was used to determine overweight as defined by Troiano et al. [7].

The data were processed using the Statistical Package for Social Sciences (SPSS) to generate the required output.

Indices used

The use of the NCHS/WHO weight-for-height index to assess the nutritional status of the children was limited by the fact that 122 (10%) of 1,208 subjects had heights beyond the limits of the NCHS/WHO reference standard for age. These included 34 public schoolchildren (2 aged 8 years, 11 aged 9, and 21 aged 10) and 88 children in private schools (18 aged 8, 25 aged 9, and 45 aged 10). Hence, BMI-for-age was used instead for the whole study population. In order to assess thinness and overweight among the children, including those 8 years of age, the table proposed by Must et al. [5] generated from NHANES I covering 6 years to adulthood was used. Cutoff points proposed by WHO [6] were applied to assess thinness (less than the 5th percentile) and risk of overweight (at or above the 85th percentile). An additional cutoff to define those more markedly overweight (at or above the 95th percentile) was also used, as suggested by Troiano et al. [7].

Results

Of the 1,288 schoolchildren in the original sample, 1,208 subjects completed all the phases of the survey, which was more than the targeted sample size of 1,092. The final sample size represented 1% of the estimated total number of enrollees in the city of Manila for the school year 1996–1997. Of this total, 642 came from public schools and 566 came from private schools. In both school categories, slightly more girls completed the study than boys (50.5% vs. 49.5%).

Mean height, weight, and BMI

Children from private schools were on average taller and heavier and had a higher BMI than those from public schools (table 1). This observation was true for both boys and girls and for all ages. Large differences in height were particularly noted among the 8-year-old children, with those in private schools, on average, taller by as much as 7 cm. On the other hand, 10-year-old private schoolchildren were heavier by almost 8 kg among the boys and 6 kg among the girls. The same was true for BMI: children from private schools had a higher average BMI at all ages than those from public schools, with the gap between the two increasing with age. Both boys and girls from public and private schools had increasing average BMI with increasing age, except for public school boys whose average BMI remained constant at 15.4 kg/m^2.

TABLE 1. Mean height, weight, and BMI of schoolchildren according to age, sex, and type of school

Sex and age (yr)	School	*n*	Height (cm) Mean ± SD	Height (cm) Mean Z score	Weight (kg) Mean ± SD	Weight (kg) Mean Z score	Mean ± SD BMI (kg/m^2)
Male							
8	Public	102	122.9 ± 6.4	–1.26	23.5 ± 5.4	–1.08	15.4 ± 2.3
	Private	95	129.2 ± 8.2	–0.09	28.0 ± 6.7	0.03	16.7 ± 3.2
9	Public	105	127.1 ± 6.0	–1.35	25.1 ± 5.8	–1.20	15.4 ± 2.6
	Private	94	131.6 ± 6.1	–0.54	29.9 ± 7.4	–0.21	17.1 ± 3.2
10	Public	110	129.9 ± 5.8	–1.59	26.0 ± 4.6	–1.41	15.4 ± 1.8
	Private	92	135.6 ± 8.3	–0.72	33.9 ± 9.4	–0.15	18.2 ± 3.7
Female							
8	Public	105	121.5 ± 6.0	–1.28	22.5 ± 4.1	–1.12	15.1 ± 1.9
	Private	90	128.9 ± 8.3	–0.08	27.2 ± 5.5	–0.08	16.3 ± 2.8
9	Public	109	127.0 ± 6.8	–1.22	26.3 ± 5.9	–1.12	15.5 ± 2.2
	Private	99	131.6 ± 6.3	–0.55	30.1 ± 7.4	–0.30	17.2 ± 3.2
10	Public	111	131.0 ± 6.7	–1.47	27.4 ± 5.9	–1.26	15.8 ± 2.3
	Private	96	136.3 ± 7.0	–0.76	33.4 ± 8.5	–0.42	17.8 ± 3.5

Prevalence of undernutrition

The prevalence of undernutrition was assessed on the basis of three indices: height-for-age, weight-for-age, and BMI-for-age, using the descriptive terms, stunting and underweight-for-age according to NCHS reference standards, and thinness according to BMI reference standards. The weight-for-height index was not used, because data from 122 schoolchildren whose heights were beyond the limits of the NCHS standards could not be analyzed by the ANTHRO Software.

Undernutrition, particularly stunting, afflicted a large proportion of schoolchildren in Manila especially among those from public schools (table 2 and fig. 1). Stunting (< –2 SD of NCHS height-for-age), which is indicative of previous or longstanding malnutrition, affected 26.5% of the children from public schools and only 6.6% of those from private schools. Whereas 18.2% of the children from public schools were underweight-for-age (< –2 SD NCHS), only 4.3% of the children from private schools were. Thinness (less than the 5th percentile of Must et al. BMI table [5]) was also common among the children from public schools, with a prevalence rate of 18.7%, whereas the prevalence was only 9.4% among children from private schools. Among all age groups, the 10-year-old public schoolchildren seemed to suffer most from underweight, stunting, and thinness.

Boys in public schools appeared to be at greater risk of suffering from the different forms of undernutrition than girls. A higher prevalence was observed among the boys for the three indicators. However, the differences between the sexes were not as apparent among private schoolchildren. In fact, in public schools thinness was more prevalent among girls than among boys.

Prevalence of overnutrition

With the use of BMI cutoffs of the 85th and 95th percentile, the prevalence of risk of overweight among private schoolchildren was much higher than that among public schoolchildren (table 2 and fig. 1). Thus, as much as 24.9% of private schoolchildren of both sexes had BMI-for-age at or above the 85th percentile, compared with only 5.8% of public schoolchildren. Likewise, the prevalence of overweight (BMI at or above the 95th percentile) among private schoolchildren was almost four times higher than among public schoolchildren. There was a generally decreasing trend of overweight with age from 8 to 10 years among public schoolchildren, but not among private schoolchildren. The difference between the sexes was not very clear. A higher prevalence of those with a BMI at or above the 85th percentile was seen among

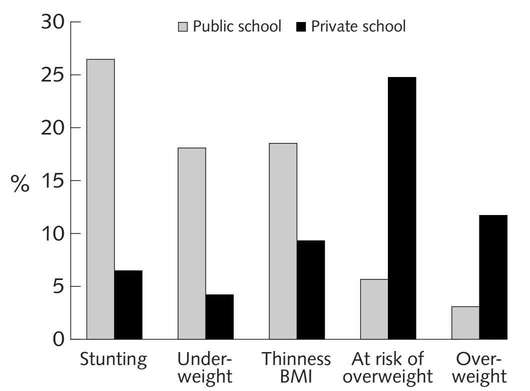

FIG. 1. Prevalence of under- and overnutrition among schoolchildren according to type of school

TABLE 2. Prevalence of under- and overnutrition among schoolchildren according to age, sex, and type of school

Sex and age (yr)	School	*n*	Stunting[a]	Underweight[b]	Thinness[c]	At risk for overweight[d]	Overweight[e]
Male							
8	Public	102	25.5	16.6	12.7	9.8	6.9
	Private	95	6.3	6.3	10.5	29.4	14.7
9	Public	105	22.9	21.9	22.9	5.8	4.8
	Private	94	7.4	3.2	9.6	21.3	14.9
10	Public	110	38.1	26.4	27.3	1.8	0.9
	Private	92	8.7	4.4	5.4	30.5	12.0
Female							
8	Public	105	21.0	15.2	14.3	5.8	2.9
	Private	90	4.4	1.1	10.0	21.1	11.1
9	Public	109	21.1	13.8	16.5	6.4	1.8
	Private	99	4.0	4.0	13.1	27.3	9.1
10	Public	111	29.7	15.3	18.0	5.4	2.7
	Private	96	8.3	6.3	7.3	19.8	10.4
All	Public	642	26.5	18.2	18.7	5.8	3.3
	Private	566	6.6	4.3	9.4	24.9	12.0

a. Height-for-age < –2 SD NCHS [7].
b. Weight-for-age < –2 SD NCHS [7].
c. BMI < 5th percentile, Must et al. [5] BMI table.
d. BMI ≥ 85th percentile, Must et al. [5] BMI table.
e. BMI ≥ 95th percentile, Must et al. [5] BMI table.

8-year-old boys from public schools and among 8- and 10-year-old boys from private schools as compared with girls. A higher prevalence of overweight (at or above the 95th percentile) was observed among boys than among girls of the same age, except among 10-year-old girls in public schools.

Discussion

This report is part of a comprehensive multicity study of the nutrition of schoolchildren in urban areas, dealing with their nutritional status and dietary and physical activity patterns. Similar studies were conducted in Kuala Lumpur, Malaysia, and in Jakarta and Bogor, Indonesia at about the same time. This will permit some intercity comparison on these important areas of study. Subsequent papers of the series that will deal with the dietary and physical activity pattern of the same subject children will throw more light on the influence of dietary and physical activity on nutritional status of these children.

This study is the first such nutritional study covering 8- to 10-year-old public and private schoolchildren in Manila. At the same time as it provides important baseline data on this age group, it shows a valid comparison of nutritional status between public and private schoolchildren in an urban area. Public schools, which are free, generally cater to the lower-income group, whereas private schools generally cater to the higher-income group. Thus, children in private schools are exposed to a richer socioeconomic environment that affects their diet, leisure and other physical activities, and learning opportunities. Thus, attendance in public or private schools could serve as a good proxy for socioeconomic status of the children.

The results of the study clearly show the effect of socioeconomic status on nutrition. Private schoolchildren were on average taller and heavier than those in public schools, and their average BMI was higher. In fact, the mean Z scores for height and weight of private schoolchildren, especially for 8-year-olds, were close to the NCHS standard, showing that these children were, on average, not far from the nutritional status of American children in the 1970s. Likewise, the mean BMI of private schoolchildren was 95% to 98% of that of American children in the 1960s [8].

According to the cutoffs that we used for defining under- and overnutrition, the lower distribution in height, weight, and BMI measurements of public schoolchildren compared with that of private schoolchildren revealed a higher proportion of undernutrition among public schoolchildren than among private schoolchildren. However, there was a higher proportion of overweight among private schoolchildren than among public schoolchildren. This finding has important programmatic implications. Nutritional interventions to remedy the high rate of undernutrition in public schools, at the same time as nutrition education and physical activity programs to prevent increasing obesity in private schools are apparently called for.

The study also showed a decreasing Z score in height-for-age and weight-for-age with age from 8 to 10 years in both public and private schools. This trend was also reflected in the increasing prevalence of stunting and underweight with age from 8 to 10 years, particularly in public schools. If this trend is real, it may have important programmatic implications. However, it may reflect, at least in part, the start of puberty and the influence of ethnicity affecting the significance of the differences from NCHS standards. As Flegal [9] pointed out, no valid comparisons in prevalence among age and sex groups may be made using statistical approaches in defining nutritional status, because variability among these groups may be constrained by the assumptions built into the cutoffs used. Thus, in contrast to public schoolchildren where thinness (BMI less than the 5th percentile) increased with age, thinness generally decreased with age among private schoolchildren. There is a need either to examine the reference standards for use in Filipino preadolescent and adolescent children or to validate the cutoff points used.

Private schoolchildren had a greater relative change in height and weight Z scores from 8 to 10 years of age than public schoolchildren, resulting in a larger increase in BMI with age. The increase in BMI with age has also been noted among American children [8]. However, the increase should be interpreted with caution because of limitations of BMI as a measure of nutritional status in older schoolchildren due to changing body composition and degree of maturity with age and the influence of ethnicity.

There was an increasing prevalence of underweight and stunting with age from 8 to 10 years, but a generally decreasing prevalence of overweight, in spite of the generally increasing BMI. However, further study is needed to determine whether these trends and differences are real and not due to reference standards and cutoff points.

In order to compare weight-for-height index with BMI in assessing wasting/thinness and overweight, the same group of children was analyzed using both the WHO indices [6] and those of Troiano et al. [7]. Children whose heights exceeded the limits of the NCHS/WHO weight-for-height table were excluded from the analysis. The results are shown in table 3 and figure 2. For both sexes combined, the prevalence of thinness, as defined by BMI less than the 5th percentile, was three times higher than that of wasting, as defined by weight-for-height < –2 SD in both public and private schoolchildren. Although this may be explained by the cutoffs used, perhaps the significance of thinness, as defined by BMI, is different from that of wasting, as defined by weight-for-height. Using the cutoff of BMI above the 85th percentile to define "at risk of overweight," as suggested by WHO [6], gives a prevalence of overweight from one to three times as high as that obtained using weight-for-height Z scores. On the other hand, the prevalence of overweight, as defined by BMI at or above the 95th percentile, was in close agreement with that defined by weight-for-age Z scores. From our data it appears that the BMI range from at or above the 85th percentile to less than the 95th percentile could better define "risk of overweight" than the whole range of BMI at or above the 85th percentile, as recommended by WHO [6], whereas BMI at or above the 95th percentile could define "overweight," as suggested by Troiano et al. [7].

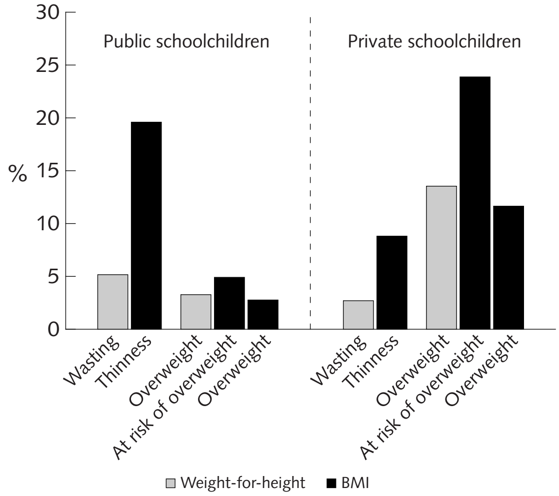

FIG. 2. Comparison of under- and overnutrition among schoolchildren according to type of school using weight-for-height Z score and BMI-for-age

Although it is generally agreed that BMI-for-age provides the better criterion for evaluating thinness and overweight, because it is a continuous indicator that can be calculated from childhood to adulthood, there is a need for a clearer definition of under- and overnutrition when using anthropometric cutoff points in various indices. In addition, there is a need for more complete reference standards, including greater heights in weight-for-height reference tables and younger ages in BMI-for-age tables.

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We thank the staff of the Nutritional Monitoring

TABLE 3. Comparison of prevalence of under- and overnutrition among schoolchildren according to age, sex, and type of school using weight-for-height Z scores and BMI-for-age

Sex and age (yr)	School	*n*	Stunting[a]	Underweight[b]	Thinness[c]	At risk for overweight[d]	Overweight[e]
Male							
8	Public	101	5.9	12.9	7.0	9.9	6.9
	Private	89	4.4	7.9	16.9	31.4	15.7
9	Public	105	11.5	22.9	5.8	5.8	4.8
	Private	92	2.2	8.7	14.1	20.6	14.1
10	Public	110	5.5	27.3	1.8	1.8	0.9
	Private	86	1.2	5.8	16.4	27.9	10.5
Female							
8	Public	104	1.9	14.4	2.0	5.8	2.9
	Private	78	1.3	5.1	9.0	23.0	11.5
9	Public	98	3.1	18.4	0.0	3.1	0.0
	Private	76	5.3	14.5	9.2	22.4	7.9
10	Public	90	2.2	22.2	2.2	3.3	1.1
	Private	57	1.8	12.3	15.8	15.8	8.8
All	Public	608	5.1	19.7	3.2	4.9	2.8
	Private	478	2.7	8.8	13.7	24.0	11.7

a. Weight-for-height < –2 SD NCHS [7].
b. BMI < 5th percentile, Must et al. [5] BMI table.
c. Weight-for-height ≥ 2 SD NCHS [7].
d. BMI ≥ 85th percentile, Must et al. [5] BMI table.
e. BMI ≥ 95th percentile, Must et al. [5] BMI table.

and Assessment Division of FNRI for conducting the interviews and anthropometric measurements for the study, and helping in the various tasks involved. We acknowledge the support and cooperation of the officials of the FNRI, the Regional and Division Offices of the Department of Education, Culture, and Sports, and the officials and teachers in the participating schools. We are particularly grateful to all the students and their parents who served as subjects for this study. We also thank Dr. Frederick L. Trowbridge of the ILSI Research Foundation and Dr. James O. Hill of the Center of Human Nutrition, University of Colorado, for their very valuable comments in the interpretation of results; Ms. Yeong Boon Yee of ILSI SEA for ably coordinating this multicountry project; and the study leaders in the other participating countries, Dr. Tee E-Siong, Institute of Medical Research, Malaysia, and Professor Soekirman, Bogor Agriculture University, Indonesia, for their valuable comments in the interpretation of results.

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Regional study of nutritional status of urban primary schoolchildren. 2. West Jakarta and Bogor, Indonesia

Soekirman, Hardinsyah, Idrus Jus'at, and Abas Basuni Jahari

Abstract

The study provides information on the nutritional status of 8- to 10-year-old primary schoolchildren in urban areas of Jakarta and Bogor, Indonesia, based on anthropometric indicators. It compares the use of the anthropometric indicators weight-for-age Z score, height-for-age Z score, weight-for-height Z score, and body mass index (BMI) to assess thinness (underweight and wasted) and overweight in children. A total of 1,367 children were examined. The nutritional status of the 8- to 10-year urban schoolchildren was better than that of urban children under 5 years old. The prevalence of underweight among urban schoolchildren ranged from 7.4% (girls) to 12.95% (boys), while underweight among urban children under 5 years old in 1998 was 29.7%. Meanwhile, the prevalence of overweight (BMI > 85th percentile) ranged from 15.3% (girls) to 17.8% (boys). There were more overweight children in the private schools than in the public schools. On average, private schoolchildren, of all ages and both sexes, were heavier and taller than public schoolchildren. The BMI indicator for "thinness" and "wasting," using the NHANES reference, indicates a false positive result. For detecting overweight in children aged 8 to 10 years, BMI is comparable to the other indices, weight-for-age, height-for-age, and weight-for-height.

Introduction

For more than three decades, Indonesia has focused its nutrition programs on children under five years old in rural areas. Therefore, most available data and information on nutrition are on preschool children, with very little on schoolchildren, especially from urban areas. Studies have shown that the nutritional status of preschool children is steadily improving. In the 1960s, more than 50% of under-five children were underweight [1]. Data in 1995 indicated that the prevalence of underweight children was around 30.5%, which is still the highest among the ASEAN countries [2]. Nutritional data on schoolchildren in Indonesia are scanty. Limited data in 1990 on primary school entrants (age six and seven) revealed that 13% to 17% were stunted [3].

The Indonesian Sixth Five-Year Development Plan (1993/1994 to 1997/1998) gave a high priority to education, primarily basic education. Within 10 to 15 years from 1993/1994, every Indonesian will have had at least nine years of basic education. To achieve this target, more attention has been given to the health and nutritional status of primary schoolchildren. One serious problem with achieving a universal nine-year basic education in Indonesia is the high dropout rates among primary schoolchildren in poor rural areas due to health and nutritional problems, among others. Most of the primary schoolchildren in rural areas are energy deficient, with an average energy intake of 70% of their requirement. The prevalence of stunting among schoolchildren ranged from 13.6% to 43.7%, 30% to 40% were anemic, and 50% to 80% suffered from worm infestation [4].

The nutritional problem among primary schoolchildren in rural areas is part of the poverty problems faced by most developing countries, including Indonesia. One program being launched in Indonesia to cope with malnutrition in poor primary schoolchildren is the School Snack Program (Program Makanan Tambahan Anak Sekolah, PMT-AS) as an integrated part of a national poverty alleviation program. This program started in 1996, and by the end of the second year (1997/1998) it covered more than 49,000 primary schools with 7.2 million schoolchildren in 26,421 villages of all regions of across the country.

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As in other developing countries in Asia, Indonesia is undergoing an epidemiologic transition. Besides a high prevalence of poverty-related undernutrition, there is a trend toward increasing cardiovascular and other noninfectious diseases, especially in urban areas. In 1972 cardiovascular disease was the 11th leading cause of death, in 1986 it jumped to number 3, and it is now the number 1 cause of death. This transition is correlated with the changing trends of risk factors for cardiovascular disease. For example, the prevalence of overweight and obesity (BMI of at least 30) in urban adults in Indonesia increased from 4.9% in 1988 to 7.6% in 1993, and the prevalence of hypercholesterolemia increased from 13.4% in 1988 to 16.4% in 1993 [5].

It is believed that the increasing risk factors for cardiovascular disease in adults are associated with eating habits and physical activity in childhood [6]. In Indonesia, data on the risk factors for cardiovascular disease during childhood are limited and focus only on body weight. A small-scale study in Jakarta indicated that about 5% of children 8 to 10 years of age were overweight, based on a weight-for-height index above 120% of the median [7]. There are no baseline data to determine whether there is a trend toward overweight and obesity among schoolchildren in Indonesia. However, with ongoing improvement in the socioeconomic status of people, it is believed that the prevalence of overweight and obesity in adults as well as in children will increase if there are no prevention efforts.

The present study attempts to answer some questions concerning the nutritional status, eating habits, and activity patterns of primary schoolchildren in Jakarta and Bogor, Indonesia.

Research questions

What is the nutritional status of the schoolchildren? Is there any significant number of children who are overweight? Is there any difference between using weight-for-age, height-for-age, and weight-for-height indices compared with body mass index (BMI) for detecting thinness or underweight and wasting ?

Objectives of the study

The general objective of the study was to provide information on the nutritional status of 8- to 10-year-old primary schoolchildren in urban areas of Jakarta and Bogor, Indonesia, based on anthropometric indicators. The specific objectives were to assess the nutritional status of the children based on indicators of underweight (weight-for-age), stunting (height-for-age), and wasting (weight-for-height); and to assess the comparability of weight-for-age, height-for-age, weight-for-height, and BMI indices for detecting underweight, wasting, and overweight in children.

Benefits of the study

Most nutrition studies in Indonesia have taken place in rural areas. There are very few studies on urban populations, especially on schoolchildren. This study is expected to encourage further urban nutrition studies in Indonesia. Nutritional status data are needed for developing specific nutritional guidelines and nutrition education materials for schoolchildren, as a part of the nutrition program to improve their nutritional status, including the prevention of overweight and obesity.

The results of the study are expected to be complementary to those of similar studies carried out concurrently in Manila, Philippines and Kuala Lumpur, Malaysia. All three studies were funded by International Life Sciences Institute of South East Asia (ILSI SEA).

Methods

Location

The study was conducted in Bogor and West Jakarta. Bogor is a city of 1.5 million, 60 km south of Jakarta, the home of a world-famous botanical garden and a national university of agriculture. Bogor is located about 500 m above sea level and is situated within West Java province. The rate of urbanization is relatively low. Since the 1990s, more people have commuted from Bogor to Jakarta to work because housing and living costs in Bogor are less expensive than in Jakarta. Compared with that of Jakarta the population in Bogor is relatively homogeneous. The gap between low- and high-income families is not as large as in Jakarta. The weather is cool most of the year because of rain and the high altitude.

West Jakarta is one of the five municipalities of the capital city of Jakarta. West Jakarta is a fast-growing area with a population of about two million (25% of the total population of Jakarta), with several different ethnic groups. It has a large number of families of low education and income who live in slum areas. There are also enclaves of expensive housing.

Sampling

The study population consisted of primary schoolchildren aged 8 to 10 years from Bogor and West Jakarta. A multistage stratified random sampling was applied according to location, type of school (public or private, reflecting the socioeconomic level of the family), age (8, 9, and 10 years), and sex.

In Bogor there are 329 primary schools (302 public and 27 private) with approximately 90,000 children aged 6 to 12 years. In West Jakarta there are 709 primary schools (517 public and 192 private) with about 200,000 schoolchildren 6 to 12 years of age.

Calculation of sample size was based on the average height of children 8 to 10 years of age (132.2 cm; SD 6.7 cm) from several primary schools in Jakarta. With a 95% confidence interval, an acceptable alpha error of 5%, a power of 80%, and an expected deviation from the population mean of 0.5 cm, the estimated total sample size is about 1,400 schoolchildren.

The number of sample children was calculated proportionally for each location [8]. The number of children for Bogor = 0.317 × 1418 = 449, and for West Jakarta = 0.683 × 1418 = 969.

With an average of 90 schoolchildren aged 8 to 10 years per school, 16 schools were required to obtain the total sample of 1,400 schoolchildren. The 11 schools in Jakarta and the 5 schools in Bogor were selected by a proportionate-to-size technique based on the total number of schoolchildren aged 8 to 10 years and the number of schools (public and private) in each location. There were approximately 15 children per age-sex group in each school.

Variables and data collection

The body weight and height of each subject were measured using the anthropometric measurement techniques recommended by Jelliffe [9] and WHO [10]. Body weight was measured using an electronic scale 890 (SECA, manufactured for UNICEF using technology developed in Australia) with a precision of 0.1 kg, and height was measured using a microtoise with a precision of 0.1 cm. All measurement tools were periodically calibrated. The children were weighed and measured in the morning before class started. To avoid any refusal or objection to the measurement, female staff members measured the girls. The children were not allowed to wear shoes, caps, or any accessories that might influence their actual body weight and height. To obtain more accurate data on body weight, a sample of the clothing usually worn by the children was weighed to obtain a correction factor for each age-sex group. The correction factor of daily clothes was 350 g for girls and 250 g for boys. All measurements were carried out by well-trained staff. The schools provided data on each child's age.

Data quality control

Prior to actual data collection, the field staff, who were new graduates from the School of Nutrition, Department of Health, Jakarta, and the Department of Community Nutrition and Family Resources, Bogor Agriculture University, were trained by experts in nutritional assessment. All questionnaires were pretested before the study was implemented. For anthropometric data, a precision and accuracy test was employed during the training to identify a group of reliable measurers. In addition, there was intensive supervision during data collection.

Data management

Data were verified by checking the consistency of information in the completed questionnaires prior to the data-entry process. All incomplete questionnaires were excluded. The data were then entered using Epi-Info version 6.10 software. The data were cleaned independently by double entry of 10% of the questionnaires. If any difference was found in the data, all the data entered were rechecked.

Data analyses

Before the data were analyzed, some new variables were generated, including: Z scores and percentile values of weight-for-age ("underweight" indicator), Z scores and percentile values of height-for-age ("stunting" indicator), Z score and percentile values of weight-for-height ("wasting" indicator), and Z score and percentile values of body mass index ("overweight" indicator). The WHO [10] reference standards were used to generate values for the first three indicators. For BMI classification tables suggested by WHO [11] and by Must et al. were used [12].

The cutoff point of –2 Z scores was used to detect the underweight, stunting, and wasting status of the children. For overweight and obesity, the cutoff points were the 85th and 95th percentiles of BMI, respectively. For the purpose of analysis on the comparability of various indicators of thinness, the 5th percentile of BMI was also used. To further explore the growth pattern of schoolchildren, the prevalence was presented by location, age, type of school, and sex. In addition, the average growth achievement according to the Z scores for weight-for-age (WA), height-for-age (HA), and weight-for-height (WH) indicators were also presented in the same manner as those of the prevalence.

Results

Sample profile

The anthropometric data from 1,367 children (687 boys and 680 girls) who participated in the study were analyzed for their underweight (weight-for-age), stunting (height-for-age), and obesity (BMI) status. However, data from only 1,245 children could be analyzed for wasting (based on weight-for-height) status, because of the limitation of the weight-for-height reference in the WHO publication (female up to 137 cm and male up to 145 cm). There were 890 children in West Jakarta and 477 children in Bogor.

Mean weight and height

Table 1 indicates that at the ages of 8 and 9, boys were heavier than girls. However, by the age of 10 years, girls were about 1 kg heavier than boys. The same pattern is also shown for mean height. At ages 8 and 9, boys were taller than girls, but at age 10 girls were about 1.5 cm taller than boys. The weight and height data of the schoolchildren from this study follow Tanner's velocity curves, in which girls begin their adolescent growth spurt (especially height) earlier than boys [13].

For all ages and for both sexes, private schoolchildren were heavier and taller than public schoolchildren. This is expected, because school status (private or public) is a proxy for social and economic status of the parents. Private school parents are economically and socially better off than parents of public schoolchildren. Figure 1 shows that, on average, the weights and heights of private schoolchildren were equal to or greater than the international/WHO-NCHS growth standard, whereas those of public schoolchildren were far below the international standard.

An attempt was made to compare the growth pattern of the schoolchildren with those found in a similar study carried out in private schools in Bandung (the capital city of West Java province) in 1978 [14]. There is a trend toward improving physical stature of the schoolchildren born in later years. The younger children are better off than their older fellows. As indicated in the Bandung study, two decades ago the physical stature of schoolchildren at the same age was much lower than that in the present study. The children in our study have been benefiting from a better social and economic environment.

Mean Z score and prevalence of underweight and overweight based on weight-for-age indicator

Table 2 displays the mean value of weight-for-age Z scores and the prevalence of underweight (< –2 SD weight-for-age). In general, the mean weight-for-age Z score for both boys and girls indicated that the nutritional status of private schoolchildren was better than that of public schoolchildren. The total mean values of weight-for-age Z scores of boys and girls in public schools were –0.93 and –0.84, respectively, whereas those of children in private schools were 0.24 and –0.18. However, the standard deviations for all of these mean values were large. As a consequence, some children fell below –2 SD and some above 2 SD. Underweight was more prevalent among children in public schools than among those in private schools.

TABLE 1. Weight and height of children according to age, sex, and type of school

Age and sex	School	*n*	Mean ± SD weight (kg)	Mean ± SD height (cm)
8 yr				
Male	Public	162	23.43 ± 5.20	124.20 ± 6.33
	Private	73	27.09 ± 7.63	127.12 ± 7.21
	Both types	235	24.57 ± 6.22	125.11 ± 6.74
Female	Public	164	23.40 ± 4.86	123.20 ± 5.86
	Private	76	25.94 ± 7.36	125.95 ± 6.51
	Both types	240	24.20 ± 5.87	124.07 ± 6.51
9 yr				
Male	Public	152	25.03 ± 5.39	127.08 ± 5.79
	Private	75	31.21 ± 9.83	132.30 ± 7.79
	Both types	227	27.07 ± 7.72	128.80 ± 8.12
Female	Public	159	24.01 ± 3.94	125.90 ± 8.12
	Private	75	27.56 ± 6.44	131.13 ± 7.54
	Both types	234	25.14 ± 5.15	127.58 ± 8.29
10 yr				
Male	Public	159	26.34 ± 4.87	131.80 ± 8.50
	Private	66	34.50 ± 12.04	136.06 ± 7.87
	Both types	225	28.73 ± 8.52	133.05 ± 8.53
Female	Public	135	27.89 ± 6.15	133.12 ± 7.63
	Private	71	33.25 ± 8.29	137.9 ± 8.24
	Both types	206	29.74 ± 7.39	134.52 ± 8.06

The distribution of overweight (> 2 SD weight-for-age) was the opposite of that of underweight. The prevalence of overweight was higher among children in private schools than among those in public schools. The prevalence of overweight among boys in private schools was about six times higher than that among those in public schools (14.95% vs. 2.33%). Similarly, the prevalences of overweight among girls in private and public schools were 6.76% and 1.31%, respectively.

Mean Z score and prevalence of stunting based on height-for-age

Table 3 displays the mean value of height-for-age (HA) Z scores and the prevalence of stunting (< –2 SD height-for-age). As for underweight, the mean height-for-age Z scores of boys and girls in private schools were in general higher than those of children in public schools. The linear growth of the young children (8 years), as represented by the mean height-for-age Z score, was better than that of the older children (9–10 years). Stunting was higher among children in public schools than those in private schools. Again, according to ages, stunting was greater in older children (9–10 years) than in younger children (8 years). As a whole, the problem of stunting among children in public schools was more than two times greater than that among children in private schools.

Mean Z score and prevalence of wasting and overweight based on weight-for-height indicator

The mean values of weight-for-height Z scores and the prevalence of wasting (< –2 SD weight-for-height) are presented in table 4. The mean values of weight-for-height Z scores indicated that in general the status of children in private schools was slightly better than that of children in public schools. This finding was also supported by the prevalence of wasting, which was higher among children in public schools (6.25% for boys 4.39% for girls) than among children in private schools (3.96% for boys and 2.37% for girls).

In general, overweight (based on > 2 SD weight-for-height) was greater among children in private schools than those in public schools, particularly among boys. For boys in private schools, overweight was about three times higher than for boys in public schools. In girls the problem of overweight was about the same in private and in public schools. As in the nutritional

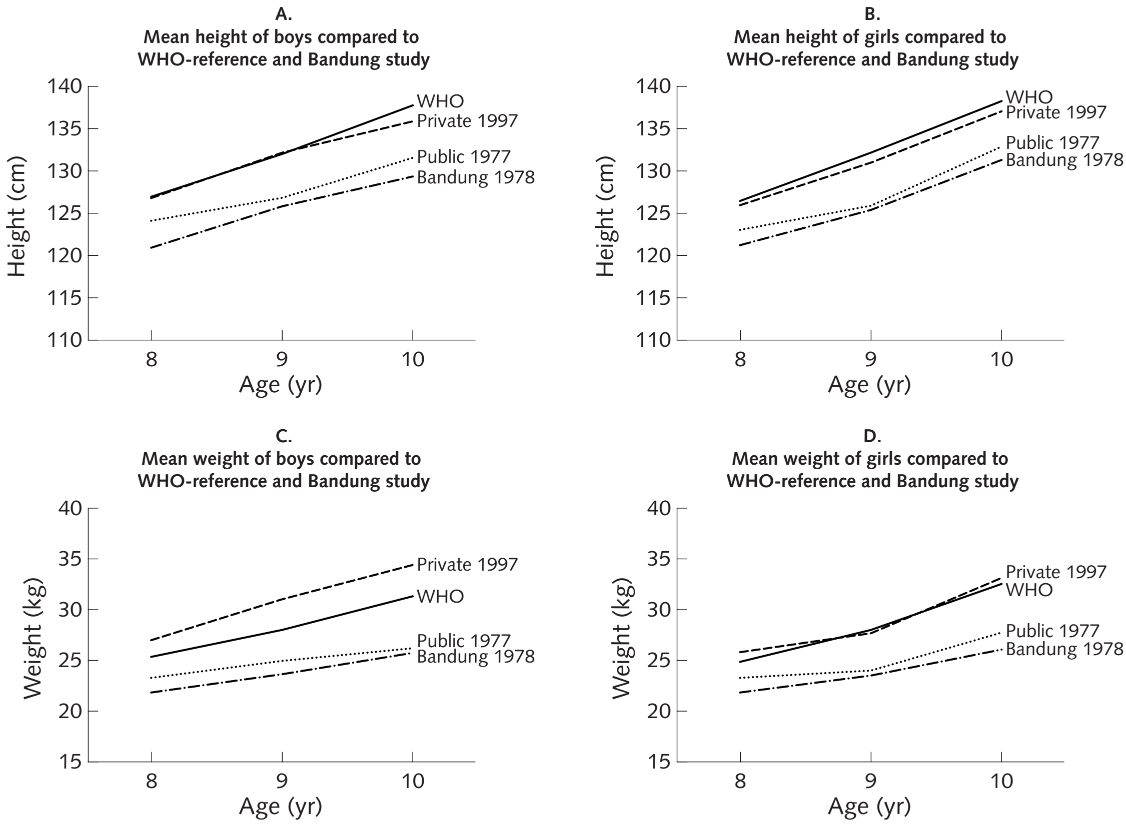

FIG. 1. Mean height of (A) boys and (B) girls, and mean weight of (C) boys and (D) girls, compared with WHO reference and Bandung study values

TABLE 2. Z score and prevalence of nutritional status according to sex, age and type of school, based on weight-for-age (WA) indicator

Sex and age (yr)	School	*n*	Mean ± SD WA Z score	Nutritional status (%)		
				< –2 SD	Normal	> 2 SD
Male						
8	Public	162	–0.7413 ± 1.3258	15.43	80.86	3.70
	Private	73	0.1885 ± 1.8307	9.59	80.82	9.59
	Both types	235	–0.4525 ± 1.5578	13.62	80.85	5.53
9	Public	152	–0.9142 ± 1.1451	11.18	86.18	2.63
	Private	75	0.3170 ± 1.8764	8.00	73.33	18.67
	Both types	227	–0.5074 ± 1.5381	10.13	81.94	7.93
10	Public	159	–1.1456 ± 0.9384	18.24	81.13	0.63
	Private	66	0.2079 ± 1.8566	7.58	75.76	16.67
	Both types	225	–0.7486 ± 1.4152	15.11	79.56	5.33
All ages	Public	473	–0.9328 ± 1.1584	15.01	82.66	2.33
	Private	214	0.2395 ± 1.8470	8.41	76.64	14.95
	Both types	687	–0.5676 ± 1.5092	12.95	80.79	6.26
Female						
8	Public	164	–0.5611 ± 1.1270	4.27	92.68	3.05
	Private	76	–0.0132 ± 1.5643	5.26	81.58	13.16
	Both types	240	–0.3876 ± 1.3036	4.58	89.17	6.25
9	Public	159	–1.0541 ± 0.8281	13.21	86.79	0.00
	Private	75	–0.3887 ± 1.1966	8.00	89.33	2.67
	Both types	234	–0.8408 ± 1.0082	11.54	87.61	0.85
10	Public	135	–0.9402 ± 0.9659	7.41	91.85	0.74
	Private	71	–0.1253 ± 1.2126	2.82	92.96	4.23
	Both types	206	–0.6594 ± 1.1237	5.83	92.23	1.94
All ages	Public	458	–0.8440 ± 1.0052	8.30	90.39	1.31
	Private	222	–0.1759 ± 1.3420	5.41	87.84	6.76
	Both types	680	–0.6259 ± 1.1681	7.35	89.56	3.09

situation based on weight-for-age, the pattern of overweight based on weight-for-height was not consistent across ages.

Mean BMI and prevalence of thinness and overweight

Table 5 presents the mean values of BMI according to sex, age, and type of school. In general, the mean value of BMI was higher among both boys and girls in private schools than among those in public schools, particularly for the older ages (9–10 years). In general, the prevalence of thinness (below the 5th percentile) among boys was higher in public schools than in private schools (27.48% for public schools and 16.36% for private schools), whereas among girls there was only a slight difference (18.78% for public schools and 16.22% for private schools). This finding was similar for each age group.

On the other hand, the prevalence of risk of obesity (≥ 85th percentile) was clearly higher among children in private schools than that among those in public schools. The risk of obesity was 32.74% for boys in private schools and 10.99% for those in public schools. For girls the prevalence of obesity was 21.17% for those in private schools and 12.45% for those in public schools. These findings were similar in all age groups for both boys and girls.

Discussion and conclusions

Nutritional status

In general, the nutritional status of urban schoolchildren aged 8 to 10 years in Bogor and Jakarta was better than that of children under 5 years of age. The prevalence of underweight was 7.4% in girls and 12.95% in boys, whereas in 1998 the prevalence of underweight among children under 5 years of age was 29.7%. Meanwhile, the prevalence of overweight (BMI ≥ 85th percentile) ranged from 15.3% in girls to 17.8% in boys. There were more overweight children in private schools than in public schools. The nutritional status of private schoolchildren, both in Jakarta and Bogor, was better than that of children in public

TABLE 3. Z score and prevalence of nutritional status according to sex, age, and type of school, based on height-for-age (HA) indicator

Sex and age (yr)	School	*n*	Mean ± SD HA Z score	Nutritional status (%)		
				< –2 SD	Normal	> 2 SD
Male						
8	Public	162	–0.5150 ± 1.1820	8.02	91.36	0.62
	Private	73	0.0305 ± 1.3486	5.48	89.04	5.48
	Both types	235	–0.3456 ± 1.2589	7.23	90.64	2.13
9	Public	152	–0.8990 ± 1.0184	16.45	83.55	0.00
	Private	75	0.0244 ± 1.3826	4.00	90.67	5.33
	Both types	227	–0.5939 ± 1.2281	12.33	85.90	1.76
10	Public	159	–0.9360 ± 1.3936	19.50	76.10	4.40
	Private	66	–0.2382 ± 1.2907	7.58	87.88	4.55
	Both types	225	–0.7313 ± 1.3981	16.00	79.56	4.44
All ages	Public	473	–0.7799 ± 1.2228	14.59	83.72	1.69
	Private	214	–0.0545 ± 1.3425	5.61	89.25	5.14
	Both types	687	–0.5540 ± 1.3044	11.79	85.44	2.77
Female						
8	Public	164	–0.5351 ± 0.9776	4.88	94.51	0.61
	Private	76	–0.0771 ± 1.2381	6.58	86.84	6.58
	Both types	240	–0.3900 ± 1.0855	5.42	92.08	2.50
9	Public	159	–0.9680 ± 1.2493	15.09	84.28	0.63
	Private	75	–0.1672 ± 1.1597	4.00	94.67	1.33
	Both types	234	–0.7113 ± 1.2750	11.54	87.61	0.85
10	Public	135	–0.7629 ± 1.1225	13.33	85.93	0.74
	Private	71	–0.1643 ± 1.2121	4.23	92.96	2.82
	Both types	206	–0.5565 ± 1.1860	10.19	88.35	1.46
All ages	Public	458	–0.7525 ± 1.1327	10.92	88.43	0.66
	Private	222	–0.1354 ± 1.1991	4.95	91.44	3.60
	Both types	680	–0.5510 ± 1.1897	8.97	89.41	1.62

schools. This result is in agreement with the use of school status (public or private) as a proxy for social and economic status of the parents. Parents of children from private schools were better educated than those of children from public schools.

The anthropometric data also demonstrated that the growth pattern of children from private schools on average was close to the WHO reference standard. This supports the established concept that the growth potential of underprivileged children is influenced more by environmental conditions than genetic factors [15].

Linear growth achievement

The study found that the younger children were taller relative to the older children when they were the same age. Schoolchildren's height has been considered a valid indicator of the nutritional status of the population and a proxy for the socioeconomic condition of the population [16, 17]. The linear growth of the school-age children is the reflection of their nutritional status during the preschool period, particularly during their critical growth period (the first two years of life).

This study showed that the average growth of 8-year-old children is better than that of 9-year-old children and that of 9-year-old children is better than that of 10-year-old children. In addition, the average linear growth of children from families of higher socioeconomic status (those attending private schools) is better than that of children from families of lower socioeconomic status (those attending public schools). Assuming that the measurement errors are random across study subjects, the differences might be associated with nutritional status during the preschool period. The question is, What was happening during their critical growth period? At the time of the study, the critical growth years for children currently 8 years old occurred in 1990 to 1991; for children 9 years old, it occurred in 1989 to 1990; and for children 10 years old, it occurred in 1988 to 1989. During the critical growth period of these children, other sources of data indicated that there had been a continuous improvement of the nutritional status of children aged 0 to 5 years [18]. This improvement is likely to be reflected in school-aged children. The nutritional status of

TABLE 4. Z score and prevalence of nutritional status according to sex, age, and type of school, based on weight-for-height (WH) indicator

Sex and age (yr)	School	*n*	Mean ± SD WH Z score	Nutritional status (%)		
				< –2 SD	Normal	> 2 SD
Male						
8	Public	161	−0.4892 ± 1.3124	7.45	86.96	5.59
	Private	72	0.1318 ± 1.5357	4.17	84.72	11.11
	Both types	233	−0.2973 ± 1.4115	6.44	86.27	7.30
9	Public	152	−0.4108 ± 1.3683	5.92	86.84	7.24
	Private	73	0.4834 ± 1.7907	2.74	76.71	20.55
	Both types	225	−0.1207 ± 1.5713	4.89	83.56	11.56
10	Public	151	−0.5109 ± 1.1507	5.30	91.39	3.31
	Private	57	0.2205 ± 1.4937	5.26	82.46	12.28
	Both types	208	−0.3105 ± 1.2923	5.29	88.94	5.77
All ages	Public	464	−0.4706 ± 1.2793	6.25	88.36	5.39
	Private	202	0.2839 ± 1.6209	3.96	81.19	14.85
	Both types	666	−0.2417 ± 1.4332	5.56	86.19	8.26
Female						
8	Public	161	−0.1965 ± 1.2813	3.73	90.68	5.59
	Private	71	−0.0855 ± 1.2303	0.00	94.37	5.63
	Both types	232	−0.1625 ± 1.2643	2.59	91.81	5.60
9	Public	154	−0.3711 ± 1.6293	3.90	92.86	3.25
	Private	59	−0.5215 ± 1.0006	6.78	93.22	0.00
	Both types	213	−0.4127 ± 1.4813	4.69	92.96	2.35
10	Public	95	−0.5320 ± 1.0717	6.32	92.63	1.05
	Private	39	0.0763 ± 2.1726	0.00	92.31	7.69
	Both types	134	−0.3549 ± 1.4957	4.48	92.54	2.99
All ages	Public	410	−0.3398 ± 1.3843	4.39	91.95	3.66
	Private	169	−0.2004 ± 1.4503	2.37	93.49	4.14
	Both types	579	−0.2991 ± 1.4041	3.80	92.40	3.80

younger children is relatively better than that of the older children when they were the same age.

Comparability of different anthropometric indices: wasting (weight-for-height) versus thinness (BMI) indicators

Anthropometric data analysis revealed that the BMI indicator of “thinness” (based on NHANES reference values) might not provide similar information to weight-for-height as an indicator of wasting. The proportion of wasted (< –2 SD weight-for-height) and thin (below the 5th percentile of BMI) children is not the same. The figure is higher when the BMI is used than when the weight-for-height indicator is used. Therefore, using the 5th percentile of BMI to detect wasting results in more false positives.

To determine overweight, this study analyzed the use of BMI and the Z scores for weight-for-age, height-for-age, and weight-for-height. BMI proved to be comparable with other indices for detecting overweight among children aged 8 to 10 years. However, BMI is not appropriate for detecting wasting and thinness for that age group. Therefore, the use of the tables from WHO [11] and Must et al. [12] to assess nutritional status should be considered.

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TABLE 5. BMI and prevalence of obesity according to sex, age, and type of school

Sex and age (yr)	School	n	Mean ± SD BMI (kg/m^2)	Prevalence of obesity (%) < 5th percentile	Normal	> 85th percentile
Male						
8	Public	162	15.10 ± 2.41	23.46	58.64	17.90
	Private	73	16.52 ± 3.15	13.70	43.84	42.47
	Both types	235	15.54 ± 2.73	20.43	54.04	25.53
9	Public	152	15.41 ± 2.54	24.34	66.45	9.21
	Private	75	17.60 ± 4.32	20.00	49.33	30.67
	Both types	227	16.13 ± 3.39	22.91	60.79	16.30
10	Public	159	15.18 ± 2.37	34.59	59.75	5.66
	Private	66	18.29 ± 4.80	15.15	60.61	24.24
	Both types	225	16.09 ± 3.56	28.89	60.00	11.11
All ages	Public	473	15.22 ± 2.44	27.48	61.52	10.99
	Private	214	17.45 ± 4.17	16.36	50.93	32.71
	Both types	687	15.92 ± 3.25	24.02	58.22	17.76
Female						
8	Public	164	15.34 ± 2.46	6.10	67.68	26.22
	Private	76	16.10 ± 2.96	3.95	63.16	32.89
	Both types	240	15.58 ± 2.64	5.42	66.25	28.33
9	Public	159	15.17 ± 2.42	27.04	69.18	3.77
	Private	75	15.83 ± 2.34	24.00	66.67	9.33
	Both types	234	15.38 ± 2.41	26.07	68.38	5.56
10	Public	135	15.62 ± 2.31	24.44	69.63	5.93
	Private	71	17.54 ± 3.61	21.13	57.75	21.13
	Both types	206	16.28 ± 2.96	23.30	65.53	11.17
All ages	Public	458	15.37 ± 2.40	18.78	68.78	12.45
	Private	222	16.47 ± 3.08	16.22	62.61	21.17
	Both types	680	15.73 ± 2.69	17.94	66.76	15.29

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Regional study of nutritional status of urban primary schoolchildren. 3. Kuala Lumpur, Malaysia

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Abstract

A total of 5,995 children (7.8% of all 7- to 10-year-old primary schoolchildren in Kuala Lumpur), randomly selected from 166 schools (97.6% of all schools), were measured for their weight and height. The analyses of all weight and height data, including the cutoffs used for defining stunting, underweight, and wasting and for thinness and overweight, were carried out as recommended by the World Health Organization (WHO). The prevalences of stunting (height-for-age Z score < –2 SD), underweight (weight-for-age Z score < –2 SD) and wasting (weight-for-height Z score < –2 SD) among all the children studied were 6.7%, 7.1%, and 4.5%, respectively. Undernutrition among boys was more serious than among girls according to all three indicators. Because it was not possible to analyze the weight-for-height data for most of the children above 8.5 years of age, body mass index (BMI)-for-age was used to determine the prevalences of thinness and overweight for all the children. Based on the reference data, the prevalence of overweight (at or above the 95th percentile) was 9.7% and 7.1% for boys and girls, respectively, and 8.4% overall.

Introduction

As a result of rapid socioeconomic development in Southeast Asia in the last 30 years, countries in the region are being confronted with both extremes of malnutrition, wherein undernutrition coexists with overnutrition problems. Nutritional deficiencies are slowly being reduced or eradicated in many of these countries. On the other hand, coronary heart disease, cancer, and diabetes have now become major health problems, particularly in urban areas. As countries in the region continue to develop rapidly, the nutritional situations are expected to change rapidly as well. It is thus important to continue to monitor the nutritional status of all community groups, including that of schoolchildren.

The rising prevalence of obesity among children and adolescents is of particular concern to many health authorities. However, there is currently a lack of adequate baseline data on the extent of the problem in the region. There has been no national nutrition survey in Malaysia. Nutritional studies of communities have thus far been conducted on specific population groups, most often in rural areas.

The International Life Sciences Institute (ILSI) (Branch) has therefore coordinated studies in three South Asia countries, Philippines, Indonesia, and Malaysia, to provide an understanding of the nutritional status (as determined by weight and height) and the dietary, and physical activity patterns of urban primary schoolchildren. The data were obtained to assist health authorities in the formulation, implementation, and evaluation of intervention programs among this important target group.

Similar approaches were used in the studies in Manila, Kuala Lumpur, Jakarta, and Bogor. This paper presents findings obtained for children in Kuala Lumpur, Malaysia.

Subjects and methods

A list of all primary schools in Kuala Lumpur was obtained from the Education Department. Visits were made to each school to obtain a list of all children in primary grades 2 to 4 (ages 7 to 10 years). A master list was then prepared for the classes within each school and the children within each class. Starting with a randomly selected number, every 10th child on the master list was selected for inclusion in the study for measurement of body weight and height. Basic socio-

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economic indicators were also collected from each child. From this group, 10% were randomly selected for determination of food consumption, activity patterns, and food beliefs and attitudes of the children and their parents.

Weight and height measurements were obtained by using an electronic beam balance with a height attachment. The study team carried the scale to the schools and calibrated the instrument before use. The scale measured body weight to the nearest 0.1 kg and height to the nearest 0.1 cm. Information on activity patterns, food intake, beliefs and attitudes, and socioeconomic indicators was obtained by using a set of structured questionnaires. These results will be presented in other papers in this series.

Data collection

Weight and height measurements of the children were analyzed for height-for-age, weight-for-age, and weight-for-height Z scores using the Anthro software of the Centers for Disease Control (Atlanta, Ga., USA). Malnourished children were identified as those with Z scores less than –2 SD of the median for the three indicators, which indicate the prevalence of underweight, stunting, and wasting, respectively. Children were considered overweight when their weight-for-height Z scores were greater than 2 SD of the NCHS reference. For children more than 9 years of age, the body mass index (BMI)-for-age was used to determine the prevalence of thinness and overweight of these children, using less than the 5th percentile and equal to or greater than the 85th percentile of the first National Health and Nutrition Survey (NHANES I) [1], respectively. The analyses of all weight and height data, including the cutoffs used for defining stunting, underweight, and wasting and for thinness and overweight, were based on World Health Organization (WHO) recommendations [2].

All data obtained, including socioeconomic data, weight, and height, and nutrient intake were entered into dBase software (Borland International, Scotts Valley, Calif., USA) and analyzed using the SPSS for windows version 8.0 software (SPSS, Chicago, Ill., USA). Independent sample *t*-tests were used to compare means between boys and girls. In all statistical analyses, $p < .05$ was taken as significant.

Results and discussion

Mean weight, height, and BMI

In 1996 we measured the weights and heights of 5,995 primary schoolchildren, 7 to 10 years old (representing 7.8% of all children in the age group), in 166 schools (97.6% of all schools) in Kuala Lumpur.

The mean weight, height, and BMI of the children, presented for boys and girls and for each age group, are shown in table 1. There was no significant difference in mean weight between the boys and girls for all the age groups, except for the 8-year-old children. In the latter group, the boys were significantly heavier than the girls. There was no consistent difference in height between the boys and girls within each of the four age groups. The boys appeared to be taller than the girls for the 7- and 8-year-old groups, but only the mean height for the latter age group was significantly different. For the 9- and 10-year-old groups, the converse was true: the mean height for girls was significantly greater than

TABLE 1. Weight, height, and BMI of schoolchildren according to sex and age

Sex and age (yr)[a]	*n*	Mean ± SD weight (kg)	Mean ± SD height (cm)	Mean ± SD BMI (kg/m²)
Male				
7	341	24.3 ± 5.5	123.8 ± 5.8	15.7 ± 2.6
8	1,066	26.5 ± 6.7	126.9 ± 6.1	16.3 ± 3.1
9	958	28.8 ± 7.6	131.2 ± 6.5	16.6 ± 3.3
10	672	32.1 ± 8.7	135.9 ± 6.9	17.2 ± 3.5
Female				
7	311	23.9 ± 5.5	123.4 ± 5.9	15.6 ± 2.7
8	1,053	25.5 ± 6.0	126.4 ± 6.1	15.8 ± 2.8
9	941	29.1 ± 7.6	132.1 ± 7.3	16.5 ± 3.1
10	653	32.0 ± 8.2	136.9 ± 7.3	16.9 ± 3.2
Both sexes				
7	652	24.1 ± 5.5	123.6 ± 5.9	15.7 ± 2.6
8	2,119	26.0 ± 6.4	126.7 ± 6.1	16.1 ± 3.0
9	1899	28.9 ± 7.6	131.7 ± 6.9	16.5 ± 3.2
10	1,325	32.1 ± 8.4	136.4 ± 7.1	17.1 ± 3.3

a. *N* for boys = 3,037; *N* for girls = 2,958; total *N* = 5,995.

that for boys. The mean BMI for boys was higher than that for girls in all age groups, but only the difference for the 8-year-old group was statistically significant.

Prevalence of undernutrition

The prevalences of stunting (height-for-age Z score < –2 SD), underweight (weight-for-age Z score < –2 SD), and wasting (weight-for-height Z score < –2 SD) among the whole group of schoolchildren studied were 6.7%, 7.1%, and 4.5%, respectively (table 2). Undernutrition was more serious among boys than girls. The prevalence of stunting was higher among boys (7.9%) than girls (5.5%). The prevalence of underweight was also higher among boys (7.7%) than girls (6.4%). The difference in wasting between boys and girls was less marked: 4.7% for boys and 4.4% for girls.

The mean height-for-age Z score of the boys was significantly lower than that of the girls, whereas the mean values of weight-for-age Z score and weight-for-height Z score of the girls were significantly lower.

Differences in growth and in the prevalence of undernutrition were observed between boys and girls within each of the four age groups of children studied (table 2 and fig. 1). The height-for-age of boys was generally poorer than that of girls. The mean height-for-age Z score of boys was lower than that of girls in all age groups. The difference was only statistically significant for the 9-year-old children and when all age groups were combined. In addition, the percentage of boys found to be stunted (height-for-age Z score < –2 SD) was about 1.2 to 1.6 times higher than the girls for all age groups. The prevalence of stunting was 7.9% among all boys and 5.5% among all girls.

In terms of underweight (weight-for-age Z score < –2 SD), the growth of boys was also generally less satisfactory than that of girls. Except for the 10-year-old group, the prevalence of underweight among boys was 1.2 to 2.1 times higher than among girls in all age groups. For the oldest group of children, the prevalence of underweight among girls was 1.1 times higher than that among boys (8.0% and 7.3%, respectively). There was no clear pattern in the difference between mean

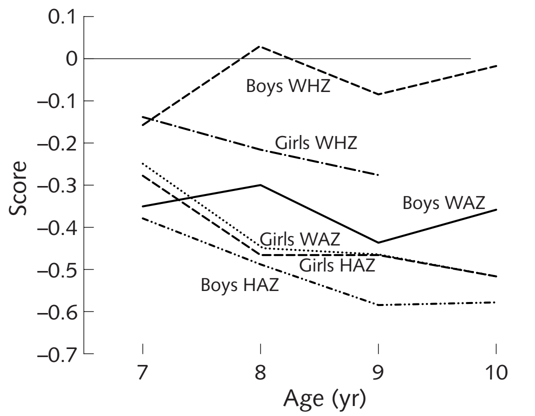

FIG. 1. Mean height-for-age (HAZ), weight-for-age (WAZ), and weight-for-height (WHZ) scores according to age and sex

TABLE 2. Height-for-age, weight-for-age, and weight-for-height of schoolchildren according to sex and age

Sex and age (yr)	Height-for-age			Weight-for-age			Weight-for-height			
	n[a]	Mean ± SD Z score	< –2 SD (%)	*n*[a]	Mean ± SD Z score	< –2 SD (%)	*n*[a]	Mean ± SD Z score	< –2 SD (%)	> +2 SD (%)
Male										
7	341	–0.38 ± 1.08	5.0	341	–0.35 ± 1.43	7.9	341	–0.16 ± 1.42	4.4	9.1
8	1,065	–0.49 ± 1.06	7.5	1,066	–0.30 ± 1.47	7.0	1,056	0.03 ± 1.53	4.6	11.6
9	955	–0.59 ± 1.07	9.0	957	–0.44 ± 1.37	8.9	930	–0.09 ± 1.41	5.1	8.0
10	672	–0.58 ± 1.08	8.4	671	–0.36 ± 1.30	7.3	610	–0.02 ± 1.36	4.3	8.5
All ages	3,033	–0.53 ± 1.07	7.9	3,035	–0.36 ± 1.40	7.7	2,937	–0.04 ± 1.45	4.7	9.5
Female										
7	311	–0.28 ± 0.98	2.9	311	–0.25 ± 1.27	3.2	307	–0.14 ± 1.39	3.9	7.8
8	1,053	–0.47 ± 0.94	5.3	1,053	–0.45 ± 1.19	5.9	1,006	–0.22 ± 1.23	4.6	5.0
9	939	–0.47 ± 1.05	5.5	941	–0.47 ± 1.22	7.0	723	–0.28 ± 1.16	4.6	4.4
10	649	–0.52 ± 1.03	7.1	653	–0.52 ± 1.16	8.0	0	—	—	—
All ages	2,952	–0.46 ± 1.00	5.5	2,958	–0.45 ± 1.20	6.4	2,036	–0.23 ± 1.23	4.4	5.1
Both sexes										
7	652	–0.33 ± 1.03	4.0	652	–0.31 ± 1.36	5.7	648	–0.15 ± 1.40	4.2	8.5
8	2,118	–0.48 ± 1.00	6.4	2,119	–0.37 ± 1.34	6.4	2,062	–0.09 ± 1.39	4.6	8.4
9	1,894	–0.53 ± 1.06	7.3	1,898	–0.45 ± 1.29	8.0	1,653	–0.17 ± 1.31	4.9	6.4
10	1,321	–0.55 ± 1.05	7.8	1,324	–0.44 ± 1.24	7.6	—	—	—	
All ages	5,985	–0.49 ± 1.04	6.7	5,993	–0.41 ± 1.30	7.1	4,973	–0.12 ± 1.36	4.5	7.7

a. The numbers of subjects are less than the numbers analyzed for weight and height because some of the measurements exceeded the capability of the Anthro program.

weight-for-age Z score of boys and girls. The mean weight-for-age Z score of girls was significantly lower than that for 8- and 10-year-old boys and for all the age groups combined.

Weight-for-height Z score could not be analyzed for about 3% of the boys and 30% of the girls. This was because the Anthro software program, which is based on the NCHS data, has an inherent limit to the maximum height and age that it can handle. Thus, it was not possible to compare the weight-for-height Z scores of 10-year-old boys and girls.

The difference in mean weight-for-height Z score of the children followed the same pattern as that observed for weight-for-age Z score. The mean weight-for-height Z score of girls was significantly lower than that of 8- and 9-year-old boys and for all the age groups combined. Except for 8-year-old children, in which there was no difference between boys and girls, the prevalence of wasting was 1.1 times higher among boys and for all age groups combined. The overall prevalence was 4.7% for boys and 4.4% for girls.

Prevalence of overweight

The prevalence of overweight (weight-for-height Z score > 2 SD) was 7.7% (table 2). This was about 1.6 times greater than the prevalence of wasting. The prevalence of overweight among boys (9.5%) was about 1.9 times greater than that among girls (5.1%). For all age groups, this prevalence was 1.2 to 2.3 times higher in boys. As explained earlier, the weight-for-height Z scores for 10-year-old girls could not be analyzed by the Anthro program.

Prevalence of thinness and overweight according to BMI-for-age

Because it was not possible to analyze about 30% of the weight-for-height data for girls, especially the older children, BMI-for-age was used to determine the prevalences of thinness and overweight of all the children in the study. The prevalence of thinness (BMI < 5th percentile of NHANES I reference data [1]) was 13.7% for boys (*N* = 3,037) and 15.4% for girls (*N* = 2,958); the combined prevalence for both was 14.5% (*N* = 5,995). The prevalence of risk of overweight (≥ 85th percentile of NHANES I reference data) was 19.2% for boys and 16.5% for girls, with a combined prevalence of 17.8% (table 3).

When the prevalences based on BMI-for-age are compared with figures derived from weight-for-height Z scores based on the NCHS reference (table 3), the prevalence of thinness was found to be about three times higher, whereas the prevalence of overweight was about two to three times higher. The comparisons made are not strictly valid, because the children in both groups are not exactly the same. Further investigations were therefore carried out by analyzing the prevalences of thinness and overweight for the same group of children using the two methods.

The group of children that could be analyzed by both methods consisted of 2,937 boys and 2,036 girls under 8.5 years of age. Table 4 shows that using BMI-for-age gave a three-times-higher prevalence of thinness among boys. The prevalence of thinness based on weight-for-height Z score was therefore only about

TABLE 4. Comparison of prevalence of thinness using weight-for-height Z scores and BMI-for-age for the same group of children

Sex and age (yr)	*n*	< –2 SD (%)	< 5th percentile (%)	BMI
Male				
7	341	4.4	6.2	1.4
8	1,056	4.6	11.5	2.5
9	930	5.1	17.0	3.3
10	610	4.3	18.0	4.2
All ages	2,937	4.7	14.0	3.0
Female				
7	307	3.9	9.4	2.4
8	1,006	4.6	15.7	3.4
9	723	4.6	18.4	4.0
10	0	—	—	—
All ages	2,036	4.4	15.7	3.6

TABLE 3. Comparison of prevalence of thinness using the weight-for-height Z scores and BMI-for-age[a]

Subjects	Weight-for-height Z score			BMI-for-age		
	n	< –2 SD (%)	> 2 SD (%)	*n*	< 5th percentile (%)	≥ 85th percentile (%)
Boys	2,937	4.7	9.5	3,037	13.7	19.2
Girls	2,036	4.5	5.2	2,958	15.4	16.5
Both sexes	4,973	4.6	7.7	5,995	14.5	17.8

a. The children analyzed using the two methods were not exactly the same; the sample sizes were also different.

4.7%, whereas the prevalence based on BMI-for-age was 14%. It can also be noted that this difference in the prevalence of thinness obtained by the two methods increased with the age of the children. A similar difference was observed for girls. In table 5, a similar tabulation for the prevalence of overweight analyzed by the two methods shows that when the cutoff point was at or above the 85th percentile of BMI-for-age, the prevalence for both sexes was about 2 to 2.5 times higher than obtained by using the weight-for-height Z score.

When the prevalence of overweight was analyzed using a cutoff point at or above the 95th percentile of the NHANES I reference data [1], the results were much closer to those obtained using –2 SD of the weight-for-height Z score (table 5); the ratios ranged from 0.7 to 1.3. The prevalence of overweight was 8.6% for boys and 5.3% for girls. It is to be noted that these children are a subsample of the study subjects, selected only to demonstrate the difference between the two methods of analysis.

The prevalence of overweight was determined for all the children in the study based on a cutoff point at or above the 95th percentile of the reference data. The data in table 6 can be taken as an estimate of the prevalences of overweight: 9.7% for boys and 7.1% for girls. The prevalences for each of the age groups for the boys and girls are also given in the table. The prevalence was slightly lower among girls. For children of both sexes, the prevalence declined with increasing age.

Comparison with rural primary schoolchildren

The prevalence of undernutrition among subjects in this study was much lower than that found in a study of rural schoolchildren [3] of about the same age that was conducted at almost the same time as this study. The sample consisted of 1,057 boys and 1,069 girls (*N* = 2,126) in 69 villages and seven estates located in nine states in peninsular Malaysia. The prevalence of stunting and underweight was about four times higher among the rural children, and the prevalence of wasting was about 1.6 times higher (table 7). The same difference was observed for both boys and girls.

The prevalence of the risk of overweight among this group of urban schoolchildren (7.7%) was about four times higher than that reported for rural primary

TABLE 5. Comparison of prevalence of overweight using the weight-for-height Z scores and BMI-for-age for the same group of children

Sex and age (yr)	*n*	> 2 SD (%)	≥ 85th percentile (%)	BMI/NCHS % ≥ 85th percentile/ % > 2 SD	≥ 95th percentile %	BMI/NCHS % ≥ 95th percentile/ % > 2 SD
Male						
7	341	9.1	16.2	1.8	10.3	1.1
8	1,056	11.9	20.0	1.7	10.6	0.9
9	930	8.0	16.0	2.0	7.3	0.9
10	610	8.5	17.2	2.0	6.4	0.8
All ages	2,937	9.6	17.7	1.8	8.6	0.9
Female						
7	307	7.8	17.9	2.3	10.1	1.3
8	1,006	5.0	13.5	2.7	5.3	1.1
9	723	4.4	11.1	2.5	3.2	0.7
10	0	—	—	—	—	—
All ages	2,036	5.3	13.3	2.5	5.3	1.0

TABLE 6. Prevalence of overweight among all subjects based on cutoff point of ≥ 95th percentile of BMI-for-age

	Boys		Girls		Both sexes	
Age (yr)	*n*	Prevalence (%)	*n*	Prevalence (%)	*n*	Prevalence (%)
7	341	10.3	311	10.3	652	10.3
8	1,066	11.2	1,053	7.2	2,119	9.2
9	958	8.9	941	7.0	1,899	8.0
10	672	8.5	653	5.5	1,325	7.0
All ages	3,037	9.7	2,958	7.1	5,995	8.4

TABLE 7. Prevalence of undernutrition among urban and rural primary schoolchildren

	Height-for-age		Weight-for-age		Weight-for-height	
Children	*n*	< –2 SD (%)	*n*	< –2 SD (%)	*n*	< –2 SD (%)
Urban						
Boys	3,033	8.1	3,035	7.9	2,937	4.8
Girls	2,952	5.6	2,958	6.8	2,036	4.5
Both sexes	5,985	6.9	5,993	7.4	4,973	4.6
Rural[a]						
Boys	1,049	34.4	1,057	29.1	950	8.2
Girls	1,066	24.9	1,069	26.1	731	6.2
Both sexes	2,115	29.6	2,126	26.9	1,681	7.3
Rural and urban						
Boys	4,082	4.4	4,092	3.7	3,887	1.7
Girls	4,018	4.5	4,027	4.1	2,767	1.4
Both sexes	8,100	4.4	8,119	3.8	6,654	1.6

a. Data from World Health Organization [2].

schoolchildren (1.9%) [3] (table 8). The prevalence of overweight among rural boys and girls was approximately the same at 2.0%. On the other hand, the prevalence of overweight among urban boys was about twice that among urban girls.

Conclusions

The mean weights and heights of boys were greater than those of girls for the younger age groups (7 and 8 years). As the ages increased (9 and 10 years), the reverse was true and the girls were heavier and taller than the boys. The mean BMI was generally greater for boys in all age groups. Undernutrition, as determined by the prevalences of stunting, underweight, and wasting, was also more serious among the boys, particularly as measured by stunting and underweight.

The prevalence of overweight was higher than that of wasting for both boys and girls in all age groups. Boys had a slightly higher prevalence of overweight than girls; the difference was larger for the older children. Both undernutrition and overweight were more frequent among boys. The prevalence of undernutrition among the urban study subjects (less than 8%) was much less than that among rural primary schoolchildren. On the other hand, the prevalence of overweight (about 8%) was much greater than among rural children (about 2%). The factors responsible for this difference in nutrition between rural and urban children should be investigated to provide useful lessons for the prevention and control of overweight.

TABLE 8. Prevalence of overweight among urban and rural schoolchildren

Children	*n*	> 2 SD (%)
Urban		
Boys	2,937	9.5
Girls	2,036	5.2
Both sexes	4,973	7.7
Rural[a]		
Boys	1,731	2.0
Girls	1,544	1.9
Both	3,275	1.9
Urban and rural		
Boys	4,668	4.8
Girls	3,580	2.7
Both sexes	8,248	4.1

a. Data from World Health Organization [2].

The analysis of weight and height measurements in this study was complicated by the fact that the study subjects ranged from 7 to 10 years old, consisting of younger primary schoolchildren in the prepuberty age group. As is well known, the NCHS data in the Anthro program are not appropriate for analyzing children over 9 years of age. The results of investigations into the use of weight-for-height Z score and BMI-for-age for the determination of thinness and overweight have been discussed earlier.

The analyses suggested that the use of cutoff points of less than the 5th percentile and equal to or greater than the 85th percentile for determining the prevalences of thinness and overweight, respectively, as recommended by WHO [2], may not be appropriate. These indicators appeared to have overestimated the prevalences by a magnitude of about two to three. To overcome the problem for overweight, the cutoff was set at at or above the 95th percentile, and the figures obtained are felt to be more realistic. The use of less than the 3rd percentile of the reference data for underweight would probably give prevalence data closer to those obtained by using the weight-for-height Z score.

It is important to determine whether these findings of differences in prevalences of thinness and overweight using the two methods of analysis are observed for other communities. It may be necessary to change the cutoffs. Since investigators would be following the WHO guidelines [2] in reporting the prevalence of overweight among adolescents, these differences would have widespread implications for programs and policies.

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Do street food vendors sell a sufficient variety of foods for a healthful diet? The case of Nairobi

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Abstract

This study examined whether street food vendors sell a sufficient variety of foods for a healthful diet. It was hypothesized that vendors sold only low-cost food groups to enable the buyer to afford the food while the vendor also made a profit. A structured questionnaire was administered to 580 vendors in three selected locations. Data included product names, ingredients, methods of preparation, and the sex of the vendor. A little more than half of the vendors (53%) sold food of only one group; 44% sold cereals. Overall, 36% of vendors, mostly men, sold only carbohydrate products. The percentage of vendors selling foods of more than one group was higher in the working area (53%) than in the slum area (43%, $p < .05$), and it was higher in both of these areas taken together than in the lower-middle income area (21%, $p < .001$). Micronutrient and mixed-nutrient products were associated with female vendors. Although a slight majority of all street vendors sell foods of only one group, women vendors are capable of supplying a sufficient variety of food groups that consumers can afford. It appears that consumer purchasing power dictates the food groups provided by vendors, especially cereal-based-foods. A policy on micronutrient fortification of cereal flours and fats used in popular street food preparation needs to be considered. This could be coupled with consumer and vendor education programs focusing on the importance of healthful diets.

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Introduction

The majority of urban dwellers in sub-Saharan Africa countries are highly disadvantaged, with very limited purchasing power. Guaranteeing the efficient distribution of low-cost but nutritious food for them is, therefore, a pressing concern [1]. The Food and Agriculture Organization (FAO) has indicated that street food vendors provide nutritious and tasty ready-to-eat foods at low prices [2, 3]. In Calcutta, for instance, an average (500-g) meal containing 20 to 30 g of protein, 12 to 15 g of fat, 174 to 183 g of carbohydrates, and approximately 1,000 kcal can be purchased on the street for only US$0.25[4]. The literature indicates that many low-income families would be worse off if there were no vendors to serve fast and relatively inexpensive foods [5–9]. Street foods have been shown to contribute a substantial proportion of energy and protein (25% to 50%) of the recommended daily allowance (RDA) for adolescents attending school [10] and urban market women [11] in Nigeria. Furthermore, they play a considerable role in the daily diet of low-income male urban workers in Hyderabad [12], urban construction workers in Nairobi [13], and street traders in Calcutta [4]. Children are also said to benefit. In Cotonou, for instance, 46% of the meals consumed by children were reported to be from street foods [14]. In addition, street food vending is a source of employment in many developing countries. One can start with minimum capital and low education, yet it provides a good and reliable income [2, 5–7, 9, 15–17]. Street food vendors are increasingly gaining recognition as a necessary component of daily urban life.

Street food vending is present in many Kenyan urban areas, but information about it is scanty. Only one study has been carried out on the proximate composition and contribution of energy and protein of street foods in the diet of manual workers at construction sites in Nairobi [13]. The study showed that street foods provided 17% to 38% of the RDA for energy and more than 50% of the RDA for protein to their consumers. Construction workers perform heavy manual work and need high-energy meals. The study, therefore, addressed only a section of street foods in Nairobi, since it did not include other vending sites, such as low-income residential areas.

Access to a variety of foods improves and maintains the quality of the diet. Urban diet quality, however, depends basically on the sanitary state of the environment and the purchasing power of consumers [18]. Income levels are a major determinant of the degree of access to food and of the nature of food choice [19]. This does not augur well for the urban poor in sub-Saharan Africa. Thus, if street foods are cheap and poor families therefore rely on them, one wonders whether they are heterogeneous enough to provide an adequately nutritious diet, as is frequently alleged in the literature. It has been thought that vendors can sell food cheaply because they obtain raw foodstuffs and cooking fuel in bulk at wholesale prices [20]. However, when buying in bulk a vendor may require considerable capital to offer a variety of foods. Hence, starting with only a little capital, vendors may not be able to provide heterogeneous food group products. In addition, since the main consumers of street foods are the urban poor, the foods must be offered cheaply while still providing profit, and thus variety may not be a priority. Therefore, it was hypothesized that vendors sold food items made mostly from foods of low-cost groups that are not heterogeneous enough to provide an adequately nutritious diet. In addition, because they are more skillful in food preparation, female vendors were expected to provide more variety than males. No study has addressed the issue of street food presentation by vendors in terms of food group variety. The objective of this study was, therefore, to determine whether street food vendors provide sufficient food group varieties for a healthful diet, with special reference to Nairobi. It also examined the links between food group array and study locations, as well as the sex of the vendor. The paper attempts to answer the following questions: What food groups dominate the street food sector in Nairobi? Do vendors present these food groups in a manner that they provide sufficient variety for nutritional adequacy?

Study setting and methods

The study took place in October and November 1997 as part of a larger survey of street foods in Nairobi. It was reviewed and approved by the Research Authorising Board in the Office of the President of Kenya in August 1997. Nairobi, the capital city, was selected because it houses people from all ethnic groups and races and was thought to be more representative than any other city.

Three areas, representing a very low-income slum settlement (Korogocho), a lower-middle income residential area (Dandora), and a working area (the industrial area) were selected on the basis that they were frequented by street food vendors. Rated according to household income, Korogocho is one of the very low-income districts in Nairobi [21]. Dandora is a lower-middle income district, and the industrial area is the only one designated as the general business area of Nairobi. These areas were thought to be representative enough, since a prior exploration of Nairobi had indicated similarities in the type of street foods sold in corresponding income areas within the city. Higher-income residential areas were not frequented by street food vendors and hence were not included. A cross-sectional general survey of all vendors found in the selected areas was carried out. To incorporate vendors selling foods for only part of the day, vending sites were visited at three different times (7–10 a.m., 12 noon–2 p.m., and 4–7 p.m.). The respondents in the study were 177 of the 229 vendors in the Korogocho slums, 150 of the 153 vendors in Dandora (the lower-middle income area), and 253 of the 264 vendors in the industrial area. Nonresponse was due to inability to respond correctly or refusal to cooperate by the vendor. The proportion of nonparticipation in Korogocho was higher because some vendors feared that the study would work against them by making the unhygienic aspects of their foods public. Although the field assistants tried their best to explain that this was not the case, some vendors still refused to cooperate. It was assumed that such vendors were spread over the study area and that they were not different from the respondents in terms of the types of food they sold; hence, their exclusion from the study was not expected to affect the outcome considerably. Trained field assistants administered a structured and pretested questionnaire to the respondents. Data on street food products included the names, ingredients, and method of preparation. The sex of the vendor was also recorded.

Based on the ingredients, street food products were classified according to the modified FAO food-commodity grouping system and the key nutrients. The FAO food-commodity grouping system is based on a commercial value system that groups foods into cereals, starchy roots and tubers, legumes and nuts, animal products, fruits and vegetables, and beverages. Although fruits and vegetables belong to one group, they are presented separately in the results to show study location and differences between men and women vendors. The mixed-dishes group consisted of items containing more than one food-group ingredient. The key-nutrient grouping included carbohydrate (cereals, starchy roots, and tubers), protein (animal products, legumes, and nuts), micronutrients (fruits and vegetables), and mixed nutrients (mixture of the key nutrients) in dishes.

To determine the nutrient contribution of some typical dishes from vendors selling foods of only one group and those selling foods of multiple groups, two vendors for each of the three most common dishes per category were selected, and a modified list-recall method [22] was used to estimate the quantities of ingredients used. Following the list of ingredients provided for each product or dish, vendors were asked to recall the usual quantities of each ingredient they used and the number of servings (including those consumed by family members) obtained per recipe. The quantities were reported in terms of weight and household or market measures. The household and market measures were converted to weights by taking weights of at least two of each of the various food ingredients according to the recorded measures. It was assumed that the ingredients used per recipe were evenly distributed among the servings. The amounts of energy and nutrients provided per serving were calculated from the Kenya food-composition table and compared with the RDAs of an average 65-kg Kenyan adult man doing light work, referred to as adult equivalents (AEs)[23]. The references used were 2,600 kcal of energy, 50 g of protein, 30% or less of energy from fat, 10 mg of iron, 750 μg of retinol equivalents (RE) for vitamin A, 500 mg of calcium, 1.2 mg of thiamine, and 1.8 mg of riboflavin [23]. We focused on energy and the listed nutrients because protein–energy malnutrition is the most devastating nutritional problem in Kenya and iron and vitamin A deficiencies are also reported to be major public health problems [24]. The extent of calcium, thiamine, and riboflavin deficiencies is not known in Kenya, but these deficiencies could be a problem where the diet is dominated by cereals, especially if the grain is refined.

Provitamin A carotenoids were converted to RE using the 6:1 ratio [23] and not the conversion ratio of 12:1 newly proposed by the Institute of Medicine [25].

Data were analyzed using SPSS for Windows. Frequencies were run to determine distributions. Proportions were compared using the chi-square and the phi and Cramer's *V* statistics. The level of significance was set at $p = .05$.

Results

Street food products and food groups

Seventy-seven different street food products were recorded in the study. Table 1 lists the most common products (sold by at least 30 vendors) and their food groups. The rest of the results are based on the 77 different products recorded in the study. Most of the foods belonged to the cereal food group, and they were mainly wheat- or maize-based.

Of the 580 vendors interviewed, 66% were women. The proportions of female vendors in Korogocho, Dandora, and the industrial area were 50%, 63%, and 78%, respectively. Of the 18 most common food products sold in Nairobi, 13 were significantly associated with the sex of the vendor (table 1). Food products from the cereal, animal products, and fruit and vegetable groups were associated with both male and female vendors. Products from the mixed dishes and the legume and nuts groups were associated with female vendors, whereas those from the beverage group were associated with male vendors. In the animal products group, fried fish was associated with female vendors,

TABLE 1. Food groups and food products commonly sold by street vendors in Nairobi[a]

Food group	Food product	Product description	No. of vendors selling ($N = 580$)	% of male vendors selling ($N = 199$)	% of female vendors selling ($N = 381$)
Mixed dishes	Githeri	Dish made from a mixture of maize and beans	78	7.0	16.3**
Cereals	Chapati	Pan-fried unleavened bread made from wheat	130	21.1	23.4
	Mandazi	Deep-fried leavened buns made from wheat	81	22.1**	9.7
	Mahindi chemsha	Boiled maize-on-cob	67	23.3	44.7**
	Ugali	Stiff porridge made from maize flour	59	14.6	7.3
	Mahindi choma	Maize-on-cob grilled on charcoal	53	13.1*	6.8
	Uji	Fermented porridge made from cereal flours	47	2.0	11.0***
	Biskuti	Biscuits	34	5.5	6.3
Meat, milk, poultry, fish	Nyama	Roasted, fried, or stewed meat	39	11.1**	4.5
	Samaki	Deep-fried fish	38	1.0	9.4***

a. Some vendors sold more than one food product.
*$p < .05$, ** $p < .01$, ***$p < .001$ by chi-square, phi, and Cramer's V statistics.

whereas roasted and fried meat was a man's business. In the fruit and vegetable group, fruits were associated with female vendors and vegetables with male vendors.

Street food groups and product varieties

The distribution of product varieties within food groups according to study location is presented in table 2. Korogocho, the slum settlement, was placed highest in product diversity, with 52 different products, as compared with 48 in the industrial area and 46 in Dandora. The animal products and cereal groups had the highest number of varieties. Except for the number of fruit varieties, there was no significant association between study location and number of varieties within food groups ($p < .05$).

Street food groups presentation

Two types of street food vendors were identified, those who sold food from one group and those who sold food from multiple groups. More than half (53%) of the vendors sold food from one group, and 44% of them sold only cereals or cereals cooked in fat. Table 3 presents the distribution of street food vendors according to food groups sold by study location. Although many vendors sold only cereal products in all three study areas, they were mostly associated with the Dandora lower-middle income area and least associated with the industrial area. There were no vendors of starchy roots in the industrial area. Few vendors sold only sugars and syrups, but they were mostly associated with the Korogocho slums ($p = .01$). The industrial area had the highest proportion of vendors selling legume and nut products, whereas Dandora had the highest proportion of vendors of animal products ($p = .001$). Less than half of the vendors sold mixed food groups; these vendors were the least associated with Dandora lower-middle income area ($p = .001$). It is worth noting that some vendors of food from only one group sold fruits, but only vendors of food

TABLE 2. Number of food products in different food groups sold by street vendors according to location in Nairobi

Food group	Total	Korogocho (slums)	Dandora (lower-middle income)	Industrial area
Mixed dishes	8	5	3	4
Cereals	16	13	12	14
Meat, milk, poultry, fish	17	12	9	6
Legumes, nuts	4	5	3	4
Vegetables	4	3	3	2
Fruits*	11	3	8	11
Starchy roots	6	3	1	2
Beverages	6	4	2	1
Sugars, syrups	4	4	4	4
Others	1	—	1	—

* $p < .05$ between study locations by chi-square, phi, and Cramer's V statistics.

TABLE 3. Percentage of street vendors selling foods of different groups according to location in Nairobi

Food group	Korogocho (slum) ($n = 177$)	Dandora (lower-middle income) ($n = 150$)	Industrial area ($n = 253$)	Total ($N = 580$)
Vendors selling food of only one group				
Cereals**	22.6	34.0	18.2	23.6
Starchy roots	5.6	5.3	—	3.1
Sugars, syrups*	6.2	0.7[a]	1.6	2.8
Meat, milk, poultry, fish***	6.8	28.0	0.8	9.7
Legumes, nuts***	0.6	4.0	9.5	5.3
Fruits**	4.5	6.0	13.0	8.6
Others	0.6	0.8	—	0.3
Vendors selling foods of more than one group***	53.1	21.3	56.9	46.6

* p .05, ** p .01, ***p .001 between study locations by chi-square, phi, and Cramer's V statistics.
a. Excluded from statistical calculation because expected value < 5.

from more than one group sold vegetables (in other words, some vendors sold only fruits, but no vendor sold only vegetables).

Figure 1 presents the distribution of vendors according to key food nutrients sold and study location. The proportion of vendors selling carbohydrate foods was significantly lower in the industrial area than in the other two areas ($p < .001$), whereas the reverse was true for the proportion selling micronutrient-rich foods ($p < .05$). More vendors sold only protein-rich foods in the Dandora lower-middle income area ($p < .001$), as compared with both the Korogocho slums and the industrial area. The proportion of vendors selling mixed-nutrient foods was higher in the industrial area than the proportion in Korogocho ($p < .05$), which in turn was higher than the proportion in Dandora ($p < .001$).

Street food groups and the sex of the vendor

Significantly more male vendors (61%) than female vendors (49%) sold food from only one group. Table 4 presents the distribution of street food vendors according to the vendor's sex and food groups in terms of key nutrients. Carbohydrate foods were associated with male vendors, whereas mixed-nutrient foods and foods rich in micronutrients were associated with female vendors. Protein-rich foods were equally distributed across male and female vendors. However, as shown in table 1, more men sold fried and roasted meat and more women sold deep-fried fish and legumes and nuts. Similar male–female differences were observed in the industrial area, but not in the other study areas.

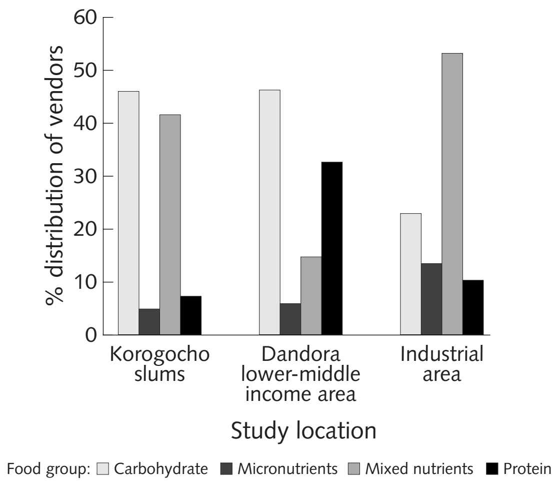

FIG. 1. Distribution (%) of street food vendors by study location and the foods they sell, grouped according to their key nutrients, in Nairobi

Energy and nutrient contribution of typical one- and multiple-food group dishes

Table 5 shows the proportion of energy from fat and the percentage of adult equivalents (AEs) for energy, protein, iron, calcium, vitamin A, thiamine, and riboflavin per serving of some typical dishes sold by one- and multiple-food group sellers. Except for a few dishes served with vegetables, less than 30% of the total energy per serving came from fat. The amounts of energy and iron per serving were comparable in both one- and multiple-food group dishes, except for mandazi and uji, which contributed a low amount of energy, and chapati and sukuma wiki, whose iron contribution was also low. The multiple-food group dishes that were served with vegetables contributed half or more of the AE for vitamin A. The one-food group dishes and the multiple-food group dishes without vegetables contributed either negligible proportions or only up to 10% of the AE. In general, one-food group dishes provided less thiamine and riboflavin than multiple-food group dishes. A notable observation is that riboflavin was generally low in all the dishes.

Discussion

Street food products and food groups

Street food items sold in Nairobi represent all the FAO food groups. Foods of the cereals group are, however, dominant among street foods because they are cheaper. This supports the hypothesis that street food vendors sell mainly foods from low-cost food groups. The FAO food grouping, however, has some limitations, since it masks the fats and oils used in the products. Grouping such products as mixed dishes can also give the wrong impression.

Traditional coarse grains (such as sorghum and millet), roots and tubers (such as taro, sweet potato, and cassava), and vegetables (such as amaranth) are absent from the list of foods commonly sold in Nairobi. This suggests a tendency toward adopting the nutrition transition trend associated with increasing income and urbanization [26, 27]. As Kennedy and

TABLE 4. Food groups in terms of key nutrients and distribution (%) of vendors according to sex in Nairobi

Nutrient	Male ($n = 199$)	Female ($n = 381$)	Total ($N = 580$)
Carbohydrate	48.7**	29.1	36.1
Protein	17.6	13.9	15.2
Micronutrients	5.0	10.8*	8.8
Mixed nutrients	28.6	45.8**	39.9

* $p < .05$, ** $p < .001$ by chi-square, phi, and Cramer's V statistics.

Reardon [28] correctly state, this tendency is worrisome, because it may have an adverse effect on rural production of indigenous foods, some of which (e.g., millet and amaranth) are rich sources of micronutrients. In addition, the production of wheat rather than local grains may be expensive and therefore not augur well for the poor.

Presentation of food groups

The food-product diversity offered depends on local food preferences, purchasing power being the limiting factor. Except for fruit varieties, the study locations in Nairobi were similar in the number of product varieties within food groups. Generally, cereal and animal products are the most varied. This was expected of cereals because they can be modeled into different products and are generally cheap. Animal products can be modeled into different varieties as well and, moreover, are made from a varied number of animal parts. The presence of more fruits in the industrial area and in Dandora is a reflection of consumer preferences. Fruits are generally expensive, contain a lot of water, are not filling, and hence are not in the interest of the urban poor.

In general, a high proportion of individual vendors lack food group variety. This is especially so in the Dandora lower-middle income residential area, where vendors sell mostly cereal products that are consumed as snacks and products of animal origin that are commonly consumed as part of home-prepared dinners or lunches. The association of products of animal origin with the Dandora lower-middle income area as compared with the other areas is probably due to differences in the ability of consumers to afford certain food groups. The cost of products of animal origin, is high and only those who can afford to buy them. Hence, although this study does not address street food consumer characteristics, the links between food group variety and study location is indicative of the type of consumers found in the study areas. This contradicts Blair's [29] assertion that street foods are democratic in that everybody consumes the same food. It is clear that the higher-income people are better able to afford street foods of animal origin, hence the greater supply. The aspect of purchasing power of consumers is well reflected here.

Differences are found in the proportions of vendors selling single-key nutrient foods between the residential areas and the industrial area. The proportion of vendors selling only energy-rich foods is high in both the Korogocho slums and the Dandora lower-middle income, and the proportion of those selling only micronutrient-rich foods (only fruits in this case) is equally low in both areas. Vegetables are never consumed on their own, and hence they are only sold by vendors selling mixed-nutrient dishes. Although the proportion of vendors selling mixed-nutrient foods is

TABLE 5. Energy and nutrient contribution of typical one- and multiple-food-group street dishes in Nairobi

Type of dish	Fat energy[a]	Energy	Protein	Iron	Calcium	Vitamin A	Thiamine	Riboflavin
		% of adult equivalent/serving						
Common one-food-group dishes[b]								
Cereal (± fat)								
Mandazi and uji	13	16	16	73	10	4	7	1
Chapati and uji	22	26	25	112	26	0.1	29	3
Mahindi chemsha and uji	9	32	20	135	10	0.1	15	10
Common multiple-food-group dishes								
Cereal and legume (± fat)								
Githeri	14	30	64	157	66	1	29	13
Githeri and uji	12	39	73	195	74	0.3	33	13
Chapati and maharagwe	27	29	62	144	68	6	55	12
Ugali and maharagwe	18	36	77	176	65	10	71	19
Cereal, legume, and vegetable (± fat)								
Githeri and mboga	17	34	73	196	83	56	33	14
Chapati, maharagwe, and mboga	28	33	68	188	99	57	63	17
Cereal and vegetable (± fat)								
Chapati and mboga	39	22	29	86	57	80	27	9
Chapati and sukuma wiki	44	22	24	41	42	48	39	3
Ugali and sukuma wiki	22	34	44	76	36	53	67	17
Cereal, meat, and vegetable (± fat)								
Ugali, nyama, and sukuma wiki	32	42	64	94	61	53	75	22

a. % of total energy/serving.
b. May be cooked in fat.

significantly higher in Korogocho slums than in the Dandora lower-middle income area, it does not exceed the proportion selling only energy-rich foods. These results support the hypothesis that vendors sell food items mostly made from cheap food groups and do not include sufficient variety to provide an adequately nutritious diet. The significant differences observed between the Korogocho slums and the Dandora lower-middle income area may be due to a higher reliance on street foods for meals in the very low-income area as compared with the lower-middle income area. Nevertheless, it appears that the demand for mixed-nutrient foods in Korogocho is not higher than that for energy-rich foods, probably because mixed-nutrient foods cost more.

Although the Food and Agriculture Organization (FAO) [3] reports that street foods may be the least expensive and best method of obtaining a nutritionally balanced meal outside the home, the consumer's choice, influenced by knowledge of proper food combinations and ability to purchase, is supreme. This study does not address ways in which consumers combine their foods when buying from vendors, but it shows that a large proportion of vendors are one-food-group sellers. It is unlikely that consumers buy from different vendors to obtain proper combinations of food for their meals, because it might be expensive to buy ready-to-eat food in this manner. In fact, serving dishes of one food group to consumers has been observed. Wide gaps in the provision of protein and important micronutrients have been shown in some typical one- and multiple-food-group dishes. The one-food-group dishes are mainly made of cereal flours, which are especially poor in vitamin A and riboflavin, whereas dairy products are absent as street foods. However, the results show that adequate iron intake can be achieved through typical street food dishes.

Vendors in the industrial area sell foods of greater group (and also product) diversity than vendors in the other areas. Most of them sell foods of multiple groups providing mixed nutrients. Hence, with proper combinations, consumers in the industrial area can obtain a healthful diet from street food vendors. This does not support the hypothesis that vendors' foods are not heterogeneous enough to provide an adequately nutritious diet. It appears that in working areas, people are able to afford mixed-nutrient foods and want to have a proper meal for their lunch. In addition, Bricas's [15] idea of individualism as one of the frames of reference that activates the dynamics of food habits may be active in working places. In other words, while away from household members, consumers can make individual food choices and eat what they like, provided it is within their means.

Street food groups and the sex of the vendor

The association of more product and food group variety with female vendors is a reflection of women's cultural tasks. They know how to cook and are used to preparing different types of foods. They have a competitive advantage over men in that they can prepare foods from different food groups. They are, hence, in a position to provide nutritionally better foods than their male counterparts and probably make more profit. Women comprise a large majority of vendors where there is a demand for proper meals. The finding that women go away from their homes to search for better-paying markets is contrary to logical expectation. Normally, women stay at home and men search for better-paying markets. This observation indicates the willingness and ability of women to compete using their competitive advantage of greater skill in cooking the type of meals that would provide adequate nutrition. Male vendors sell items of a single food group, probably because of their incompetence unless they are backed by a female counterpart. This study did not investigate the role of wives in male vending units and how it affects food group variety. General observations in residential areas, however, indicated that in many male vending units with multiple food group items, women were involved in food preparation. The association of meat products with male vendors also reflects their cultural roles.

Conclusions and policy implications

Although the street food sector in Nairobi offers products from all food groups, most vendors are one-food-group sellers, with cereals as the prominent group. Therefore, a high proportion of individual vendors do not sell enough variety of foods for a healthful diet. The presentation of street foods in working areas, however, implies that particularly female vendors are capable of supplying a variety of nutritionally adequate foods. However, the consumers' ability to buy dictates what is offered.

There is, therefore, the need to improve the variety of street foods if an adequate nutrient supply is to be realized. This is especially important in urban poor settlements, where reliance on street foods may be high. Although basic nutrition education of vendors emphasizing the use of multiple food groups might help to achieve this, consumers also need to be educated on how to achieve proper food combinations and be made aware of the benefits of healthful diets. Street food preparation processes and how these affect the nutrient content of products need to be assessed so that bad preparation habits can be pointed out in the education package.

However, there is a risk that improvement of the nutrient supply of street foods may increase their prices, putting them out of reach of consumers. Hence, a policy of fortification of cereal flours used in the preparation of popular dishes with the deficient micronutrients, without passing the cost of fortification to the consumer, is desirable. Although there are claims of fortification of some brands of cooking oil in Kenya with vitamin A, there is no governing legislation on this, and the quantities are not regulated. Introduction of energy-saving cooking techniques could also help reduce costs. For example, a firewood cooking stove that can save energy by as much as 50% has been developed in Kenya. The nutrition and home economics staff, in collaboration with poverty alleviation agencies, need to venture into developing such cooking technology appropriate to street food vendors. The use of local food crops can also prevent an increase in prices. The agriculture and nutrition staff need to encourage the use of such foods by educating both consumers and vendors on their benefits. Although food safety and water issues are not addressed in this paper, vendors generally lack water and have to buy from water vendors, thus increasing the costs of street foods. The health staff, city authorities (especially planners and economists), interested nongovernmental organizations, and the street food vendors should collaborate to develop a better system with the necessary amenities, such as a safe water supply to vending sites.

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Iron and energy supplementation improves the physical work capacity of female college students

S. K. Mann, Satinderjit Kaur, and Kiran Bains

Abstract

*A nutritionally controlled study was conducted on two groups of 15 female college students aged 16 to 20 years, selected from Punjab Agricultural University, Ludhiana, Punjab, India. The girls were either anemic (hemoglobin 7.7 g/dl) but energy adequate (AEA), or anemic (hemoglobin 7.4 g/dl) and energy deficient (AED). The AEA group was given iron supplementation (60 mg iron/day) for 6 to 9 months along with 100 mg of ascorbic acid, and the AED group was given iron as well as energy supplementation for 3 months. There was a significant (*p *< .01) increase in weight, body mass index, mid-upper-arm circumference, and body fat in the AED group after iron–energy supplementation. Hemoglobin, serum iron, transferrin saturation, total iron-binding capacity, and unsaturated iron-binding capacity were below normal in both groups; however, after iron and iron–energy supplementation, there was a significant (*p *< .01) increase, and these indices were in the normal range. There was a significant (*p *< .01) increase in exercise time and maximum work load tolerance after iron and iron–energy supplementation. Combined energy and iron deficiency had a greater adverse effect on physical work capacity than energy or iron deficiency alone.*

Introduction

Despite economic growth and an increase in food production, the energy gap continues to be the major nutritional disorder in India due to the population explosion. Adults can adapt to some extent to an energy deficit by decreasing body mass and energy expenditure related to physical activity. Under such circumstances, body energy stores, basal metabolic rate, and physical activity are reduced. Lean body mass and fat content are reduced in energy-deficient individuals [1]. Satyanarayana reported that VO_{2max}, maximal aerobic power per kilogram, and submaximal aerobic power per kilogram were significantly lower in undernourished than in well-nourished individuals [2]. Undernourished individuals had a higher heart rate when given a submaximal workload, indicating that their cardiopulmonary function was below par [3]. Restricted energy intake leads to a reduction in energy expenditure, which may appear in the form of decreased metabolic rate and limited work capacity [4]. The most important factor causing variation in energy expenditure is the physical activity pattern. Assessment of habitual physical activity must, therefore, be done to study the relationship of energy status and physical work capacity [5].

Anemia due to iron deficiency affects an estimated 2,170 million people worldwide, of whom 90% are in developing countries [6]. Iron-deficiency anemia is also a major nutritional problem for reproductive-aged women in India [7]. Iron deficiency appears to be due mainly to low dietary intake and poor absorption of iron from cereal-based vegetarian diets coupled with excessive body needs among women. Iron deficiency is potentially an important determinant of physical work capacity [8], and it is more important when combined with energy deficiency [9]. The functional consequences of anemia are of particular concern in women, in view of the high prevalence of anemia in this group. Iron supplementation helps to conserve energy and increases work output through improvement in body iron status [10, 11]. The present study was designed to determine the effect of iron and energy deficiency and supplementation on physical work capacity.

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Mention of the names of firms and commercial products does not imply endorsement by the United Nations University.

Materials and methods

Selection of subjects

Thirty female college students, aged 16 to 20 years, who volunteered were selected for this controlled study from Punjab Agricultural University, Ludhiana, Punjab, India. Malkit [12] reported that young woman with hemoglobin levels of 10.4 g/dl had nonsignificant differences in physical work capacity when compared with nonanemic young women. Further, 37.5% of subjects from the rural College of Home Science Kaoni, Punjab Agricultural University, had hemoglobin levels below 9 g/dl. Therefore, the subjects with hemoglobin levels below 9 g/dl were selected for this study. The subjects were divided into two groups. The first group was anemic (hemoglobin 7.7g/dl) but energy adequate (AEA), whereas the second group was anemic (hemoglobin 7.4g/dl) and energy deficient (energy gap of 338 to 854 kcal/day)(AED). The subjects were otherwise normal and had not had any episode of disease in the past six months. Fecal samples of all the subjects were examined for intestinal infestations [13], and those with infestations were treated.

Anthropometry

Height, weight, mid-upper-arm circumference, and skinfold thickness at four different sites (triceps, biceps, subscapular, and suprailiac) were measured according to the methods of Jelliffe [14]. Total body fat was calculated by the equation given by Durnin and Womersley [15]. Body mass index (BMI) was obtained by the equation given by Garrow [16].

Dietary survey

A dietary survey was conducted by weighing cooked foods for three consecutive days. Duplicate samples were homogenized, dried, ground, and stored in decontaminated containers for later analysis for dietary energy, protein, and iron. The gross energy and protein content of the samples were determined by the method given by the Association of Official Analytical Chemists (AOAC) [17, 18]. The food samples were analyzed for iron using an atomic absorption spectrophotometer (GBC-902) after digestion with the diacid mixture of nitric acid and perchloric acid (4:1) according to the procedure of Piper [19]. Ascorbic acid was calculated by the MSU Nutriguide computer program [20].

Total daily energy expenditure

Total daily energy expenditure (TDEE) was estimated using the MSU Nutriguide computer program [20]. The subjects recorded their 24-hour activities for the three days of dietary survey. These activities were then categorized into sleep and light, moderate, and heavy activity. The data on the age, height, and weight of the subjects were entered into the computer. Information regarding no episode of any serious disease was also recorded. From the number of hours of sleep and time spent on light, moderate, and heavy activities, the total energy expended was calculated for each subject.

Biochemical analysis

Hemoglobin levels were estimated by the cyanmethemoglobin method [21]. For iron, serum samples were digested [19] and the iron concentration was determined in the atomic absorption spectrophotometer. The method of Teitz [22] was used to measure the total iron-binding capacity (TIBC). Transferrin saturation (TS) was calculated from serum iron and TIBC [23].

Treadmill test

To determine physical fitness, the candidates underwent a treadmill stress test, using Bruce or Modified Bruce protocols [24] under the supervision of a trained cardiologist; a Marque He Case 12 Computerized treadmill was used. The basal heart rate and blood pressure were recorded along with a baseline electrocardiogram while the subject was lying in a supine position. Heart rates were again recorded when the subject was standing and during hyperventilation. Then each subject walked on the treadmill and performed five stages of graded exercise. The electrocardiogram was monitored continuously throughout the exercise and the recovery period. The exercise continued until the subject was exhausted. The maximum blood pressure and heart rate attained during exercise were recorded. The heart rate was also recorded after a recovery period of 4 minutes. The different stages of treadmill test exercise were standardized in terms of time, speed, and grade and are given in table 1.

The workload was calculated by the computer in terms of metabolic equivalents (MET), which are the double product of heart rate and systolic blood pressure.

Iron supplementation

All subjects were given a supplement of Fefol capsules (one capsule per day) for 7 to 9 months to bring the hemoglobin level to the normal level of 12 g/dl and above [25]. Each capsule contained 150 mg of ferrous sulfate (60 mg of iron) and 0.5 mg of folic acid. Along with iron capsules, 100-mg ascorbic acid tablets were provided daily.

Energy supplementation

Based on the energy gap, an energy supplement in the form of *pinnies* was given to the energy-deficient subjects. Pinnies were prepared from whole wheat flour, semolina, whole soy flour, refined oil, sugar, whole milk powder, and crushed groundnut kernels in the ratio of 1.5:0.5:0.5:0.8:1.5:0.5:0.5 by weight. Each 60-g pinni provided 325 kcal. The subjects were supplemented with 1.5 to 3 pinnies according to their energy deficiency.

Statistical analysis

The paired *t*-test was used with repeated measures [26] to test the effects of different treatments on the same group. The levels of significance were set at 1% and 5%.

Results and discussion

Anthropometry

The anthropometric measurements of the anemic but energy adequate (AEA) group and the anemic and energy deficient (AED) group are given in table 2. There was no significant difference in the weight of the AED group before and after iron supplementation.

TABLE 1. Stages of treadmill test exercise

Stage	Time in phase (min)	Duration of stage (min)	Speed (miles per hour)	Grade (%)
1	3.00	3.00	1.7	10.0
2	6.00	3.00	2.5	12.0
3	9.00	3.00	3.4	14.0
4	12.00	3.00	4.2	16.0
5	15.00	3.00	5.0	18.0
Recovery	4.00	4.00	0.0	0.0

However, a significant difference ($p < .01$) was found in the same group after iron–energy supplementation. According to the Indian Council of Medical Research (ICMR), young women 16 to 20 years of age should weigh between 40.8 and 43.2 kg [27]. The values observed in this study were higher than the ICMR values. Riumallo et al. [28] reported a significant increase in body weight after 60 days of energy supplementation. There was a significant ($p < .05$) increase in the triceps skinfold thickness, but the increase in mid-upper-arm circumference and calculated body fat of the subjects was highly significant ($p < .01$) after iron–energy supplementation, which indicated a gain in body weight in the AED group. The AEA subjects were robust in health. The majority of their anthropometric measurements were superior before as well as after iron supplementation, as compared with the AED subjects in all three stages.

The mean BMI of subjects in the AED group was 17.95 kg/m^2 before iron supplementation, 17.88 kg/m^2 after iron supplementation, and 19.54 kg/m^2 after iron–energy supplementation. A significant ($p < .01$) improvement in BMI was found after iron–energy supplementation. The normal range for BMI is 18 to 21 kg/m^2 [29]. The BMI for the AEA group was in the normal range before and after iron supplementation, but in the AED group it was in the normal range only after iron–energy supplementation. After energy supplementation, the mean values of BMI were more than 18.0 kg/m^2, indicating the normal energy status of the AED group.

Nutrient intake

The average daily intakes of energy, protein, and iron are shown in table 3. The average daily energy intake of the AEA group was 1,966 kcal before and 1,989 kcal after iron supplementation. The corresponding values

TABLE 2. Anthropometric measurements of subjects in the anemic but energy-adequate (AEA) and the anemic and energy-deficient (AED) groups ($n = 15$)[a]

Measurement	AEA		AED			p value (c vs e)
	Before iron supplementation (a)	After iron supplementation (b)	Before iron supplementation (c)	After iron supplementation (d)	After iron–energy supplementation (e)	
Age (yr)	18.1 ± 0.4	18.9 ± 0.4	17.0 ± 0.1	17.9 ± 0.1	18.0 ± 0.1	NS
Height (cm)	158.2 ± 1.5	—	159.2 ± 0.8	—	—	—
Weight (kg)	53.5 ± 0.9	54.1 ± 0.9	45.3 ± 0.3	45.6 ± 0.6	49.8 ± 0.4	< .01
Triceps skinfold thickness (mm)	18.2 ± 0.3	18.4 ± 0.4	11.5 ± 0.5	11.5 ± 0.5	14.8 ± 0.5	< .05
Mid-upper-arm circumference (cm)	25.1 ± 0.2	25.2 ± 0.2	23.1 ± 0.2	23.2 ± 0.2	24.3 ± 0.2	< .01
Body mass index (kg/m^2)	21.45 ± 0.28	21.6 ± 0.33	17.95 ± 0.10	17.88 ± 0.13	19.54 ± 0.16	< .01
Body fat (%)	28.4 ± 0.31	28.4 ± 0.29	23.70 ± 0.32	23.59 ± 0.34	26.13 ± 0.27	< .01

a. Values are means ± SE. NS, Nonsignificant. Differences between a and b and between c and d are nonsignificant for all measurements.

TABLE 3. Average daily intakes of energy, protein, iron, and ascorbic acid by subjects in the anemic but energy-adequate (AEA) and the anemic and energy-deficient (AED) groups[a]

Nutrient	AEA		AED			*p* value (c vs e)	RDA
	Before iron supplementation (a)	After iron supplementation (b)	Before iron supplementation (c)	After iron supplementation (d)	After iron–energy supplementation (e)		
Energy (kcal)	1,966 ± 22	1,989 ± 26	1,334 ± 32	1,351 ± 31	1,932 ± 12	< .01	1,966[b], 1,851[c]
Energy (kcal/kg body wt)	36 ± 0.44	37 ± 0.49	24 ± 0.82	30 ± 0.65	39 ± 0.49	—	41
Protein (g)	49.0 ± 1.8	52.6 ± 2.1	43.0 ± 1.3	45.7 ± 1.5	50.1 ± 1.5	NS	54[d], 49[e]
Protein (g/kg body wt)	0.90 ± 0.92	0.96 ± 0.02	0.93 ± 0.03	1.0 ± 0.03	1.0 ± 0.02	—	–1.0
Iron (mg)	12.1 ± 0.6	15.7 ± 1.0	8.9 ± 0.8	9.1 ± 1.0	14.5 ± 1.2	< .01	30
Ascorbic acid (mg)	33 ± 6	32 ± 3	27 ± 5	31 ± 4	33 ± 4	NS	40

a. Values are means ± SE. RDA, Recommended daily allowance; NS, nonsignificant. Differences between a and b and between c and d are nonsignificant for all nutrients.
b,c. RDA for energy on body weight basis of AEA and AED.
d,e. RDA for protein on body weight basis of AEA and AED.

for the AED group were 1,334 and 1,351 kcal, but after iron–energy supplementation, their energy intake was 1,932 kcal, which was significantly ($p < .01$) higher. The energy intake of the AEA group before and after iron supplementation and that of the AED group after iron–energy supplementation was close to the recommended daily allowance (RDA) of 1,966 kcal for the AEA group and 1,851 kcal for the AED group, as recommended by the ICMR [7], whereas the energy intake of the AED group before and after iron supplementation was much below the RDA. A number of studies of college women reported that their energy intake was deficient, ranging from 1,673 to 1,906 kcal/day [12, 30–32].

The AEA group had a daily protein intake of 49.0 g before and 52.6 g after iron supplementation. The AED group had a daily protein intake of 43.0 g before iron supplementation, 45.7 g after iron supplementation, and 50.1 g after iron–energy supplementation. Compared with the RDA of 1 g of protein per kilogram of body weight [7], the intake of the subjects was slightly lower in both groups before as well as after iron supplementation. Malkit [12] and Bains [32] reported daily protein intakes of 45.0 and 48.6 g by young college women, respectively, which was close to the results of this study. The AEA group had an average daily dietary iron intake of 12.1 mg before and 15.7 mg after iron supplementation, whereas the intakes for the AED group were 8.9 mg before iron supplementation, 9.1 g after iron supplementation, and 14.5 mg after iron–energy supplementation. A significant ($p < .01$) increase was found in dietary iron intake after iron–energy supplementation. However, the mean daily dietary iron intake of subjects at every stage was inadequate as compared with the RDA of 30 mg/day [7]. Bains [32] reported that young college women had daily iron intakes of 13.2 and 15.8 mg in summer and winter, respectively, values close to those obtained in the present study. The subjects in both groups were supplemented with Fefol capsules. Thus, the daily intakes of iron were 76 mg in the AEA group after iron supplementation, 69 mg in the AED group after iron supplementation, and 75 mg in the AED group after iron–energy supplementation; all these values are greater than the RDAs.

The daily intake of ascorbic acid in the AEA group was 33 mg before and 32 mg after iron supplementation. The corresponding values for the AED group were 27 and 31 mg, and after iron–energy supplementation the value was 33 mg/day. In addition, each subject received a 100-mg ascorbic acid tablet along with the Fefol capsules.

Basal metabolic rate and total daily energy expenditure

No significant difference was observed in the basal metabolic rate (BMR) of the AEA group after iron supplementation, but there was a significant ($p < .01$) increase in BMR in the AED group after iron–energy supplementation due to a significant increase in body weight. The total daily energy expenditure of the AEA group was 1,926 kcal before and 1,932 kcal after iron supplementation. The AED subjects had daily energy expenditures of 1,831 kcal before iron supplementation, 1,880 kcal after iron supplementation, and 1,885 kcal after iron–energy supplementation. There was no significant increase in energy expenditure after iron–energy supplementation (table 4).

Energy balance

The daily energy balance of the AEA group was 40 kcal before and 57 kcal after iron supplementation.

The AED group had a daily energy balance of –498 kcal before iron supplementation, –457 kcal after iron supplementation, and 48 kcal after iron–energy supplementation. There was a significant ($p < .01$) difference in the daily energy balance after iron–energy supplementation (table 4).

Blood iron indices

The values for hemoglobin, serum iron, total iron-binding capacity (TIBC), and transferrin saturation (TS) of AEA and AED subjects are given in table 5. Hemoglobin, serum iron, and TS increased significantly ($p < .01$) after iron supplementation, whereas TIBC showed a significant ($p < .01$) decline after the supplementation. It took 6 to 9 months to bring the hemoglobin level of anemic subjects to 12 g/dl.

Treadmill test

Exercise time and maximum work load on the treadmill increased significantly ($p < .01$) after iron supplementation and after iron–energy supplementation in both groups (table 6), indicating improved physical fitness after iron supplementation and still better physical fitness after iron–energy supplementation. Edgerton et al. [35] and Gopaldas and Seshadri [36] reported an improvement in physical fitness with an increase in hemoglobin level. Rowland et al. [37] also reported that the treadmill endurance time improved significantly with iron supplementation. The minimal level for maximal work load to estimate physical fitness is 11 MET. The AEA group before and after iron supplementation, and the AED group after iron–energy supplementation, had an exercise capacity above the minimal level of fitness, i.e., 11 MET. However, before supplementation, the treadmill exercise capacity of the AED group was below the fitness level, which means that with both energy and iron deficiency the fitness level was unsatisfactory, but after supplementation there was a satisfactory improvement in fitness in both groups. There was no significant change in initial systolic blood pressure of either group after iron and iron–energy supplementation. Similarly, there was no significant difference in postexercise systolic blood pressure before and after supplementation. However, the subjects were able to exercise for a longer time after iron supplementation.

TABLE 4. Energy intake, basal metabolic rate, energy expenditure, and energy balance of subjects in the anemic but energy-adequate (AEA) and the anemic and energy-deficient (AED) groups[a]

	AEA		AED			
Value (kcal/24 h)	Before iron supplementation (a)	After iron supplementation (b)	Before iron supplementation (c)	After iron supplementation (d)	After iron–energy supplementation (e)	p value (c vs e)
Energy intake	1,966 ± 22	1,989 ± 26	1,334 ± 32	1,351 ± 31	1,932 ± 12	< .01
Basal metabolic rate	1,353 ± 12	1,352 ± 12	1,284 ± 70	1,286 ± 8	1,324 ± 60	< .01
Energy expenditure	1,926 ± 38	1,932 ± 39	1,831 ± 28	1,808 ± 28	1,885 ± 28	NS
Energy balance	40 ± 33	57 ± 34	–498 ± 43	–457 ± 37	48 ± 18	< .01

a. Values are means ± SE. NS, Nonsignificant. Differences between a and b and between c and d are nonsignificant for all nutrients.

TABLE 5. Blood iron status of subjects in the anemic but energy-adequate (AEA) and the anemic and energy-deficient (AED) groups ($n = 15$)[a]

	AEA			AED				
							p value	
Blood value[b]	Before iron supplementation (a)	After iron supplementation (b)	t value (a vs b)	Before iron supplementation (c)	After iron supplementation (d)	After iron–energy supplementation (e)	(c vs d)	(c vs e)
Hb (g/dl)	7.7 ± 0.2	12.2 ± 0.06	22.61**	7.4 ± 0.1	12.1 ± 0.05	12.1 ± 0.7	< .01	< .01
Serum iron (μg/100 ml)	51.3 ± 2.8	94.6 ± 6.1	6.69**	51.6 ± 3.0	90.4 ± 4.0	93.1 ± 4.2	< .01	< .01
TIBC (μg/100 ml)	577 ± 13.7	332 ± 9.1	15.46**	554 ± 18.3	339 ± 12.1	349 ± 10.8	< .01	< .01
Unsaturated iron-binding capacity (μg/100 ml)	525 ± 16.2	237 ± 13.6	14.13**	502 ± 21.0	248 ± 11.8	256 ± 14.2	< .01	< .01
TS (%)	9.2 ± 0.8	29.0 ± 2.2	8.88**	9.8 ± 1.0	27.2 ± 1.6	27.4 ± 1.8	< .01	< .01

a. Values are means ± SE. Hb, Hemoglobin; TIBC, total iron-binding capacity; TS, transferrin saturation.
b. The normal values are Hb, 12 g/dl [25]; serum iron, 63–202 μg/100 ml [33]; TIBC, 250–416 μg/100 ml [34]; unsaturated iron-binding capacity, 0–500 μg/100 ml [22]; and TS, 16%–37% [23].
**$p < .01$.

TABLE 6. Exercise time, maximum work load, and blood pressure of subjects in the anemic but energy-adequate (AEA) and the anemic and energy-deficient (AED) groups ($n = 15$)[a]

Measurement	AEA: Before iron supplementation (a)	AEA: After iron supplementation (b)	AEA: t value (a vs b)	AED: Before iron supplementation (c)	AED: After iron supplementation (d)	AED: After iron–energy supplementation (e)	p value (c vs d)	p value (c vs e)
Exercise time (min/s)	9/57 ± 1.20	11/38 ± 0.94	3.81**	7/39 ± 1.31	10/15 ± 0.85	10/58 ± 0.66	< .01	< .01
Maximum work load (MET)	11.0 ± 1.19	12.66 ± 1.11	4.15**	8.80 ± 1.32	11.53 ± 1.24	11.80 ± 0.67	< .01	< .01
Systolic BP (mm Hg)								
Before exercise	121 ± 9	118 ± 6	NS	120 ± 10	117 ± 7	117 ± 7	NS	NS
After exercise	156 ± 14	153 ± 9	NS	158 ± 7	157 ± 8	158 ± 7	NS	NS

a. Values are means ± SE. MET, Metabolic equivalents; BP, blood pressure; NS, nonsignificant.
**$p < .01$.

In the AEA group, there was no significant decrease in the heart rate after iron supplementation when the subjects were in the supine position, during exercise stages 2 and 3, and during peak exercise on the treadmill. However, a significant ($p < .05$) decrease was observed in heart rate after iron supplementation during exercise stage 1. Similarly, in the AED group, a nonsignificant decrease in maximum heart rate was observed during the supine position, during exercise stages 2 and 3, and during peak exercise on the treadmill after iron and iron–energy supplementation. However, the subjects were able to exercise for a longer time without any significant difference in heart rate, indicating an improvement in physical fitness after iron and iron–energy supplementation (fig. 1). In the AEA group, the ECG during the supine position, standing, and exercise was normal in 13 subjects before iron supplementation, but after iron supplementation, the number of subjects with a normal electrocardiogram increased to 14. Similarly, in the AED group, the number of subjects with a normal electrocardiogram increased after iron supplementation. Anemia is one of the causes for the ST change in the electrocardiogram (table 7).

Severe iron and energy deficiency affected physical work capacity, and supplementation with iron or energy or with both improved physical work capacity in terms of exercise time, blood pressure, and heart rate. Combined energy and iron deficiencies had a worse effect on physical work capacity than energy or iron deficiency alone.

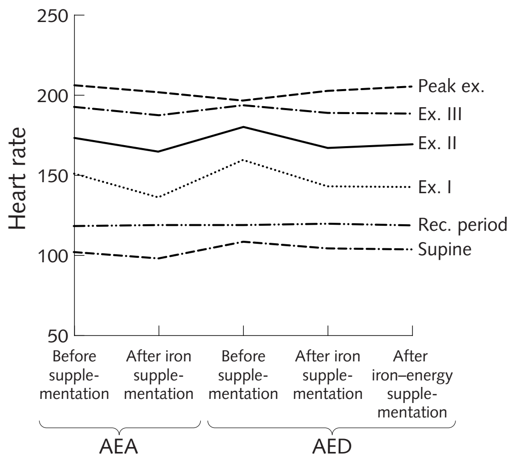

FIG. 1. Heart rate during supine position, different exercises on treadmill, and recovery period of subjects

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TABLE 7. Electrocardiographic pattern of subjects in the anemic but energy-adequate (AEA) and the anemic and energy-deficient (AED) groups ($n = 15$)

	AEA		AED		
	Before iron supplementation	After iron supplementation	Before iron supplementation	After iron supplementation	After iron–energy supplementation
Electrocardiogram	no. of subjects				
Supine position					
Normal	13	14	15	15	15
ST change[a]	2	1	0	0	0
Standing					
Normal	13	14	12	14	14
ST change	2	1	3	1	1
During exercise					
Normal	13	14	13	15	15
ST change	2	1	2	0	0

a. ST is the distance between the end of the T-wave and the beginning of the S-wave in the electrocardiogram.

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Toward better compliance with iron–folic acid supplements: Understanding the behavior of poor urban pregnant women through ethnographic decision models in Vadodara, India

Jai Ghanekar, Shubhada Kanani, and Sucheta Patel

Abstract

This study made an attempt to develop ethnographic decision models to understand and improve iron–folic acid supplement procurement and compliance-related behaviors of poor urban pregnant women in Vadodara, India, based on data obtained through the use of qualitative research tools. Open-ended, in-depth interviews were conducted with 36 pregnant women (17–32 weeks of gestation) purposively selected from four urban slums. Fortnightly home visits were made to the houses of 20 pregnant women–family member pairs to elicit behaviors related to iron–folic acid supplement procurement and compliance at the household level, from which the ethnographic decision models were developed. The hemoglobin levels of these women were also assessed. Regular counseling until delivery, based on the ethnographic data, helped to improve compliance, which resulted in 95% of the women consuming over 90% of the required dose. The mean hemoglobin level also improved from 9.6 to 11.08 g/dl until the end of the last trimester. This study highlighted the need for qualitative ethnographic data to develop such models that would help in the understanding of specific behaviors that influence program acceptance. Such data would have policy-level implications, for example, developing appropriate information-education-communication material and counseling strategies.

Introduction

Nutritional anemia is a widely prevalent disorder in all segments of the population in the developing world, especially affecting pregnant women. In India, despite the existence of the National Nutritional Anemia Control Program since the 1970s, anemia continues to be widespread, with prevalence as high as 80% among pregnant women in some parts of the country [1].

The major constraints to effective management of iron supplementation programs, as identified by Gillespie et al. [2], include ineffective and irregular supply, procurement, and distribution of supplements; low accessibility and utilization of antenatal care services by pregnant women; inadequate counseling of mothers; undesirable side effects experienced by women; and low compliance of the pregnant women with the supplementation regimen.

Evidence suggests that the outcome of iron-supplementation programs is affected by the behavior of the health-care providers and, more importantly, the pregnant women themselves. Qualitative anthropological research can help greatly in understanding issues related to procurement of and compliance with iron supplements, particularly specific behaviors among the pregnant women and their families. Further, drawbacks in the health system can be identified, including factors that hinder the effective distribution of supplements and counseling of women by the health-care providers.

Qualitative research can also help identify factors for facilitating behavioral change through education and counseling, for example, how to motivate pregnant women to consume iron supplements regularly.

In view of the above, it was considered worthwhile to explore and understand household-level factors that might be responsible for poor compliance with iron supplementation by pregnant women living in the urban slums of Vadodara. Therefore we attempted to develop ethnographic decision models (EDMs) to understand and improve procurement- and compliance-related behaviors of poor urban pregnant women with regard to iron supplements. EDMs are qualitative, causal pathways that predict what kinds of choices people make under specific circumstances. EDMs diagrammatically display the sequential pattern of people's decision-making behaviors based on research data obtained through the use of qualitative, open-ended research tools [3].

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Objectives

The objectives of the study were to understand the household-level behaviors of slum-dwelling pregnant women and their family members related to procurement of and compliance with iron supplements in an urban setting using qualitative research tools; to develop EDMs displaying the pathway of sequential behaviors of pregnant women as they registered for antenatal care, procured iron supplements, and consumed them; and to improve the compliance of pregnant women with respect to the consumption of iron supplements as a result of counseling based on the data obtained from the EDMs.

Methods

The urban health-care system of Vadodara city

The Vadodara Municipal Corporation's Health Department offers antenatal care services at no cost to slum-dwelling pregnant women through its Health Posts and Family Welfare Centers. The Family Welfare Program of the Corporation provides various health and nutrition services, such as family planning, maternal, and child-health services, which include antenatal care services, immunization of mothers and children, nutrition health education, and emergency health-care services in case of epidemics and natural calamities such as floods. In this urban setting, multiple health-care facilities were available to these women in government hospitals, family welfare centers, and *Anganwadis*, as well as clinics of private medical practitioners. Anganwadis are centers run by the Integrated Child Development Services (ICDS), a national-level nutrition program in India for preschool children, pregnant and lactating women, and women between 15 and 45 years of age belonging to the low-socioeconomic group. Each Anganwadi covers a population of 1,000 in urban and rural areas and 700 in tribal areas.

Study site and sample

Four urban slums under a municipal ward in Vadodara with access to both government and private medical facilities were purposively selected for the study. All pregnant women in these slums who were at 17 to 32 weeks of gestation formed the sample of the study ($n = 36$). The pregnant women were identified with the help of local ICDS Anganwadi workers. The Anganwadi workers resided in the same areas and hence were familiar with the residents.

Experimental design

In-depth interviews were conducted with all 36 pregnant women and 20 of their family members (either a husband or a mother-in-law). The interview protocol contained open-ended questions pertaining to information regarding their perceptions and use of antenatal care services, especially procurement and consumption of iron supplements by the subjects.

Fortnightly home visits were made to a subsample of 20 pregnant women to trace their behaviors during the previous fortnight related to their procurement of and compliance with iron supplementation. The women were asked about the number of tablets procured (including source of procurement) and consumed. In addition, tablets were counted to verify reported data. The hemoglobin levels of the women were also assessed in the initial visit by the cyanmethemoglobin method [4].

Subsequently, EDMs were developed based on the qualitative data obtained through the open-ended interviews and fortnightly visits. The EDMs followed the pathway regarding procurement- and compliance-related behaviors of the women.

The women were then given counseling about maternal anemia, with the aid of a flip chart, during home visits that were continued fortnightly until the end of pregnancy. The focus of the counseling was determined by the data emerging from the EDMs. The major goal was to motivate women to continue with supplementation and to cope with any side effects. The counseling was followed by measurement of hemoglobin levels of the pregnant women at term.

Data management and analysis

The qualitative data were collected mainly by in-depth interviews. The questions were formulated according to themes and were given thematic codes after translation into English. The raw field notes were recorded in detail in a dialogue-script form in the local language, Gujarati, by the investigators. These notes were expanded and subsequently translated into English, keeping the translation as close as possible to the original responses in the local language. Significant verbatim quotes were retained in Gujarati. The expanded and translated notes were keyed in a word-processing software package and filed. These files were later coded according to a previously prepared code list, which was modified if necessary as data coding progressed. The codes were created according to the respondents' perspective and meaning of the questions.

A data-search computer software package (DT Search) was used to search theme-wise responses, which were further categorized and summarized. For example, in searching for information on the source of the iron supplements, a code of "iron tablets—place of procurement" was used to compile information from all subjects in this regard.

The behavioral data gathered in fortnightly home visits were recorded in separate files for all subjects and verified by tablet counts at each visit. Informal conversations were carried out with family members present during home visits.

Results

Profile of the subjects

The pregnant women (aged 21–28 years) who participated in the study lived in a deprived slum environment with poor access to basic amenities. The women were in the second or third trimester of pregnancy. Nearly all of them were housewives. All of the women had attended primary school, and their monthly income ranged from Rs. 1,000 to 2,500 (US$22 to $55). About 80% of them had registered for antenatal care either at a government hospital or at private medical clinics.

Prevalence of anemia

Hemoglobin analysis revealed that 75% of the women were anemic (hemoglobin < 11 g/dl), and 13% had severe anemia (hemoglobin < 7 g/dl). The mean hemoglobin level was 9.6 g/dl.

Perceptions of pregnant women and their family members

Of the 36 pregnant women and 20 family members interviewed (table 1), a majority of the women (75%) and 50% of the family members were aware that the iron supplements were distributed to pregnant women as a part of the antenatal care program. They believed that the iron supplements gave strength. Nearly two-thirds of the women said that they received advice regarding the benefits of the iron supplement, that is, that the tablets would give them strength, improve and increase their blood, and improve their appetite. Only a few women had received dietary advice, such as incorporating green leafy vegetables and pulses in their daily diet. The family members were aware only of the strength-giving property of the tablets. A little over half of the family members (60%) said that they reminded the women to take the tablets.

All 36 pregnant women interviewed had consumed iron supplements in their current pregnancy. Many of them (80%) had started consuming the supplements in the fourth, fifth, or sixth month of pregnancy. The major source of the supplements was the ICDS Anganwadi worker: 58% of the women received the supplements distributed by these workers, either at the Anganwadi or during home visits. A few women purchased the supplements at the local pharmacy, and a few others purchased supplements as prescribed by their private medical practitioner. The next most frequent source was government hospitals, where they received the supplements at no cost. Thus, women reported multiple sources. The women were given 25 to 35 tablets at a time.

Based on the qualitative data related to the procurement- and consumption-related behavior of the pregnant women, two EDMs were developed. The EDMs were developed by using a combination of the women's and family members' perceptions, their reported procurement- and consumption-related behavior, observations made during the course of the study, and tablet counts. For example, if the woman was aware of the benefits of consuming iron supplements and reported consuming them regularly, tablet counts were carried out to verify this information. If a mother-in-law or husband said that she or he reminded or encouraged the pregnant woman to consume iron supplements, these data were corroborated with the woman's earlier response, or else the woman was asked about it in the mother-in-law's absence. The woman and her family members were interviewed separately to minimize their influence on each other.

The frequent responses depicted in the EDMs are those that were given in 50% or more respondents. The infrequent responses were received from less than 50% of the total respondents.

TABLE 1. Perceptions of pregnant women and their family members regarding iron–folic acid supplements

Major responses	Pregnant women ($n = 36$)	Family members ($n = 20$)
	no. (%) of respondents	
Awareness of distribution of supplements		
Yes	27 (75)	10 (50)
No	9 (25)	10 (50)
Importance of consuming supplements		
Give strength	25 (70)	13 (65)
Advice received during procurement of supplements		
Yes	24 (67)	10 (50)
No	12 (33)	10 (50)
Dietary advice received		
Yes	7 (19)	4 (20)
No	29 (81)	16 (80)
Reminder needed to consume supplements		
Yes	15 (42)	12 (60)
No	21 (58)	8 (40)

Procurement-related behavior of pregnant women

The EDM given in fig. 1 summarizes the pathway taken by the women to procure iron–folic acid supplements from various sources. When a woman confirms her pregnancy, she tells a family member, either her husband or her mother-in-law. Sometimes the family members take her to a government or private hospital or an Anganwadi center, or they do not show any interest; however, the latter happens rarely. At the government hospital and at the Anganwadi, iron supplements in the form of iron–folic acid tablets are provided free of cost to the woman. At a private hospital, the doctor who examines her usually writes a prescription for iron supplements, which the woman may or may not purchase from the local pharmacy. The pregnant women who go to the Anganwadi for supplementary food may also receive iron–folic acid tablets, or they can get the tablets when the Anganwadi worker makes a home visit. The women may also receive iron–folic acid tablets from the Vadodara Municipal Corporation auxiliary nurse midwives or multipurpose female workers when they visit the slum areas or at the maternal and child health clinics conducted by the corporation health posts every week.

Although all the women in this study had access to free iron–folic acid supplements, some women received them from government health facilities or purchased them from pharmacies as prescribed by their private medical practitioners. Some women received the supplements from multiple sources, such as ICDS Anganwadis or government hospitals, and they also purchased them from pharmacies, thus often receiving many more tablets than the minimum dose of 100.

However, although the iron–folic acid supplements were available to the women from multiple sources that were easily accessible in the study areas, this might not be the case in certain slums located away from government hospitals and private clinics.

Compliance-related behavior

The in-depth interview data revealed certain household-level factors influencing the consumption of the supplements by the women, which are depicted in the

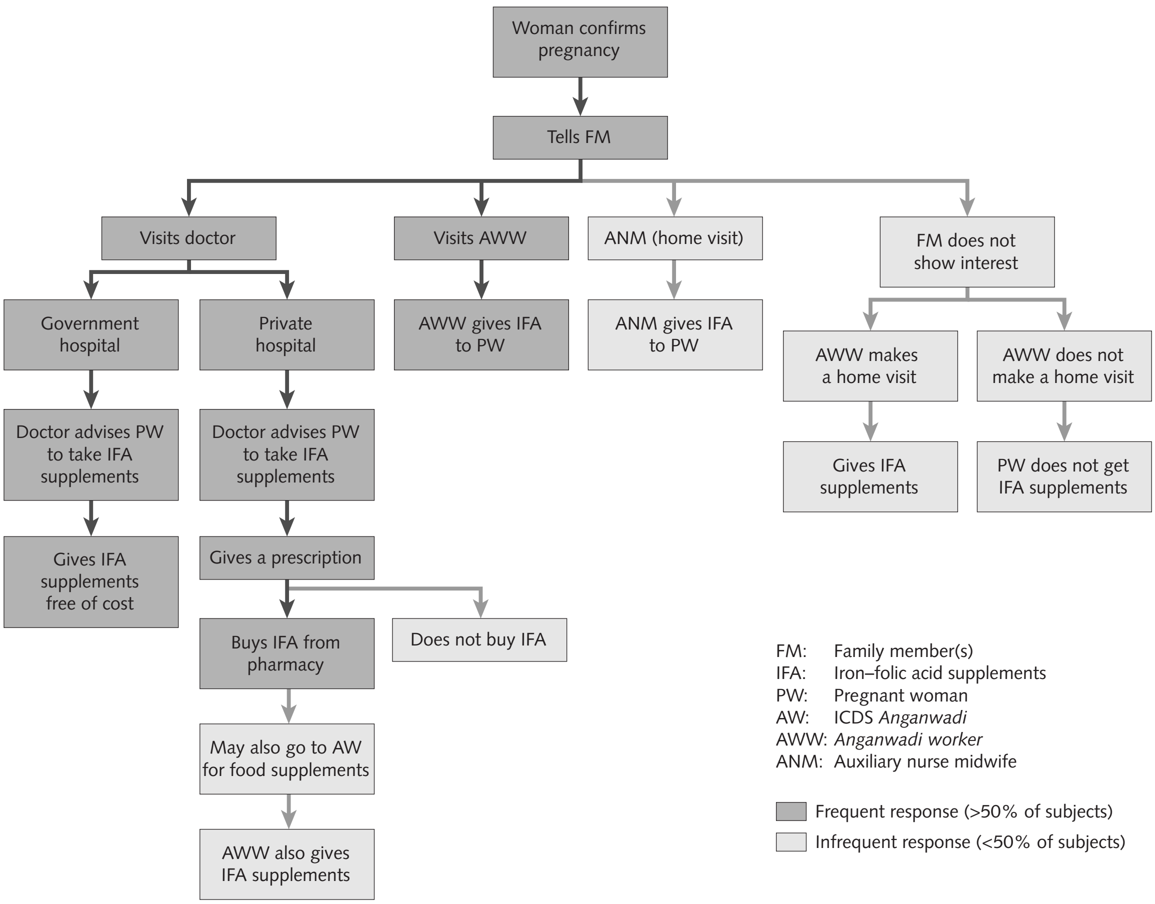

FIG. 1. Procurement of iron–folic acid supplements: an ethnographic decision model

form of an EDM (fig. 2). When a woman procures supplements from the sources mentioned above, her family members play a major role in permitting or supporting her to consume them. It is more common for the family members not to have any objection to the woman's consuming the tablets. In a few cases, a mother-in-law may persuade a woman not to take the supplements because of cultural beliefs, such as that the tablets are "hot" and may cause miscarriage, and as a result, the woman never takes the tablets. The women often forget to take the tablets regularly and may stop consuming them altogether if there is no one to encourage them at home. If a woman is self-motivated to consume the tablets regularly, she may experience benefits or side effects, which would ultimately make her decide whether to continue or discontinue taking the tablets. Experience of benefits motivates the women to continue with the iron supplementation.

Agreement between reported and actual behavior

Because the study was conducted on a free-living population and consumption of the supplements was not supervised, the EDMs were developed primarily on the basis of behavior reported during fortnightly home visits. However, the data were verified by cross-checking information with family members and performing regular tablet counts. Further, the data on positive changes in the women's hemoglobin levels and the increasing proportion of the pregnant women experiencing benefits suggest there was not much difference between reported and actual behavior.

Perceived and experienced benefits and side effects

Compliance with consumption of the supplements was directly related to benefits perceived by the women, which in turn were those experienced by them. Nearly 70% of the 36 women interviewed felt that the tablets gave them strength (*shakti aape*). The 86% of the 36 women who regularly consumed the tablets said that they experienced several benefits, and that was the reason given for regular consumption. A third of them stated that they were able to eat food regularly (*khorak levay chhe*), that their bodies remained healthy (*sharir tandurust rahe chhe*) due to tablet consumption, and that the tablets improved the quality of their blood (*lohi no sudharo thay*). Five women said that they felt strong enough to do household work (*kam karvanu mann thay chhe*) as a result of regular tablet consumption. However, despite the availability of tablets and some awareness of their importance, the women gave variable responses as to the number of tablets consumed (table 2).

Only 5 of the subsample of 20 women who received fortnightly home visits complained of side effects during the counseling period. These discomforts included constipation, mild nausea, and sometimes vomiting. It is interesting that after counseling, three women continued to take the tablets despite their discomfort, because at the same time they experienced

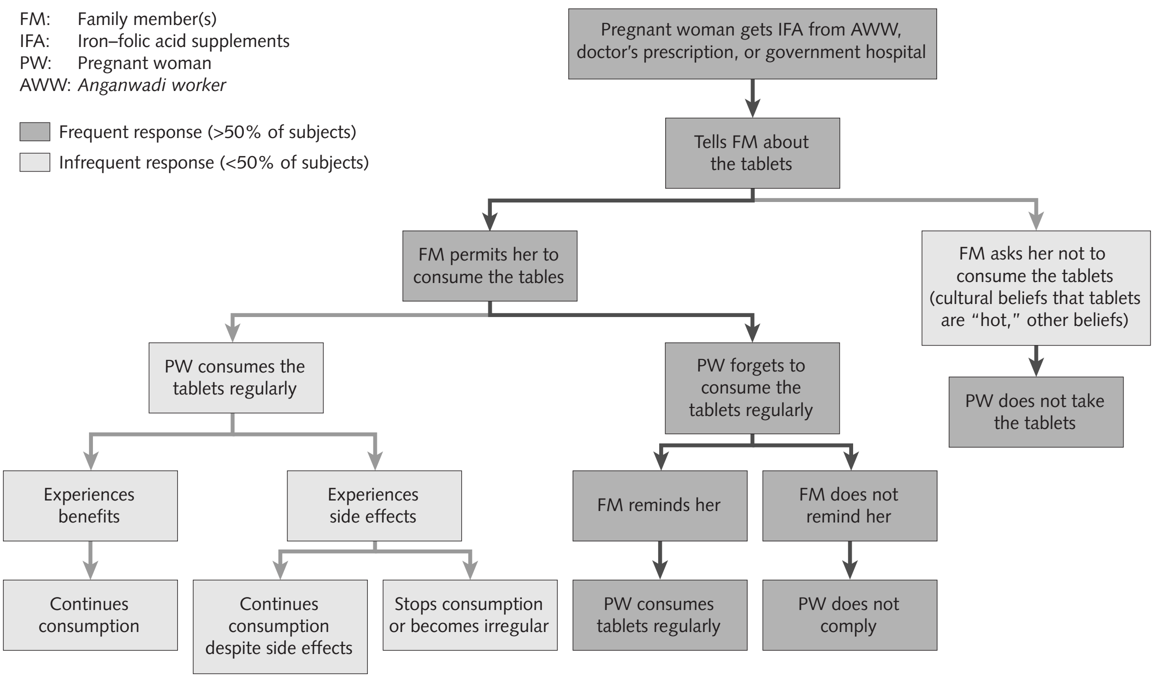

FIG. 2. Consumption of iron–folic acid supplements: an ethnographic decision model

TABLE 2. Consumption pattern of iron–folic acid tablets by subjects following fortnightly home visits and counseling ($N = 20$)

Month of pregnancy	No. of subjects	Value	No. of days covered	No. of tablets received	Expected no. of tablets consumed[a]	Actual no. of tablets consumed	% target dose consumed
5	5	Mean	56	132	71	71	99
		Range	44–95	105–205	44–102	43–100	95–104
6	4	Mean	69	135	83	81	98
		Range	47–107	50–190	47–107	50–100	93–100
7	8	Mean	48	127	84	80	94
		Range	29–62	50–175	39–124	56–120	87–106
8	3	Mean	50	110	76	72	92
		Range	32–72	100–125	64–92	60–80	87–96

a. The expected number of tablets consumed is one or two per day, as recommended by the doctor or health worker, for the remainder of pregnancy.

certain benefits, such as feeling healthy, experiencing strength, and reduction in weakness.

Counseling to improve compliance

Counseling material

The flip chart on anemia prevention during pregnancy was prepared with the objective of creating awareness among pregnant women regarding the signs and symptoms and the adverse consequences of anemia, the importance of consuming iron supplements and foods rich in iron and vitamin C, sources of iron supplements, and the need to complete the course of at least 100 tablets until delivery. The flip chart was full of colorful illustrations depicting the story of two pregnant women, one anemic and the other nonanemic.

Focus of counseling

As the EDM data suggested, the women were especially counseled regarding the benefits of iron supplementation and ways of overcoming side effects, if any, so that they could be motivated to continue and complete the full dose of the supplement prescribed. Family members were also included in the process, particularly in persuading the women to remind them to procure and take the iron supplements on a regular basis.

Impact of counseling during fortnightly home visits on compliance

As a result of the counseling process, which was refined on the basis of the EDM data, on average, the women procured an adequate number of iron–folic acid tablets, sometimes more than required (table 2), and 95% of them consumed over 90% of the required number of tablets.

Impact on benefits experienced

Table 3 presents the data on the benefits actually experienced by the women before and after counseling. Among the women who said that they regularly consumed iron–folic acid tablets at first contact (group A), the proportion experiencing the benefits markedly increased as they continued taking the tablets. An additional benefit, not reported by them earlier, was that they could work more. In this group, counseling helped to sustain regularity of consumption when the women tended to be forgetful and not procure the tablets. For the women who were irregular consumers of iron–folic acid tablets at the first contact, counseling greatly motivated them to consume tablets regularly, especially after its benefits were explained with the aid of the flip chart. As they started experiencing these benefits, their motivation to continue with the supplement increased. Thus, before the intervention only two types of benefits were reported in group B, and very few women reported any benefits; but after the intervention four types of benefits were reported, and by a larger proportion of women (table 3).

The benefits of iron–folic acid tablets experienced by the women were more likely to motivate them to continue consumption of the tablets, since most of the women who experienced benefits were the ones who consumed the tablets regularly.

Impact on hemoglobin levels

The mean hemoglobin level, which was 9.6 g/dl at the first contact, improved to 11.08 g/dl toward the end of the last trimester. The prevalence of anemia also decreased from 75% to 30%. The 13% of women who were severely anemic at the first contact shifted to the category of being moderately anemic (hemoglobin 7.0–9.99 g/dl).

Discussion

Much has been documented in the literature regarding the poor compliance with and inadequate impact of iron–folic acid supplementation interventions among deprived pregnant women. What needs to be further

TABLE 3. Benefits experienced by pregnant women as reported by them before and after counseling during fortnightly home visits ($N = 20$)

	Before counseling		After counseling	
	Group A[a]	Group B[b]	Group A	Group B
Benefit	no. (%) of subjects			
Appetite has increased	7 (35)	2 (10)	11 (55)	5 (25)
Feel energetic	4 (20)	—	12 (60)	—
Able to do work	4 (20)	2 (10)	9 (45)	8 (40)
Tiredness has decreased	2 (10)	—	7 (35)	4 (20)
Feel healthy; sense of well-being	4 (20)	—	8 (40)	—
Blood has increased and improved	2 (10)	—	10 (50)	4 (20)
Can work more	—	—	11 (55)	—

a. Group A consisted of women who were consuming tablets regularly at first contact.
b. Group B consisted of women who were consuming tablets irregularly at first contact.

understood are the household-level factors influencing compliance and factors in the health system impeding or compromising the quality of implementation of anemia control programs. An effective strategy, as described in this study, was the development of ethnographic decision models (EDMs) based on findings of formative qualitative research, and the use of EDMs to improve counseling approaches for enhancing compliance among pregnant women. In particular, in the context of an urban health system (which is less frequently studied than the rural system), EDMs helped to uncover microlevel determinants of procurement of and compliance with iron–folic acid supplements among individual women and their families. For example, in urban slums, the presence of multiple sources of the supplement may in fact lead to some women having too many iron–folic acid tablets.

Compliance is determined, in part, by the woman's ability to remember to take one tablet daily (she is often forgetful) and her motivation to continue with supplementation for 100 days, which is perceived as a long time. According to a review on determinants of compliance with iron supplements [5], the common problems observed were inadequate or unevenly distributed supplies of tablets, insufficient monitoring and supervision by the health workers, irregular antenatal visits and late seeking of treatment by women, side effects, beliefs such as that the tablets are "hot," and fear of having big babies.

This study found that the EDM data helped to determine the focus of counseling, in particular, in emphasizing the benefits of iron–folic acid consumption and giving support and encouragement to continue in case of side effects. The use of visual aids to generate interest was also helpful.

The study sample was a mixed group of women, some experiencing their first pregnancy and others who already had one or two children. Across the group, the key factor that appeared to motivate the women to continue with consumption of iron–folic acid tablets was family support, coupled with the experience of benefits. The fortnightly counseling helped this process, reinforcing the need for regular home visits by health functionaries.

Thus, with the use of open-ended research tools, development of EDMs appears to be a useful strategy for studying households to understand decision-making pathways of beneficiary groups within families and communities, which markedly influence the utilization and impact of nutrition services. On the basis of such understanding, more effective information-education-communication materials could be developed and health workers could be helped to implement better anemia control in pregnancy.

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Development and validation of a short food-frequency questionnaire for screening women of childbearing age for vitamin A status in northwestern Iran

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Abstract

A high percentage of women in their childbearing years suffer from subclinical vitamin A deficiency; 10% to 20% of pregnant women worldwide are vitamin A deficient. This study aimed to design and validate a short food-frequency questionnaire to serve as a simple screening tool for vitamin A status in women of childbearing age. The sample consisted of 187 healthy, nonpregnant, nonlactating women 15 to 49 years of age, from urban and rural areas of Marand district in East Azerbaijan. Dietary intake was evaluated by a face-to-face interview using a 24-hour dietary recall for two consecutive days and a 41-item qualitative food frequency questionnaire. Height, weight, and serum retinol were measured. Serum retinol values were less than 20 μg/dl for three subjects, while an additional 34 subjects (18%) had values between 21 and 30 μg/dl. Principal-component analysis performed on the food-frequency questionnaire identified five components that together defined 34.4% of the variance in estimated vitamin A intake and were used to derive a 20-item short food-frequency questionnaire. Internal consistency of the short instrument was acceptable (Cronbach's alpha = .59). Serum retinol was significantly correlated with total vitamin A intake and with intake of vitamin A from plant sources, as estimated by the short food-frequency questionnaire. Important sources of provitamin A in these women's diets included some not typical of other populations: nuts and green leaves of types used elsewhere in small quantities as herbs, but important in Iran because the amount and frequency of consumption are relatively high. We conclude that the questionnaire is relatively valid and potentially useful in identifying women at risk for vitamin A deficiency in this population.

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Introduction

Vitamin A deficiency is a major public health problem in less-developed and developing countries and has a high impact on morbidity and mortality [1, 2]. About 100 million children in the world are estimated to be vitamin A deficient [3]. A high percentage of women of childbearing age suffer from subclinical vitamin A deficiency: 10% to 20% of pregnant women worldwide are vitamin A deficient [3]. Iran, like most of the Middle East, is not an area of severe vitamin A deficiency, but mild-to-moderate vitamin A deficiency is widespread in vulnerable groups. Dietary studies in Iran conducted from the 1960s through as recently as 1995 indicate an inadequate intake of vitamin A, especially in rural areas [4].

A variety of biochemical methods exist to evaluate the vitamin A status of communities [5]; however, biochemical methods are invasive and relatively expensive [6, 7]. Thus, development of alternative methods that are inexpensive and easy to perform in the field setting is a priority. In this context, dietary assessment methods have been recommended for identifying groups at risk for vitamin A deficiency and for assessing food habits as a basis for designing effective interventions to improve vitamin A status [8]. The targeted food-frequency questionnaire has been proposed as a simple, inexpensive dietary assessment method with low interview and recording error as well as minimal recall bias [9]. However, food-frequency questionnaires need to be tailored to the food-consumption patterns and culture of the population under study [10, 11]. Biochemical indicators can then be used to validate the food-frequency questionnaire, identify food items with maximum discriminating effect, and exclude those with little predictive value, despite having high content of the nutrient of interest [12].

Since the 1970s, several attempts have been made to design and validate dietary questionnaires (mostly food-frequency questionnaires) as screening tools to identify risk of poor vitamin A status. At least three food-frequency questionnaires have been developed and tested for preschool children in developing countries. One of these originated in Indonesia [13] and one in Mexico [14]. The third, developed by Helen Keller International, is meant for local adaptation and widespread use [15]. The Helen Keller instrument has been evaluated in preschoolers in Thailand [7], Iran [16], the Philippines, Guatemala, and Tanzania [6], and in pregnant and lactating women in Bangladesh [17]. In the majority of these studies [6, 7, 14–16], serum or plasma retinol has been used as the biomarker for validation of the questionnaire; the Indonesian study [13] used serum β-carotene. Only one study [16], which was conducted on preschool children in the province of Ilam, western Iran, failed to find a significant correlation between serum retinol and vitamin A intakes as estimated with the adapted Helen Keller International instrument. In contrast to the findings in populations at risk for vitamin A deficiency, in vitamin A-sufficient populations there is generally no relationship between intakes estimated from targeted food-frequency questionnaires and serum retinol levels [11, 18–20].

The present study aimed to design and validate a short food-frequency questionnaire to serve as a simple screening tool for vitamin A status in women of childbearing age in an area where overt hypovitaminosis A is rare but mild deficiency is probably common.

Methods and materials

Study population and sampling

The study population included urban and rural women from the Marand district of East Azarbaijan, an agricultural area in northwest Iran. The study was performed during the month of April (the beginning of spring in the area), as part of an intervention study focused on iron-deficiency anemia. For this study, a convenience sample was selected from an ongoing study of anemia in the region. The Research Council of the Ministry of Health and Medical Education approved the study protocol. Sampling was carried out in two phases. In the first phase, a sample of 1,000 women was selected through random sampling from those women under coverage of the primary health-care system in the area. Approximately 100 of these women were diagnosed as anemic. In the second phase, the latter group was matched with nonanemic women based on parity, age, and area of residence. The sample consisted of 187 healthy, nonpregnant, nonlactating women 15 to 49 years of age.

Dietary assessment

Dietary intake was evaluated on two consecutive days by a face-to-face interview using a 24-hour dietary recall and a 43-item qualitative food-frequency questionnaire. The interviewers were undergraduate nutrition students who were given a two-day course in dietary interviewing prior to the study and frequent supervision by the first author (N. O.) during the course of the study. A pictorial food album and common household measures were used as memory aids in the interview.

The 43-item food-frequency questionnaire (hereafter referred to as the long food-frequency questionnaire) was designed to evaluate the usual frequency of consumption of 43 food items determined to be major contributors to the Azerbaijani diet, as reported by previous dietary studies in the area [4]. There was special emphasis on foods that provide iron, vitamin C, and vitamin A. For each item, the subjects were asked to specify their frequency of intake over a day, week, month, and year. “Never” and “rarely” were included as possible options and were scored as zero.

Since the food-frequency questionnaire did not ask for the portion sizes, the portion sizes were estimated by using the portion sizes reported in the 24-hour recalls and those reported in the national household-consumption survey that was available from neighboring West Azerbaijan [Hooshiar-rad A, National Institute of Nutrition and Food Technology, Tehran: personal communication, 2000]. Vitamin A content (retinol equivalents) for each typical portion was then calculated based on the Iranian food-composition table [21]. For food items whose vitamin A content was not reported in the Iranian table, other tables were used [22, 23]. In this way, a table of vitamin A-containing local foods with usual portion sizes was developed (appendix 1). Estimates of vitamin A intake were obtained for each subject by multiplying the frequency of consumption of each food item per week by the vitamin A content of the medium-portion size of that food and then summing over all intakes.

Biochemical assessment

A 3-cc sample of venous blood was obtained by antecubital puncture from nonfasting subjects at the first visit. Specimens were immediately transferred to shielded tubes, placed in a cool box, and taken to a laboratory in Marand city. Serum was separated by centrifugation within 2 hours and stored shielded from light at –20°C until analysis. Frozen serum samples were then transferred to the National Nutrition Institute laboratory in Tehran. Serum retinol was determined by high-performance liquid chromatography as described by Bieri et al. [24]. Samples were available for 177 women.

Anthropometric measurements

Height and weight were measured by trained nutritionists. Body weight was measured using calibrated beam scales and was recorded to the nearest 0.5 kg. The subjects were measured barefoot wearing light clothing. Height was measured using a mounted tape with the subject's arms hanging freely at her sides and recorded to the nearest 0.5 cm. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared.

Data analysis

Statistical analyses were performed using SPSS for Windows, version 6.1. Factor analysis using principal component analysis with varimax rotation was performed on the food-frequency items to identify main factor groupings and the final food list for the short questionnaire. Main factor groupings were defined as those with eigenvalues above 1 and responsible for more than 5% of the total variance. The relative validity of the questionnaire was evaluated through computation of Pearson correlation coefficients to examine the relationship between vitamin A intake assessed by the short food-frequency questionnaire and serum concentration of retinol, and by examination of the ability of the short food-frequency questionnaire to divide the population into tertiles that corresponded to tertiles of serum retinol concentration. The sensitivity and specificity of the questionnaire for prediction of serum retinol levels were calculated.

Results

Description of subjects and serum retinol concentrations

No significant differences in demographic variables were observed at baseline between urban and rural dwellers; therefore, data were pooled. Nearly all subjects were married housewives. In terms of educational attainment, 36% were illiterate, 36% were low literate (less than 5th grade formal schooling), and the rest were high school or university graduates. The mean age of the subjects was 29.8 years. The mean values for characteristics of the study subjects, including age, weight, height, BMI, and serum retinol, are presented in table 1. Table 2 shows the distribution of serum retinol levels. Approximately 20% of the subjects fell within the deficient range (< 30 µg/dl), but almost all were within the marginally deficient range; only three subjects (< 2%) had serum retinol in the intermediate or severe deficiency range.

Identification of items for short form of questionnaire

Means and standard deviations for frequency of consumption of food items per week and retinol equivalents contributed by each food item per week are presented in tables 3 and 4, respectively. The principal components solution for the food-frequency questionnaire identified five components with eigenvalues above 1.6 that together defined 34.4% of the variance. The 20 food items that comprise the short food-frequency questionnaire are presented in appendix 2, and their factor loadings in table 5. Internal consistency of the items on the short food-frequency questionnaire was evaluated using Cronbach's alpha. The alpha coefficients for short food-frequency questionnaire items ranged from 0.555 to 0.586. The overall alpha coefficient of the questionnaire was 0.587.

Relationship of intake estimates to serum retinol concentration and to short-term vitamin A intake estimated by recall for two consecutive days

The relative validity of the questionnaire was evaluated by assessing the correlation between retinol intake estimates by the short food-frequency questionnaire and vitamin A intake by the 24-hour recall as well as serum retinol concentration. Serum retinol was significantly correlated with total vitamin A intake

TABLE 1. Characteristics of the sample

Variable	Mean	SD	*n*
Age (yr)	29.8	8.47	186
Weight (kg)	60.1	11.68	186
Height (cm)	155.8	8.69	187
Body mass index (kg/m^2)	24.6	4.48	186
Serum retinol (µg/dl)	40.7	12.23	177

TABLE 2. Distribution of vitamin A status based on serum retinol levels

Vitamin A status	*n*	%
Severe deficiency (0–10 µg/dl)	1	0.5
Intermediate deficiency (11–20 µg/dl)	2	1.1
Marginal deficiency (21–30 µg/dl)	34	18.2
Adequate (> 30 µg/dl)	150	80.2

($r = .21$, $p = .01$) and with vitamin A intake from plant sources ($r = .10$, $p = .02$), as estimated by the short food-frequency questionnaire, but not with intakes estimated by the recall method (table 6). Estimates of total vitamin A intake by the long food-frequency questionnaire were also correlated with serum retinol, and both food-frequency questionnaire divided the population into similar quartiles. There was no correlation between the estimates of vitamin A intake by either food-frequency questionnaire and those from the 24-hour recalls.

TABLE 3. Frequency of consumption of food items according to the original (long) food-frequency questionnaire

Food	Frequency (times/week) Mean	Frequency (times/week) SD	Never or rarely consumed (% of subjects)
Animal-based foods			
Feta cheese	7.07	3.9	4
Yogurt	3.75	4.2	11
Red meat	3.72	2.9	2
Eggs	2.99	2.5	5
Lard	1.97	3.2	41
Milk	1.80	2.8	22.5
Chicken	0.56	0.9	19
Butter	0.53	1.3	41
Cream	0.41	1.1	52
Ice cream	0.32	0.5	35
Liver	0.18	0.4	36
Kashek[a]	0.13	1.0	80
Fish	.06	0.1	71
Plant-based foods			
Bread	20.31	4.9	0.5
Vegetable oil	13.07	3.9	0.5
Onions	7.34	3.9	3
Potatoes	6.78	3.2	0.5
Tomatoes	5.01	3.8	2
Apples	5.00	5.0	5
Green leafy vegetables[b]	4.71	4.5	4
Rice	4.13	2.4	0.5
Beans	3.73	2.7	0.5
Cherries and apricots	1.76	1.8	2
Citrus fruits	1.51	2.0	5
Melons	1.48	1.0	2
Grapes	1.40	1.8	6
Carrots	1.28	1.8	9
Zucchini and eggplant	1.03	1.1	10
Pasta	0.92	1.1	17
Walnuts	0.72	1.4	20
Dates	0.68	1.3	21
Pomegranates	0.45	0.8	17
Dried apricots	0.43	1.1	51
Almonds	0.39	1.0	30
Lentils	0.28	0.6	50
Pistachios	0.26	0.98	42
Bell peppers	0.26	0.7	55
Pumpkin	0.03	0.2	96

a. Dried yogurt from skimmed sheep milk [21].
b. Includes spinach, parsley, cilantro, and dill.

Relationship of serum retinol to other dietary and anthropometric variables

The relationships between serum retinol and age, BMI, energy, protein, and fat intake based on the

TABLE 4. Estimated intakes of retinol according to the original (long) food-frequency questionnaire

Food	Retinol intake (μg RE/wk) Mean	Retinol intake (μg RE/wk) SD
Animal-based foods		
Eggs	388.59	327.09
Liver	145.99	335.72
Milk	102.68	161.20
Butter	86.12	204.03
Feta cheese	63.64	35.39
Yogurt	60.00	67.52
Red meat	27.88	20.85
Chicken	23.84	36.38
Ice cream	20.88	34.96
Lard	1.97	3.22
Kashek[a]	1.30	10.41
Fish	0.84	2.83
Cream	0.41	1.06
Plant-based foods		
Green leafy vegetables[b]	2,946.32	2,786.94
Carrots	886.68	1,219.52
Melons	289.38	366.11
Tomatoes	212.72	160.10
Citrus fruits	188.99	246.04
Apples	54.95	54.77
Cherries and apricots	32.51	33.92
Dried apricots	23.91	59.60
Grapes	16.79	21.89
Zucchini and eggplant	14.43	15.67
Potatoes	13.57	6.41
Vegetable oil	13.07	3.95
Pistachios	3.68	13.72
Walnuts	3.23	6.16
Pumpkin	3.17	28.48
Bell peppers	3.10	8.85
Raisins	1.69	4.81
Dates	0.68	1.29
Lentils	0.14	0.30
Bread	0.02	0.00
Onions	—	—
Rice	—	—
Beans	—	—
Pomegranates	—	—
Almonds	—	—
Pasta	—	—

a. Dried yogurt from skimmed sheep milk [21].
b. Includes spinach, parsley, cilantro, and dill.

recall method were examined by one-way analysis of variance. Serum retinol was weakly correlated with fat intake estimated from 24-hour recall ($r = .15$, $p = .04$); no relationship was observed between serum retinol and other dietary variables. Serum retinol levels did not differ according to BMI or for anemic versus nonanemic subjects.

Sensitivity and specificity

Sensitivity and specificity analyses of intake estimates from the short food-frequency questionnaire in relation to serum retinol yielded values of 29.5% (sensitivity) and 82% (specificity). This short food-frequency questionnaire in this population performed substantially better in terms of specificity, but worse in terms

TABLE 5. Factor loadings for food items on the short food-frequency questionnaire

Food	Factor 1	2	3	4	5
Pistachios	.5920				
Dates	.5587				
Walnuts	.5154				
Zucchini and eggplant	.5143				
Tomatoes	.4910				
Feta cheese	.4254				
Ice cream	.3924				
Cherries and apricots	.3913				
Liver	.3469				
Melons		.4916			
Grapes		.4888			
Dried apricots		−.3852			
Green leafy vegetables			.4950		
Lentils			.4280		
Vegetable oil			.4213		
Citrus fruits			.4082		
Raisins				−.5065	
Eggs				−.4619	
Yogurt				−.4030	
Carrots					.5210

Factor	Eigenvalue	% of variance	Cumulative percentage
1	3.9	11.7	11.7
2	2.2	6.6	18.3
3	1.9	5.8	24.1
4	1.8	5.3	29.5
5	1.6	5.0	34.4

TABLE 6. Relationships between short and long food-frequency questionnaire (FFQ) intake estimates with intake from 24-hour recall and with serum retinol (Pearson correlation coefficients)

Intake	Value	Serum retinol: Short FFQ	Serum retinol: Long FFQ	24-h recall: Short FFQ	24-h recall: Long FFQ
Total retinol	*r*	.206	.194	.083	.076
	p	< .05	< .05	NS[a]	NS
Animal food	*r*	.113	.118	.019	.019
	p	NS	NS	NS	NS
Plant food	*r*	.194	.187	.086	.090
	p	< .05	< .05	NS	NS

a. NS, Not significant.

of sensitivity, than a targeted intake assessment similarly validated among preschool children in rural Thailand [7]. Infection was more likely to influence serum retinol levels among the Thai children than in the present sample, whereas intake *per se* is more important in the present sample of Iranian women.

Discussion

The purpose of this pilot study was to design and validate a short food-frequency questionnaire for screening women's vitamin A status. A 20-item short food-frequency questionnaire was developed. Validity and reliability tests indicate that the questionnaire is relatively valid and reliable for the purpose of identifying women at risk for vitamin A deficiency as indexed by serum retinol level. The correlation between short food-frequency questionnaire estimates of dietary vitamin A intake and serum concentration of retinol is similar to that reported for children [6, 13, 14] and for pregnant and lactating women [17]. These findings stand in contrast to observations in populations of vitamin A-sufficient adults in which no correlations or only weak relationships between serum retinol and intake were found [18–20].

The findings of the present study indicate a lack of correlation between estimates of vitamin A intake by recall over a 48-hour period and serum retinol concentrations. This observation is consistent with previous studies demonstrating higher reliability of intake estimation by food-frequency questionnaire than that by 24-hour recall with respect to vitamin A status. Serum vitamin A levels are a function of long-term intake of vitamin A-containing foods. Therefore, short-term measurement of vitamin A intake is subject to fluctuation and does not reflect the risk of deficiency.

Two items rather specific to this population emerged from this analysis. The most striking is the importance of nuts in the diet. Although nuts are relatively low in provitamin A, their regular intake by the study subjects makes their contribution to vitamin A intake significant. The second is the importance of green leaves of the type utilized in other cuisines as herbs (parsley, dill, cilantro, and others). These are eaten regularly and in large quantities, are grown in household gardens to assure a steady supply for the table, and are basic to Iranian dietary habits.

A previous study in Ilam Province of Iran showed a lack of correlation between frequency of intake of vitamin A-containing foods, according to the Helen Keller International short food-frequency questionnaire, and serum retinol in preschool children [16]. This questionnaire allows for modification of some of the food items based on the dietary pattern of the population under study. The modified version of the questionnaire applied in the Ilam study demonstrated low internal consistency. The lack of association observed between the food-frequency questionnaire estimates of vitamin A intake and serum retinol in the Ilam study may have arisen from differences in study design, populations, and specific food items included in the questionnaire as compared with the core foods eaten, affecting the overall validity and reliability of the questionnaire.

The short food-frequency questionnaire designed for this study represents one of the first attempts to develop standardized dietary tools for the Iranian population. Application of a biochemical indicator provided an independent measurement for assessment of the validity of the questionnaire for screening vitamin A status. Further study is needed to evaluate the accuracy and applicability of the questionnaire in different communities in the area and whether it could be successfully utilized by auxiliary health workers with minimum training.

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Appendix 1. Retinol equivalent (RE) content of food items based on different serving sizes reported by adults, Marand, East Azerbaijan 1998

Food	Serving size (g)			RE (µg/100 g)	Vitamin A score[a]
	Small	Medium	Large		
Animal sources					
Butter	12.5	25	50	650	Medium
RE (µg)	81	162	325		
Cheese	7.5	15	30	60	Low
RE (µg)	4.5	9	18		
Cream	—	15	—	Trace	
RE (µg)	—	1	—		
Eggs	25 (½)	50 (1)	100 (2)	260	Medium
RE (µg)	21	130	260		
Fish	30	50	100	30	Low
RE (µg)	9	15	30		
Ghee	—	5	10	Trace	Low
RE (µg)	—	1	2		
Ice cream	—	50	100	132	Medium
RE (µg)	—	66	132		
Kashek[b]	NA[c]				
RE (µg)					
Liver	50	100	150	800	High
RE (µg)	400	800	1200		
Milk	100	150	200	38	Low
RE (µg)	38	57	76		
Poultry	25	50	120	85	Low
RE (µg)	21	42.5	102		
Red meat	20	30	65	25	Low
RE (µg)	5	7.5	16		
Yogurt	50	100	250	16	Low
RE (µg)	8	16	40		
Plant sources					
Almond	—	16 (17)	—	0	Low
RE (µg)	—	—	—		
Apples	100–120	150		10	Low
RE (µg)	10	15			
Beans and yellow split peas	15	25	50	Trace	Low
RE (µg)	—	—	—		
Bell pepper	30	60	100	20	Low
RE (µg)	6	12	20		
Bread, Bar-Bari	70	140	280	Trace	Low
RE (µg)	—	—	—		
Bread, flat (Lavash)	58	120	180	Trace	Low
RE (µg)	—	—	—		
Bread, brown, flat (Sangak)	50	150	300	Trace	Low
RE (µg)	—	—	—		
Carrots					
Dark orange	50	100	150	691	High
RE (µg)	345.5	691	1,036.5		
Light orange (Persian)	50	100	150	63	Low
RE (µg)	31.5	63	94		
Cherries and apricots	50	100	150	18.5	Low
RE (µg)	9.2	18.5	27.7		
Citrus fruits	½ (each)	1(each)	2 (each)	125	Medium
RE (µg)	62.5	125	250		

continued

(continued)

Food	Serving size (g)			RE (μg/100 g)	Vitamin A score[a]
	Small	Medium	Large		
Dates	—	26 (3)	—	4	Low
RE (μg)	—	1	—		
Dried apricots	—	26.5 (3)	—	210	Low
RE (μg)	—	55.6			
Grapes	—	145–150		8	Low
RE (μg)	—	12			
Green leafy vegetables[d]					
Raw	50	100	150	600	High
RE (μg)	300	600	900		
Cooked	20	50	100	650	Medium
RE (μg)	130	325	650		
Lentils					
Raw	—	25	—	Trace	Low
RE (μg)	—	—	—		
Cooked	—	50	—	Trace	Low
RE (μg)	—	—	—		
Melons	150	300	—	130	Medium
RE (μg)	195	390	—		
Onion					
Raw	25	50	—	0	—
RE (μg)	—	—	—		
Cooked	5	10	15	0	—
RE (μg)	—	—	—		
Pistachios and hazelnuts	—	15.5 –15.7		87	Low
RE (μg)	—	14			
Pomegranates	—	100	—	Trace	Low
RE (μg)	—	—	—		
Potatoes	50	100	150	2	Low
RE (μg)	1	2	3		
Pumpkin	—	50	—	242	High
RE (μg)	—	121	—		
Raisins	—	18.5	—	20	Low
RE (μg)	—	3.7	—		
Rice	150	220	300	Trace	Low
RE (μg)	—	—	—		
Tomatoes					
Raw	25	50	75	90	Low
RE (μg)	22.5	45	67.5		
Cooked (paste)	5	10	15	400	High
RE (μg)	20	40	60		
Vegetable oil (shortening)	10	15	30	0	
RE (μg)	5	7.5	15		
Walnuts	—	15 (3.5)	—	30	Low
RE (μg)	—	4.5	—		
Zucchini and eggplant	40	75	140	18.5	Low
RE (μg)	7.4	14	25.9		

a. Vitamin A score: micrograms of vitamin A per small serving; low (< 50 μg), medium (50–250 μg), high (> 250 μg).
b. Dried yogurt from skimmed sheep milk in the form of a small ball [21].
c. Vitamin A analysis not available; content probably negligible.
d. Includes spinach, parsley, cilantro, and dill.

Appendix 2. Final list of foods on the short food-frequency questionnaire

1. Pistachios
2. Dates
3. Walnuts
4. Zucchini and eggplant
5. Tomatoes
6. Feta cheese
7. Ice cream
8. Cherries and apricots
9. Liver
10. Melons
11. Grapes
12. Dried apricots
13. Green leafy vegetables
14. Lentils
15. Vegetable oil
16. Citrus fruit
17. Raisins
18. Eggs
19. Yogurt
20. Carrots

Factors associated with successful pregnancy outcomes in Upper Egypt: A positive deviance inquiry

Mahshid Ahrari, Attallah Kuttab, Samir Khamis, Amal Ali Farahat, Gary L. Darmstadt, David R. Marsh, and F. James Levinson

Abstract

*A positive deviance inquiry was conducted in Al-Minia, Upper Egypt, to identify factors associated with achievement of good pregnancy outcomes despite limited resources. As compared with women with poor weight gain (*n = 30*), low-income women with weight gain greater than 1.5 kg per month in the second trimester of pregnancy (*n = 11*) were more likely to report multiple antenatal care contacts (80% versus 43%), increased rest during pregnancy (67% versus 7%), and more consumption of meat (33% versus 13%) and vegetables (82% versus 37%), and were less likely to report symptoms consistent with urinary tract infection (50% versus 90% with dysuria and 0% versus 57% with cloudy or reddish urine). Similar characteristics distinguished low-income women in a more economically advantaged community whose newborns weighed more than 3 kg (*n = 18*) as compared with mothers of smaller newborns (*n = 18*). These characteristics were similar to those identified in the National Research Center's Al-Minia birthweight study. The positive deviance inquiry is an affordable, participatory step to identify accessible individuals, behaviors, and conditions for improved perinatal health.*

Introduction

In most communities throughout the world, the uncommon behaviors of a few insightful, enterprising "positive deviant" individuals enable them and their families to find more effective solutions to pervasive problems than their neighbors with whom they share the same resource base. The positive deviance approach is based on the belief that solutions to community problems that are identified within the community itself are more likely to be effective, affordable, acceptable, and sustainable. A positive deviance inquiry [1] attempts to identify rapidly and at low cost those uncommon practices, linked to a good outcome, that a follow-up program can help spread throughout the community to improve the outcome of interest. Typically, the positive deviance inquiry team and community key informants stratify the population into four groups based on outcome (good versus not good) and risk (higher versus lower). Those at higher risk who demonstrate the good outcome are the positive deviants.

The positive deviance concept was first applied to nutrition in the late 1980s by Zeitlin et al., who observed that most low-income communities included a few poor households with well-nourished children, thus raising the question of how such households could do this when their neighbors could not [2]. Since then, Save the Children Federation/US has applied the positive deviance approach to rehabilitate malnourished children in multiple settings [3, 4]. Save the Children recently declared a Positive Deviance Initiative to affirm its commitment to the approach and to apply it to new programming contexts [5].

Pregnancy outcomes in Egypt are suboptimal. The national rate of low birthweight (10%) is probably an underestimate because of the practice of weighing newborn infants with heavy coverings. Moreover, almost one in three infants (30%) weigh less than 3 kg at birth, and infants weighing 2,500 to 2,999 g at birth are 2.5 times more likely to die than those with birthweights of 3,000 to 3,499 g [6]. It is also likely that low birthweight contributes to the high rates of moderate and severe malnutrition (< –2 SD), affecting an estimated 45% of children under the age of two years in Al-Minia Governorate in Upper Egypt.* Save the Children has used the positive deviance approach

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* El-Sayed NA. Evaluation of positive deviance: a pilot nutrition intervention in Minia Governorate. Report to UNICEF and Save the Children. Unpublished report, May 1999.

successfully to reduce child malnutrition in Egypt since 1997.

With the objective of intervening against childhood malnutrition at its root cause, Save the Children applied the positive deviance inquiry to pregnancy outcomes in Al-Minia to identify key behaviors associated with improved pregnancy weight gain and birthweight.

Methods

Save the Children conducted this positive deviance inquiry in its program area in Al-Minia Governorate between June and November 2000 in two large rural communities, Al-Ghatousha and Etsa-Albalad. Outcomes included pregnancy weight gain in Al-Ghatousha and birthweight in Etsa-Albalad [7]. Save the Children mobilized women to participate in both communities, and health clinic staff obtained outcome measurements. Determination of pregnancy weight gain involved monthly weighing sessions on standard bar scales between the fourth and seventh months of pregnancy. Birthweights over the same three-month period were obtained in Etsa-Albalad within 48 hours of delivery on Samson coil scales. "Good outcomes" were an average monthly weight gain over the two-month period of more than 1.5 kg, excluding cases of edema; or birthweight greater than 3.0 kg. "Not good outcomes" were an average monthly weight gain of less than 1 kg and birthweight less than 3.0 kg. We also measured women's height as a possible indicator of lifetime health and nutritional well-being.

Security regulations in Al-Minia precluded household surveys but permitted group interviews. Thus, two months after the weight and height measurements were completed, trained fieldworkers interviewed individual women, one at a time, as they sat in groups of 11 to 24. During these group interviews, information was sought about demographics, use of antenatal care, water and sanitation, symptoms of possible urinary or reproductive tract infection, pregnancy workload, exposure to tobacco, and diet. Because confidentiality was impossible, sensitive topics were avoided. The variation in the responses suggested that the group did not unduly influence individual respondents.

A group of senior village officials estimated economic status and categorized families into classifications that enabled us to divide women with good outcomes into higher- and lower-income subgroups across variables that seemed to be important contributors to good outcome. On the same day and on the day after the survey, we conducted three focus group discussions in each community, one each with low-income positive deviant women, their husbands, and their mothers-in-law to understand better the quantitative findings. We posed questions in English through an Arabic translator and made hand-written notes. We assumed that wide differences in characteristics were likely to be programmatically important without the need for statistical tests.

Results

Pregnancy weight gain in Al-Ghatousha

The total sample of 74 women gained an average of 1.08 kg per month (range, –1 to 2.8 kg). The sample for the positive deviance inquiry included 30 (41%) "poor gainers" who gained less than 1 kg/month and 24 (32%) "good gainers" who gained at least 1.5 kg/month. Eleven (46%) good gainers were positive deviants, i.e., low-income. We followed the good and the poor gainers from similar points in their gestations (20.8 and 20.9 weeks, respectively).

Overall, the women in both weight-gain groups were similar in height, age, age at marriage, age at first pregnancy, and time between the last two pregnancies (table 1). None of the women worked outside the home. Good gainers reported fewer pregnancies than poor gainers (3.0 versus 3.8), were less likely to have a low income (46% versus 80%), and were more likely to have had some schooling (29% versus 13%). Good gainers overall and low-income good gainers were nearly twice as likely as poor gainers to report multiple antenatal care contacts (83%, 80%, and 43%, respectively). Good gainers and the low-income subset were more likely to use tap water than the poor gainers (38%, 18%, and 0%, respectively). Poor gainers were likely to have dysuria than good gainers (90% versus 50%) and reported cloudy or reddish urine far more often (57% versus 0%).

Good gainers overall and low-income good gainers were 10 times as likely as poor gainers to rest more during pregnancy (63%, 67%, and 7%, respectively). On the other hand, both good and poor gainers reported eating less overall during pregnancy (70% versus 77%). However, good gainers overall and low-income good gainers were more likely than poor gainers to eat more meat (57%, 33%, and 13%, respectively) and vegetables (57%, 82%, and 37%, respectively). Consumption of dairy products and vegetable oil was more common among good gainers (22% and 11%, respectively) than among poor gainers (0% and 0%, respectively). On the other hand, poor gainers consumed more beans than good gainers (20% versus 4%).

Birthweight in Etsa-Albalad

We recorded 66 birthweights (mean, 3.00 kg; range, 2.00–3.50 kg). Only one baby weighed less than 2.5 kg,

TABLE 1. Characteristics of pregnant women according to amount of midpregnancy weight gain in Al-Ghatousha

Characteristic	Weight gain (kg/mo) > 1.5 (*n* = 24)	> 1.5 (low-income subgroup) (*n* = 11)	< 1.0 (*n* = 30)	Likely important differences
Mean height (cm)	154.5	155.4	152.8	
Low income—%(no.)	45.8 (11/24)		80 (24/30)	X
Mean age (yr)	24.0		24.8	
Mean age at marriage (yr)	17.3		16.6	
Mean age at 1st pregnancy (yr)	18.0		18.2	
First pregnancy—%(no.)	33 (8/24)		17.2 (5/29)	
Mean gravidity	3.0		3.8	X
Mean interval between last two pregnancies (mo)	38.9		36.4	
Any schooling—%(no.)	29.2 (7/24)	18.2 (2/11)	13.3 (4/30)	X
Out-of-home employment—%(no.)	0 (0/24)		0 (0/30)	
≥ 1 antenatal visit—%(no.)	100 (24/24)	100 (11/11)	70.0 (21/30)	X
≥ 3 antenatal visits—%(no.)	83.3 (20/24)	80.0 (8/10)	43.3 (13/30)	X
Tap water—%(no.)	37.5 (9/24)	18.2 (2/11)	0 (0/30)	X
Latrine—%(no.)	83.3 (20/24)	66.7 (6/9)	63.3 (19/30)	
Painful urination—%(no.)	50 (12/24)		90.0 (27/30)	X
Cloudy or reddish urine—%(no.)	0 (0/24)		56.7 (17/30)	X
Nonwhite vaginal discharge—%(no.)	0 (0/24)		6.7 (2/30)	
Vaginal discharge with unpleasant odor—%(no.)	9.5 (2/21)		13.3 (4/30)	
More than usual rest with pregnancy—%(no.)	62.5 (15/24)	66.7 (6/9)	6.7 (2/30)	X
Pregnancy daytime rest > 90 min/day—%(no.)	62.5 (15/24)	50 (5/10)	33.3 (10/30)	X
Frequent help with chores during pregnancy—%(no.)	54.2 (13/24)		70.0 (21/30)	
Smoking during pregnancy—%(no.)	0 (0/24)		0 (0/30)	
Secondhand smoke exposure during pregnancy—%(no.)	83.3 (20/24)		56.7 (17/30)	
Consumed more food than usual—%(no.)	5.0 (1/20)		6.7 (2/30)	
Consumed less food than usual—%(no.)	70.0 (14/20)		76.7 (23/30)	
Greater than usual consumption of particular foods—%(no.)				
Rice	5.6 (1/18)		0 (0/30)	
Wheat products	16.7 (3/18)	33.3 (3/9)	0 (0/30)	
Meat	55.6 (10/18)		13.3 (4/30)	X
Fish	5.6 (1/18)		0 (0/30)	
Eggs	5.6 (1/18)		0 (0/30)	
Beans	3.9 (7/18)	81.8 (9/11)	20.0 (6/30)	X
Vegetables	55.6 (10/18)		36.7 (11/30)	X
Fruit	61.1 (11/18)		63.3 (19/30)	
Dairy products	22.2 (4/18)		0 (0/30)	X
Oil or fat	11.1 (2/18)		0 (0/30)	X

and 18 (27%) weighed less than 3.0 kg. An additional 18 (38%) of the mothers whose infants had good birthweights were low-income and thus positive deviants. This village was economically more advantaged than Al-Ghatousha (36% versus 62% low-income), and more women had some schooling (82% versus 21%) and access to tap water (79% versus 21%). The women were similar in height, age, age at marriage, age at first pregnancy, gravidity, time between the last two pregnancies, and schooling, regardless of birthweight outcome (table 2).

In Etsa-Albalad income was not associated with birthweight (38% of mothers of babies of higher birthweight and 33% of mothers of lower birthweight belonged to the low-income subgroup). Mothers of higher-birthweight babies were less likely to be in their first pregnancy than mothers of lower-birthweight infants (25% versus 56%). Mothers of higher-birth-

TABLE 2. Characteristics of pregnant women according to infant's birthweight in Etsa-Albalad

Characteristic	Birthweight (kg) > 3 (*n* = 48)	> 3 (low-income subgroup) (*n* = 18)	< 3 (*n* = 18)	Likely important differences
Mean height (cm)	154.1	152.6	156.3	
Low income—%(no.)	37.5		33.3	
Mean age (yr)	24.0		24.5	
Mean age at marriage (yr)	17.7		18.5	
Mean age at 1st pregnancy (yr)	18.6		19.1	
First pregnancy—%(no.)	25 (12/48)		55.5 (10/18)	X
Mean gravidity	3.1		2.6	
Mean interval between last two pregnancies (mo)	45.9		41.6	
Any schooling—%(no.)	87.5 (42/48)		75 (12/16)	
≥ 3 antenatal visits—%(no.)	81.3 (39/48)	66.7 (12/18)	41.2 (7/17)	X
Cloudy or reddish urine—%(no.)	6.3 (3/48)		50.0 (9/18)	X
More than usual rest with pregnancy—%(no.)	31.3 (15/48)	33.3 (6/18)	16.7 (3/18)	X
Pregnancy daytime rest > 90 min/day—%(no.)	37.5 (18/48)	16.7 (3/18)	25.0 (4/18)	X

weight babies, including those in the low-income subgroup, had more antenatal care visits than mothers of lower-birthweight babies (81%, 67%, and 41%, respectively, had three or more visits). Fewer mothers of higher-birthweight babies reported cloudy or reddish urine than mothers of lower-birthweight babies (6% versus 50%). Finally, mothers of higher-birthweight babies, including the low-income subgroup, were more likely than mothers of low-birthweight babies to report resting more than usual during their pregnancy (31%, 33%, and 17%, respectively). There were no reported dietary differences between the groups (data not shown).

Positive deviance focus groups

Low-income positive deviance women faced more serious time and economic limitations than their economically advantaged neighbors. Nonetheless, they sacrificed to receive antenatal care "to protect pregnancy." Public services only provided free tetanus immunizations, necessitating visits to private physicians for other aspects of antenatal care; each visit would cost up to one-quarter of their household's monthly income. Women often sold wheat, corn, chickens, or even their jewelry, purchased medicines on credit, or borrowed money.

A pregnant woman's daytime rest depended on the willingness of other household members to help with tasks. Despite the generally greater workload and time constraints, positive deviance women, placing high premiums on rest, were able to generate such assistance from acquiescent sisters-in-law or mothers-in-law.

Women ate less during pregnancy because of their perception that digestive problems from larger meals "makes me tired," "disturbs my breathing," "prevents me from sleeping soundly," and "causes stomach pain." Interestingly, most mothers and mothers-in-law agreed that increased food consumption during pregnancy would be healthier for both the mother and the child. Positive deviance mothers in Al-Ghatousha consumed more meat, the most expensive local food, but considered it "necessary for health and for preventing weakness"; their husbands sacrificed some or their entire share. Positive deviance women also increased their consumption of less expensive ("high in vitamins") vegetables.

Discussion

These positive deviance inquiries used pregnancy weight gain and birthweight as outcome indicators to yield a set of common findings for informing pregnancy outcome-related programs. The most important characteristics that distinguished low-income women who had good weight gain during pregnancy and offspring with good birthweight from other women who did not have these desired outcomes were increased number of antenatal visits, more rest, and the absence of symptoms suggesting urinary tract infection. Moreover, these associations were observed in two communities with markedly different economic conditions. Increased meat and vegetable consumption appeared to be less robust, since this was found only in low-income women with good pregnancy weight gain, but not in low-income women whose offspring had good birthweight. Nevertheless, further exploration of these associations appears warranted. Other associations—which are generally less amenable to short-term programming—included economic status, parity, maternal schooling, and use of tap water and latrines. The vulnerability of high-parity women to low pregnancy weight gain and of primiparous women to lower birthweight underlines the importance of special attention to both of these groups.

This pregnancy-related positive deviance inquiry represents a new application of positive deviance. The pilot nature of the study, together with the unusual data-collection methods required by local authorities, demands a cautious interpretation. The results, however, are consistent with those of a large study of risk factors for low birthweight in Al-Minia Governorate in 1996–97 that followed 617 pregnant women and their offspring, examining a wide range of variables, including biochemical measurements [8]. Multivariate analysis found antenatal care and protein intake to be the most significant predictors of low birthweight, except for congenital abnormalities and rare cases of birth intervals of less than one year. Bivariate analysis identified urinary tract infection and first pregnancies as significant risk factors. The incidence of low birthweight was nearly one and a half times greater for women who did not have daytime rest.

International research on low birthweight consistently cites the maternal environment as its most important determinant, specifically factors that prevent normal circulation across the placenta, thus restricting nutrient and oxygen supply to the fetus. These factors often include maternal malnutrition, endemic malaria, anemia, diabetes, and chronic infections, including sexually transmitted diseases and urinary tract infections [5]. Regarding diet, the importance of animal protein consumption as a positive deviance behavior in Al-Ghatousha was underscored by the nonavailability of iron–folic acid antenatal supplements. The increased bean consumption among the poor gainers brings to mind the potential of fiber to bind nutrients, such as zinc [9]. On the other hand, the increased oil and dairy consumption among good gainers may have boosted their intake of essential fatty acids, protein, and total calories. Because food grains, beans, and fats represented a larger proportion of total daily calories than meat and vegetables, it was possible for these women to increase the latter two during pregnancy while decreasing overall caloric intake.

The reporting of possible urinary tract symptoms by those with worse outcomes is provocative. Although cloudy or bloody urine has a vast differential diagnosis, including schistosomiasis, bacterial vaginosis, dehydration, nephrotic syndrome, glomerulonephritis, and consumption of urate-high foods, the likelihood that these symptoms were, at least in part, due to urinary tract infection is increased by findings from the Al-Minia birthweight study of the National Research Center[8].

This preliminary report has limitations. The limitations in methods of gathering data have already been mentioned. In addition, the information gathered from the true positive deviants (the low-income good gainers or the low-income mothers with higher-birthweight infants) was probably limited. Additionally, we are concerned by the unrealistically low rate of low birthweight (1 in 66, or 1.5%), as compared with that reported in the Al-Minia birthweight study (8.8%).

Although the positive deviance inquiries reported here were fewer than in the Minia birthweight study, they were substantially more elaborate than the small-scale (6–10 households), rapid (2–3 days) positive deviance inquiries normally carried out by Save the Children to guide projects that rehabilitate malnourished children. In this study, however, subject enrollment was of necessity a protracted process, because of the special target group and the small total population. In the future an effort should be made to organize the data collection, including the administration of brief questionnaires within existing health services in order to mobilize health providers and communities for local problem solving with local data. There is also a need to probe further into the motivational factors leading to less common healthful practices.

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Difference in goiter rates between regular and occasional users of iodized salt in Mongolia

Chieri Yamada and Dalphjabin Oyunchimeg

Editorial introduction

This paper was accepted for publication not only for its positive findings but also for a negative observation. On the positive side, it is of interest there was no difference in goiter and urinary iodine excretion between families that regularly used iodated salt and those that used it only half of the time. The former constituted 20% of the families and the latter 30%. The possibility must be recognized that the five groups differed in other factors in addition to iodated salt consumption. Ultrasound examination is not needed to determine iodine-deficiency disorder status when urinary iodine excretion is available. However, since it was used in this study, it would have been desirable to determine the relative size of the goiters and not just their presence or absence.

On the negative side is the observation that the consumption of iodated salt was limited by a price that was three to seven more than noniodated salt. When salt was first fortified with potassium iodate in Guatemala in 1956, iodated salt was being sold in the United States at the same price as noniodated salt. When it was ascertained that the cost of iodizing salt with potassium iodate in Guatemala was so small per kilogram that it did not justify an increase in the retail cost of salt, the decree requiring universal iodation of salt for human consumption so specified. Potassium iodate was used for the first time instead of potassium iodide because studies of the Institute of Nutrition of Central America and Panama (INCAP) demonstrated that its iodine was equally available [1] and that it could be added with only a small loss, even under unprotected tropical conditions [2]. This meant that there was no need to dry and refine it and sell it in moisture-proof packages or to increase the price.

Today the water-insoluble potassium iodate is the basis for salt iodation in developing countries, since the quality and packaging of the salt are unimportant to its correction of iodine deficiency. Salt with iodine should not cost the consumer significantly more than salt without iodine, but there are complicating circumstances. In Mongolia refined iodated salt must reach rural areas through a geographically difficult supply chain, and it cannot be expected to be sold at the same price as crude local salt. Nevertheless, there is no justification for the huge price differential observed by the authors. This violates the human rights of the population and is unacceptable. There should be no economic obstacle to substituting iodated salt for noniodated salt.

There is clearly a need for any agency that promotes the national iodation of salt in countries to ensure it is not made a pretext for price-gouging of those most in need. Unfortunately, governments sometimes do not recognize the importance of having salt with iodine available at the lowest possible cost and impose value-added taxes and other taxes on it, as is currently the case in Mongolia. Locally gathered salt can be cheaper, therefore, because producers do not pay these taxes. The recent initiative by the Asian Development Bank and UNICEF to promote the universal iodation of salt in the countries of Central Asia and Mongolia calls for the removal of all tariff barriers to the production and sale of iodated salt. This has been accepted as a requirement for financial support by all of the participating countries, and when implemented, should improve the prospects for affordable salt in Mongolia.

Remarkably, soon after this editorial was first drafted, the same authors submitted a Letter to the Editor (page 108) that provides an excellent response to it. Recognizing that a high price for iodated salt was inhibiting its use, particularly in rural areas, they initiated a pilot study using a simple method of adding potassium iodate to the local crude salt at the village and family level in three villages. The resulting salt sold for a price similar to that for noniodized salt. It is clear that this approach is labor intensive, and, as they note, it would require a strong communication and education program. For these

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reasons it may be difficult to scale up to a larger program. However, it is extremely important for governments to find ways to avoid a significant price differential between iodated and noniodated salt, such as occurs in Mongolia. Ideally there should be no difference in price between salt with and without iodine, as in the United States, or there should be universal iodation of salt, as in many countries. The latter will not necessarily stop some locally produced and consumed salt that is not iodated, but it will ensure that the majority of the population receives the benefits of iodated salt. Where commercially iodated salt cannot be made available in rural areas without significantly higher prices than that of unfortified locally produced or contraband unfortified salt, the feasibility of using village-level iodation, as described in the Letter to the Editor, should be explored further.

Nevin Scrimshaw, Editor

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Abstract

In Mongolia many households use iodized salt only occasionally. We investigated whether the occasional use of iodized salt had an impact on the reduction of goiter size. We examined 685 children (8–11 years old) in five groups of households that (1) used iodized salt regularly, (2) used more than 10 kg of iodized salt annually, (3) used 6 to 10 kg annually, (4) used less than 6 kg annually, (5) and regularly used noniodized salt. The prevalence of goiter as determined by ultrasound in these five groups was 31.1%, 30.3%, 40.6%, 52.1%, 56.6%, respectively. There was no difference between goiter rates among the first three groups, but these groups had significantly lower rates than the last two groups. We concluded that annual use of more than 6 kg of iodized salt, preferably more than 10 kg, by a household had a beneficial effect on the rate of goiter. In addition, the possibility was suggested that households that consumed only iodized salt consumed less salt than other households.

Introduction

Iodine-deficiency disorders are a cause of goiter and physical and neurological damage that in pregnancy can permanently affect the infant [1]. Almost 1 billion people worldwide are at risk of iodine-deficiency disorders, and 20 million suffer from various degrees of reduced cognitive performance [2]. Over 100 countries recognize iodine-deficiency disorders as a public health threat and have launched salt iodization programs to control it [3].

Mongolia recognized this problem, mainly from the high prevalence of goiter, and started the national salt iodization program in 1996. The Mongolian Ministry of Health and the Japan International Cooperation Agency have conducted several monitoring studies of iodine-deficiency disorder status and progress of the iodine-deficiency disorder program throughout the nation since 1996. We found that by 1998, 42% of the salt consumed nationally was iodized [4], and that there were obstacles to popularizing the use iodized salt, e.g., the higher price of iodized salt as compared with noniodized salt and its poor distribution in rural areas [5].

Our study found that there were five groups of households in Mongolia in terms of their usage of iodized salt usage: (1) those that used only iodized salt regularly, (2) those that used more than 10 kg of iodized salt per year, (3) those that used between 6 and 10 kg of iodized salt per year, (4) those that used less than 6 kg of iodized salt per year, and (5) those that never used iodized salt. Approximately 20% of households belonged to group 1, 30% to group 2, 30% to groups 3 and 4 combined, and 20% to group 5 [6].

On the basis of the average daily salt intake of 14.6 g by adult women in Mongolia [7] and the recommended iodine intake in salt of 30 ± 10 ppm, those who used iodized salt regularly, or who used both iodized and noniodized salt, had an adequate intake of iodine, i.e., at least 150 µg per day for adults and 90 to 120 µg for children [8]. Thus, households in categories 1 and 2 have sufficient iodine intake for the prevention of iodine-deficiency disorders.

Unfortunately, because of its poor availability in rural areas and its higher price as compared with that of noniodized salt, many people in Mongolia cannot use iodized salt every day. It was assumed that even occasional iodine intake would be of some benefit. However, no information was available on the degree of effectiveness of occasional use of iodized salt. Therefore, we performed a study to determine whether iodine-deficiency disorder status is improved by the occasional use of iodized salt at different levels.

Methods

Target population

We selected Zavhan province and Uvs province because of their low usage rates of iodized salt (16.9% and 10.2%, respectively) and their high goiter rates (24.8% and 25.2%, respectively), as reported in our 1999 study of iodine-deficiency disorders [4]. According to our previous studies of iodine-deficiency disorder status in 11 provinces in 1996 to 1999, the mean annual salt consumption per household in those areas was restricted to a small range: 21 to 27 kg. Thus, we divided households that were occasional users of iodized salt into three categories: those consuming less than 6 kg annually, those consuming between 6 and 10 kg, and those consuming more than 10 kg.

Five villages in two provinces were randomly selected, and the study began in November and December of 2000. Mothers of randomly selected children aged 8 to 11 years in a primary school from each of the five villages were interviewed about their households' pattern of salt usage in the prior year. Each mother was asked what kind of salt they used in each of the last 12 months and the amount of their annual consumption of noniodized and iodized salt. The number and ages of the family members were recorded.

The children were classified as regular users of iodized salt, regular users of noniodized salt, and occasional users iodized salt. The selection procedure was continued until a representative number of each group was obtained. The categorized groups were children from households that (1) used only iodized salt (65 girls and 34 boys), (2) used more than 10 kg of iodized salt annually (60 girls and 39 boys), (3) used 6 to 10 kg of iodized salt annually (62 girls and 34 boys), (4) used less than 6 kg of iodized salt annually (58 girls and 36 boys), and (5) never used iodized salt (164 girls and 133 boys).

Ultrasonographic examination and cutoff points for determination of goiter

For the ultrasonographic examination, ALOKA ultrasound diagnostic equipment, SSD-2100DXII (7.5 mHz), Japan, was used. Two Mongolian endocrinologists conducted the examination without being told the child's category. The thyroid volume was calculated using the equation

Thyroid volume (ml) = [Right lobe (width (cm) × length (cm) × thickness (cm) × 0.479) + Left lobe (width (cm) × length (cm) × thickness (cm) × 0.479)] [9]

In order to determine a magnitude of malnutrition among the schoolchildren and to select a criterion of goiter by ultrasonography, height and weight were analyzed by the software program ANTHRO (CDC/WHO, v 1.02, 1999). It was found that 73.1% of all children were underweight (less than –2 SD of weight-for-age), 7.6% were stunted (less than –2 SD of height-for-age and less than –2 SD of weight for height), and 16.8% were wasted (less than –2 SD of weight-for-age and less than –2 SD of weight-for-height) based on the Waterlow system [10].

Because of the high prevalence of malnutrition according to the anthropometric criteria, the cutoff points from body surface-area values were based on the WHO/ICCIDD recommendation [8,11].

Laboratory examination

Laboratory analysis of urinary iodine excretion from spot urine samples from the study children was performed at the Public Health Institute (PHI) in Ulaanbaatar. Ammonium persulfate digestion on a microplate (APDM, Hitachi Kasei Company, Japan) was used to determine urinary iodine excretion .

Statistical analysis

In addition to the use of ANTHRO, data were processed by SPSS 9.0 for Windows for statistical analysis of proportions and means.

Results

Salt consumption

Among the five groups in the two provinces, the mean annual salt consumption per household varied from 21.9 to 36.2 kg. The mean for the households that used only iodized salt was significantly lower than that for each of the other four groups. No difference was found in numbers of adults and children per household among the groups (table 1). The mean rates of use of iodized salt among occasional users of iodized salt were 46.2% in group 2 (more than 10 kg), 30.4% in group 3 (6 to 10 kg), and 15.4% in group 4 (less than 6 kg). Details of the data on the five groups are presented in table 2.

Goiter rate

The prevalence of goiter as determined by ultrasound in groups 1, 2, 3, 4, and 5 was 31.3%, 30.3%, 40.6%, 52.1%, and 56.6%, respectively. Means and 95% confidence interval are shown in table 3. The rates of goiter among children from households that used more than

TABLE 1. Total annual consumption of salt, annual consumption of iodized salt, and consumption of iodized salt as a percentage of total consumption by households grouped according to their consumption of iodized salt (means ± SD)

Group	Total annual salt consumption (kg)	Annual consumption of iodized salt (kg)	% iodized salt	Household size	
				Adults	Children
1. Iodized salt only	21.9 ± 8.3	21.9 ± 8.3	100	2.6 ± 0.54	3.4 ± 0.8
2. >10 kg iodized salt annually	31.6 ± 12.1*	12.8 ± 1.5	46.2 ± 16.7	2.4 ± 0.9	3.1 ± 1.4
3. 6–10 kg iodized salt annually	30.5 ± 11.7*	7.9 ± 1.4	30.5 ± 15.2	2.4 ± 1.0	3.3 ± 0.3
4. < 6 kg iodized salt annually	29.7 ± 11.2*	3.9 ± 1.5	15.4 ± 8.9	2.8 ± 0.9	3.2 ± 0.8
5. No iodized salt	36.2 ± 11.4*	0	0	2.7 ± 0.6	3.6 ± 1.1

* Significant difference from group 1 ($p < .001$).

TABLE 2. Rate of goiter of children from households grouped according to household consumption of iodized salt

Group	*n*	Goiter rate (%)	95% confidence interval (%)
1. Iodized salt only	99	31.3	22.2–40.4
2. > 10 kg iodized salt annually	99	30.3	21.2–39.4
3. 6–10 kg iodized salt annually	96	40.6	30.8–50.4
4. < 6 kg iodized salt annually	94	52.1*	41.6–61.6
5. No iodized salt	297	56.6*	51.0–62.2

*Significant difference from group 1 ($p < .01$).

TABLE 3. Urinary iodine excretion (μg/L) of children from households grouped according to household consumption of iodized salt

Group	*n*	Median	Mean ± SD
1. Iodized salt only	99	82.0	95.5 ± 64.2
2. > 10 kg iodized salt annually	99	97.2	115.6 ± 65.9
3. 6–10 kg iodized salt annually	96	58.7	73.4 ± 58.8
4. < 6 kg iodized salt annually	99	56.2	70.7 ± 59.1
5. No iodized salt	297	29.5	43.4 ± 52.7

10 kg of iodized salt annually and those who used 6 to 10 kg annually were not different from that of children from households that were regular users of iodized salt. In contrast, the rates of goiter among children from households that used less than 6 kg of iodized salt annually or that used noniodized salt were significantly greater than those of children from households that regularly used iodized salt ($p < 0.01$).

Urinary excretion of iodine

The median values of the five groups are presented in table 3. Only the children from households that used noniodized salt had moderate iodine deficiency, whereas the other four groups showed mild iodine deficiency [9]. However, the median urinary iodine excretion values in children from households that used iodized salt regularly or that used more than 10 kg annually were very close to normal (> 100 mg/L).

Discussion

These results indicate that when half of a household's salt consumption is iodized at current levels, this is sufficient to prevent iodine-deficiency disorders in the Mongolian population, but when less than one-third of salt consumption is iodized, iodine-deficiency disorders are not prevented. When between one-half and one-third of household salt is iodized, goiter rates are improved, even though iodine-deficiency disorders are not fully prevented. There was no statistically significant difference in the rate of goiter between children from households whose annual consumption of iodized salt was less than one-third of total salt usage and those from households that used only iodized salt.

Children from households that purchased half of their salt as the more expensive iodized form had a reduction of goiter rate almost identical to that of children from households that were regular users of iodized salt. Moreover, median urinary iodine excretion values in both groups also demonstrated similarity of level and adequacy of iodine intake. Thus, the threshold of iodized salt intake deemed effective in significantly lowering iodine-deficiency disorders may be less than is usually assumed. However, it should be pointed out that even regular users of iodized salt in the two provinces showed a high rate of goiter (31.3%), indicating a severe iodine deficiency in the population. Although goiters in children respond rapidly to iodine, those in adults are often associated with chronic iodine-deficient status [12] and do not disappear because they are fibrotic. Thus, a reduction of goiter rates in an adult population may need time [13], and a year of mandatory salt iodization may produce no change [14]. Even those groups that use iodized salt regularly need a longer time for goiter rates to return to normal (less than 5%) [15].

We recommend that similar studies be implemented in other countries, especially in areas that face difficulty in expanding their salt-iodization programs due to geographic barriers or political and economic factors. If further studies confirm the effectiveness of the occasional use of iodized salt in excess of more than 10 kg per family annually in the prevention of iodine-deficiency disorders, it could encourage the government to adopt a different health-education approach to the people who cannot afford to use only iodized salt. Currently the criterion for adequacy of a national salt-iodation campaign is 90% coverage [14]. However, the findings of our study and of other studies should cause a reconsideration of the extent of iodized salt coverage needed for success. Longitudinal studies, with observation of participants over longer periods of consumption, should now be implemented

Regular users of iodized salt consumed less salt. This may have been because iodized salt costs three to seven times more than noniodized salt in the areas studied. In our previous study in 1996 [6], we speculated that pregnant women who were highly aware of iodine-deficiency disorders used more iodized salt because they believed that it was better for their health. However, this was contradicted by our salt-intake study in 1998; pregnant women simply ate more food and consequently consumed more salt [7].

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Iron-deficiency anemia in young working women can be reduced by increasing the consumption of cereal-based fermented foods or gooseberry juice at the workplace

Tara Gopaldas

Abstract

This efficacy trial for both employers and employees (young working women 18 to 23 years of age) was undertaken to determine whether culturally acceptable dietary changes in lunches in the workplace and at home could bring about a behavioral change and improvement in their iron-deficiency anemia status. Maximum weight was given to increasing consumption of iddli*, a popular cereal-based-fermented food, or of gooseberry juice. Four small factories were selected in periurban Bangalore, with a sample of 302 women. The 180-day interventions were supervised at the workplace. In unit 1 (72 women), the intervention consisted of* iddli *four times a week plus information, education, and communication (IEC) related to iron-deficiency anemia. Unit 2 (80 women) received 20 ml of gooseberry juice (containing 40 mg of vitamin C) three times a week plus IEC once a month. Women in unit 3 (70 women), the positive control, received 400 mg albendazole once plus ferrous sulfate tablets (60 mg elemental iron) two times a week. No IEC was given. Unit 4 (70 women) served as the negative control and received no intervention. The pre-post impact measures were dietary and nutrient intake, knowledge and practice, and hemoglobin status. In units 1, 2, and 3, the hemoglobin status of the women improved significantly from 11.10 to 12.30 g/dl, 11.20 to 12.70 g/dl, and 11.50 to 13.00 g/dl, respectively. In unit 4 there was no change: the values were 10.90 g/dl before and after intervention. The results show that the type of workplace lunch was of greater significance than IEC. Knowledge gains were impressive, but behavioral change was not sustained. It was concluded that the hemoglobin levels of the workers can easily be improved by cost-effective workplace lunches that also lead to better employer–employee relations.*

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Mention of the names of firms and commercial products does not imply endorsement by the United Nations University.

Introduction

The population of young working women (18 to 23 years of age) in most of India's cities and towns is a phenomenon of this millennium. Women are working more than ever before for economic reasons. Iron-deficiency anemia is highly prevalent in this group because most come from low-income-group families. Iron-deficiency anemia has clear effects on physical work capacity [1–3] and cognition [4, 5]. This workplace-lunch with an information-education-communication (IEC) study was designed to increase the bioavailability of everyday foodstuffs by simple dietary changes. The emphasis was on cereals, which are consumed in large quantities. Fermentation of cereal-pulse batter is well accepted in South India, where the present study was conducted from 1998 to 2000. Fermentation of such batters reduces the inhibitory action of phytate-iron, thus making the iron more bioavailable. Gooseberry juice, a well-known dietary iron enhancer because of its vitamin C content, was offered along with IEC at the workplace.

Methods

Experimental design

Details of the interventions are set out in table 1. There were 302 subjects in the four selected units. The aims, objectives, and scope of work and collaboration were fully explained to the owners and managers, and they gave full cooperation. All of the workers agreed to the medical examination and the hemoglobin measurements. Signed agreements for the various tests were also obtained from the management.

Visiting homes and making inventories of food shopping, cooking, and eating habits

Thirty representative homes of the women were visited

TABLE 1. Features of the interventions

Feature	Unit 1: *iddli* ($n = 72$)	Unit 2: gooseberry juice ($n = 80$)	Unit 3: medicinal supplements ($n = 70$	Unit 4: negative control ($n = 80$)
IEC[a]	Intense, once a week	Less intense, once a month	No	No
Food or drugs administered	Fermented, steamed dumplings *(iddlis)* with relish and lentil soup 3 times a week at 2 p.m. when shifts changed	20 ml of gooseberry juice to deliver 40 mg of vitamin C 3 times a week	400 mg of albendazole once a week + 60 mg of elemental iron as ferrous sulfate twice a week	No
Supervision of food or drug administration	Yes	Yes	Yes	No
Lectures to augment IEC	Lectures on nutrition, health, and reproductive health twice a month	No	No	No
Expected benefit of intervention	Cleaving of phytic acid from iron, making iron much more bioavailable	Increasing the bioavailability of iron with a known enhancer	The above regimen was used by us with a high rate of success earlier	No intervention
Responsible for cost of intervention	Management	Management	Tara Consultancy Services	No cost
Cost for 6 mo (RS)[b]	156/– per worker, 11,232/– for all workers	68/– per worker, 5,460/– for all workers	4.30/– for iron + 5/– for deworming = 9.30/– per worker, 744/– for all workers	No cost

a. Information-education-communication.
b. Rs. 46 = US$1.00.

to develop the workplace lunches, the IEC content, and the pre-post questionnaire.

Food shopping habits

All the homes visited held ration cards that entitled them to buy rice, sugar, and kerosene at subsidized rates through the public distribution shops. The majority of the households used the kerosene ration only for cooking food, because the ration shops were far away. Further, there was not much difference in the price of rice or wheat in the open market. Depending on the size of the family, about 60 kg of rice, 10 kg of wheat, and 10 kg of *ragi* (*Eleusine coracana*) were purchased every month. Meager quantities of sugar, oil, and pulses (all very expensive) were purchased. Very spicy food was eaten, and therefore large quantities of red chilies, tamarind, and other condiments were bought. Generally 1 kg of meat and a few eggs were bought once a week; ½ kg of seasonal vegetables, especially tomatoes, and 250 to 500 ml of milk were purchased every day. Almost all families purchased iodized salt. Greens were consumed in lentil curry at least twice a week. Beetroot and tomatoes were favorites because they were tasty. Because of their red color they were perceived to heighten the red color of the blood. Fruit consumption was limited to bananas, jackfruit, and seasonal mangoes. Guavas (rich in ascorbic acid) were believed to cause sore throat. Lime was bought for lime rice (once a week) and by some of the women for lime juice (in summer).

Cooking and eating habits

Lifestyles have changed dramatically. All male and female family members over 16 years of age work to earn money and enjoy better food and clothing. Hence, if the working woman was unmarried, the mother or some other relative did the cooking and controlled the kitchen. All homes had discontinued using brass, copper, and iron vessels, and cooking was done in aluminum vessels. All homes had aluminum pressure cookers. Food was served on stainless steel plates, which are a status symbol.

Cooking was done on kerosene pump stoves. Most homes possessed small electrical grinders for grinding spices, whole grains, coconut, etc. Hardly any had a refrigerator. All food was consumed on the day it was prepared.

The packed lunch of choice and convenience was rice and pulse curry, which as eaten three or four times a week. Fermented, steamed dumplings (*iddli*) were eaten once a week, and lime rice or curd rice twice a week. No beverage was carried to work, since tea was served several times at the workplace.

Although fermented, steamed dumplings and fermented, fried pancakes were great favorites, it was laborious to soak and grind the rice and pulse and to steam or fry the fermented batter more than once a week. Fermented food lunches were the Monday treat and were eaten with spicy coconut chutney or pulse curry. Special food, including meat, was prepared on Sunday, the day for entertaining guests.

All the earnings of these working women were handed over to the head of the household, but a small amount was given back to them for personal needs. We did not see the dire poverty or raw hunger of rural or slum India in this population group. Generally three to five adult members earned a collective income of Rs. 3000/– to Rs. 5000/– per month (Rs. 46 = 1US$).

Water, space, and sanitation

Few of the homes had piped water, private toilets, or clean surroundings. Water had to be fetched in buckets (at a nominal cost) from a common tap or borewell and stored at home. Very few homes had water filters in the kitchen. The most pronounced negative factors were the extreme congestion of the living space, absence of privacy, and absence of a separate kitchen. Almost all family members complained of worm infections or chronic diarrhea (amebiasis) and repeatedly asked for prescriptions for treatment. A few families that had a patch of ground grew greens, chilies, coriander, and vegetables for home consumption.

Development and pretesting of the IEC content

A list of 21 messages was developed. Each message was made into a large, colorful poster with simple captions in the local language. Each of these was tested over a one-month period, one a day per poster, at another ancillary unit that was similar to the four units where our study was to be conducted. All the messages were understood and appreciated. The women were concerned about their appearance and grooming, but not necessarily their health. They showed particular interest in the posters showing how to rid oneself and family members of intestinal infections. Almost all the women in the unit where we did the pretesting and at our four study units had more than a primary school education in the local language, Kannada.

Standardization and use of other methods

Well-known standard methods were used for all measures or indicators [6]. Hemoglobin estimations were performed by the direct cyanmethemoglobin method on all subjects within a week of completion of the dietary surveys [7, 8]. The World Health Organization (WHO) cutoffs used for hemoglobin levels were severe anemia (< 7 g/dl), moderate anemia (7–9.9 g/dl), mild anemia (10–11.9 g/dl), and normal (12 g/dl) [8].

Dietary and nutrient intake survey

At least two home visits were made for each subject to obtain 24-hour recall data. The raw food commodities were weighed on the first visit. The cooked food and that consumed by the woman (inclusive of her packed lunch) were assessed the next day on a subset of 180 randomly selected families. The nutritive value of raw foods was calculated from 1989 Indian Council of Medical Research (ICMR) data [9]. The recommended daily allowance of nutrients was calculated from ICMR 1992 data [10].

A few informal participatory research assessments were held at the workplace in unit 1, to get to know whether more of the fermented food *iddlis* was being made and consumed at home in response to the IEC, and if not, what were the real constraints. The supervisors (also employees) gave useful feedback in units 1 and 2.

Data processing and analysis

The data were entered using Foxbase, and data files were created. After the data were checked and validated for internal consistency, SPSS was used for tabulation and statistical analysis. All test results were considered significant at $p < .05$.

Results

The socioeconomic profile of the sample is given in table 2. The average age of the women in each unit ranged from 20 to 23 years. In each of the four units, most of the women had a primary school or junior college level of education in the local language, Kannada. Hence, overall they were in a good position to comprehend the IEC and the lectures given by our staff. Approximately half of the women had married, usually at 18 to 20 years of age, except for unit 4 (the negative control), where were all still unmarried at a mean age of 20.

Dietary intakes

The average daily intakes of foodstuffs by the women before and after the study are given in table 3.

Cereals and millets. The Nutrition Profile of Karnataka [11] indicates that adolescent girls (over 16 years) and young women consume on average of 605 g cere-

TABLE 2. Socioeconomic profile of the working women

Characteristic	Unit 1: *iddli* ($n = 72$)	Unit 2: gooseberry juice ($n = 80$)	Unit 3: medicinal supplements ($n = 70$)	Unit 4: negative control ($n = 80$)
Average age (yr)	23	21	22	20
Education (%)				
Illiterate	11	8	17	0
Up to primary school	15	30	23	0
Primary school and/or college	74	62	60	100
Marital status (%)				
Married	54	48	64	0
Unmarried	46	52	36	100
Urban or rural background (%)				
Urban	100	100	83	66
Rural	0	0	17	34
Years of work experience (%)				
< 1	0	0	0	0
1–3	56	89	91	88
> 3	44	11	9	12

TABLE 3. Average daily food intake (grams) before and after intervention

Food	RDA[a]	Unit 1: *iddli* ($n = 45$)		Unit 2: gooseberry juice ($n = 45$)		Unit 3: medicinal supplements ($n = 45$)		Unit 4: negative control ($n = 45$)	
		Before	After	Before	After	Before	After	Before	After
Cereals	440	491 ± 39	670 ± 21**	483 ± 41	667 ± 19*	513 ± 9	593 ± 3*	589 ± 30	609 ± 21 NS
Pulses	45	28 ± 8	35 ± 4**	21 ± 2	21 ± 9	29 ± 9	30 ± 2	34 ± 8	34 ± 7*
Green leafy vegetables	100	11 ± 9	19 ± 4*	16 ± 3	20 ± 8*	10 ± 4	8 ± 3	10 ± 2	10 ± 1 NS
Other vegetables	40	21 ± 3	29 ± 9**	19 ± 3	22 ± 4*	22 ± 2	24 ± 1	24 ± 2	25 ± 5 NS
Roots and tubers	50	31 ± 1	33 ± 3 NS	29 ± 9	30 ± 2 NS	31 ± 2	30 ± 3	40 ± 2	42 ± 1 NS
Oils and fats	25	6 ± 1	6 ± 2 NS	5 ± 1	7 ± 2*	6 ± 1	7 ± 4 NS	7 ± 3	8 ± 4 NS
Milk	150	33 ± 4	35 ± 1 NS	30 ± 4	31 ± 3*	27 ± 3 NS	27 ± 1	30 ± 3	31 ± 1 NS
Sugar and jaggery	20	21 ± 4	20 ± 3 NS	25 ± 3	30 ± 1*	20 ± 3 NS	21 ± 4	30 ± 9	31 ± 8 NS
Fruit	100	27 ± 9	38 ± 4*	20 ± 1	28 ± 5*	19 ± 3 NS	20 ± 1	22 ± 3 NS	23 ± 5 NS
Meat and eggs	30	15 ± 1	19 ± 3**	10 ± 1	11 ± 3 NS	12 ± 2	13 ± 3 NS	19 ± 2	19 ± 3 NS

a. Recommended daily allowance.
* $p < .1$; ** $p < .01$; *** $p < .001$; NS, not significant.

als daily, as compared with the RDA of 440 g. In our study the daily intake of cereals increased from 519 to 635 g.

Pulses. The mean intake of pulses among our subjects at presurvey was 28 g, as compared with the RDA of 45 g. Pulses are very expensive. Generally, to make *iddli*, a fermented food, two measures of raw rice to one measure of split black gram (*Phaseolus mungo* Roxb.) is used in middle- to upper middle-class homes. However, we noted that only half to one-fifth the amount of black gram was used due to its high cost. The pulse soup, which was an everyday item also contained minimal quantities of red gram (*Cajanus cajan*). To compensate, large quantities of red chili powder and tamarind pulp (to sour the soup) were used. A significant increase in pulse consumption at the postsurvey was noted only in unit 1.

Green leafy vegetables. The presurvey revealed an extremely poor consumption of green leafy vegetables. The mean intake was 12 g as compared with the RDA of 100 g. In the postsurvey, the intake of green leafy vegetables increased significantly in units 1 and 2 where the IEC was given. The seasonal green leafy vegetables were drumstick leaves (*Moringa oleifera*), knol-khol (*Brassica oleracea*), agathi (*Sesbanis grandiflora*), coriander (*Coriandrum sativum*), and cabbage.

Other vegetables. In India tomatoes are considered a vegetable and not a fruit. They were used in daily cooking and gave body and taste to the pulse soup. Depending on the season and available finances, other vegetables bought were beetroot, cauliflower, carrots, yellow pumpkin (*Cucurbita maxima*), onions, ridge gourd (*Huffa acutangula*), ash gourd (*Benincassa hispida*), brinjal (*Solanum melongena*), cluster beans (*Cyamopsis tetragonoloba*), field beans (*Dolichos lablab*), and ladies' fingers (*Abelmoschus esculentus*), etc. The mean intake of vegetables was about 22 g at the presurvey versus 25 g at postsurvey, as compared with the RDA of 40 g per day. The IEC appears to have been successful in persuading families in units 1 and 2 to consume more of the above vegetables.

Roots and tubers. Potatoes head the list of tubers. However, a separate vegetable dish is not eaten every day, except in the homes of the better-off. The mean intake was 33 g at the presurvey versus 34 g at postsurvey, as compared with the RDA of 50 g. No significant increase was observed in any of the four units at postsurvey.

Oils and fats. The intake of oils and fats was extremely low, as also observed in the Nutrition Profile of Karnataka [11]. The mean intake at presurvey was a mere 6 g versus 7 g at postsurvey, as compared with the RDA of 25 g. Oil is also a very expensive item. It was reserved for seasoning the condiments used in the pulse soup or the occasional vegetable dish. Most of the oils and fats (hydrogenated) were consumed on Sunday when a special nonvegetarian dish was served.

Milk. Milk intake was extremely low, with a mean of 30 ml per day. This, however, is one and a half times the intake reported for women over 18 years of age in the rural, slum, or low-income-group areas of Karnataka [11]. There was no significant increase in milk intake. Milk intake was 30 ml at presurvey versus 31 ml at postsurvey, as compared with the RDA of 150 ml. Tea was the beverage of choice, with a dash of milk to whiten it. Milk in the form of curd (used for the weekly curd-rice) was a favorite.

Sugar and jaggery. Although jaggery (for hemoglobin enhancement), instead of sugar, formed an important lesson of our IEC, hardly anyone switched from sugar to jaggery. The mean intake of sugar was 24 g at the presurvey versus 26 g at postsurvey, as compared with the RDA of 20 g.

Fruit. Fruit is economically beyond the means of the households of the women. The mean intake of fruit at presurvey was 22 g versus 27 g at postsurvey, as compared with the RDA of 100 g. The IEC did have a positive impact, since there was a significant rise from 27 to 38 g of fruit in unit 1 and from 20 to 28 g in unit 2. The increase in gooseberry juice intake in unit 2 (receiving the gooseberry juice intervention) was almost entirely due to the employers' giving the employees gooseberry juice three times a week. The consumption of lime as lime-rice, lime-pickle, and, very occasionally, lime juice increased somewhat.

Meat. The mean intake of meat and eggs was 20 g at presurvey versus 16 g at postsurvey, as compared with the RDA of 30 g.

Nutrient intakes

Differences in intake by the women before and after the study are shown in table 4.

Calories. The mean intake at the presurvey was 2,620 kcal, as compared with the RDA of 2,225 kcal for a woman doing moderate work. Since few of our women were obese, it would appear that according to their observed work, they should be positioned between the moderate and heavy worker categories, with an RDA of 2,925 kcal for women [10]. The significant

TABLE 4. Average daily nutrient intake before and after intervention

Nutrient	RDA[a]	Unit 1: *iddli* (*n* = 45)		Unit 2: gooseberry juice (*n* = 45)		Unit 3: medicinal supplements (*n* = 45)		Unit 4: negative control (*n* = 45)	
		Before	After	Before	After	Before	After	Before	After
Energy (kcal)	2,225[a]	2,546 ± 258	2,709 ± 201 *	2,507 ± 211	2,699 ± 204 *	2,609 ± 198	2,641 ± 179 *	2,618 ± 213	2,635 ± 249 *
Protein (g)	50	65 ± 4	72 ± 9 *	68 ± 3	74 ± 8 *	70 ± 2	75 ± 5 *	74 ± 4	73 ± 8 NS
Iron (mg)	30	0	32 ± 3 *	29 ± 1	31 ± 2 *	25 ± 3	26 ± 2 NS	24 ± 4	25 ± 6 NS
Calcium (mg)	400	511 ± 35	539 ± 41 *	502 ± 25	501 ± 34 NS	521± 31	513 ± 33 NS	605 ±39 NS	611 ± 44 NS
Vitamin A (μg)	600	239 ± 31	300 ± 52 *	241 ± 11	295 ± 19 *	205 ± 23	219 ± 11 NS	381 ± 8	373 ± 24 NS
Vitamin C (mg)	40	24 ± 4	31 ± 3 *	29 ± 9	49 ± 4 **	28 ± 4	29 ± 3 NS	34 ± 5	35 ± 7 NS

a. Recommended daily allowance (RDA) for workers doing moderately heavy work.
* $p < .1$; ** $p < .01$; *** $p < .001$; NS, not significant

increase of 163 kcal from pre- to postsurvey in unit 1 was due mostly to the consumption of *iddli* for lunch at the workplace. In unit 2 the increase was 192 kcal. In summary, the food-based intervention and the IEC in units 1 and 2 appear to have increased food energy intake significantly.

Protein. The mean protein intake at presurvey was about 70 g, mainly from cereals and pulses, as compared with the RDA of 50 g. At postsurvey there were significant increases in protein intake of 6 g in unit 1, 7 g in unit 2, and 5 g in unit 3.

Iron. This study was primarily focused on a workplace lunch plus an IEC strategy based on removal of dietary inhibitors of iron in unit 1 and the addition of a dietary iron enhancer in unit 2. The mean dietary iron availability at baseline was 27 mg, as compared with the RDA of 30 mg. However, very little of it appears to have been available. In units 3 and 4 there were small and nonsignificant increases of 1 g of dietary iron at postsurvey.

There appears to have been some impact of our IEC messages on consumption of vegetables and fruits. However, by inference, the much greater or more frequent consumption of *iddlis* at the workplace and at home appears to have been the main reason for the significant increase in the mean hemoglobin values of the women in unit 1. In unit 2 (given gooseberry juice), the major reason for enhancement of the hemoglobin values at postsurvey appears to have been the regular, although intermittent, consumption of gooseberry juice at the workplace. Vitamin C-rich gooseberry is a powerful enhancer of iron absorption [12]. The Indian gooseberry is one of the richest sources of vitamin C (63 mg/100 g edible portion) in India [9].

Calcium. The mean intake of calcium was 534 mg at presurvey, as compared with the RDA of 400 mg. In unit 1 there was significant increase in dietary intake of calcium from 511 mg at presurvey to 539 mg at postsurvey. No increase was observed in the other three units. Calcium is known to be an inhibitor of iron bioavailability [13].

Vitamin A. India is one of the more vitamin A-deficient countries in the world [14]. Our dietary and nutrient intake data confirm that even young women who are not from the poorest group may be deficient in vitamin A. The mean intake of vitamin A or its precursor β-carotene was only 267 μg, as compared with the RDA of 600 μg. The intake of vitamin A increased significantly in units 1 and 2, due mostly to a higher consumption of tomatoes, a rich source of β-carotene (590 μg/100 g edible portion). Ripe tomato is also a good source of folic acid (30 μg/100 g by high-performance liquid chromatography) and vitamin C (27 mg/100 g) [9].

Vitamin C. The mean intake of vitamin C was 29 mg at presurvey, as compared with the RDA of 40 mg. It increased significantly in unit 1 from 24 mg at presurvey to 31 mg at postsurvey. This reflects a change in behavior, perhaps due to a combination of the food intervention and the IEC. The greatest and most significant enhancement of vitamin C was seen in unit 2, mostly consumption of gooseberry juice at the workplace.

Impact on knowledge responses

As shown in table 5, the presurvey spontaneous recall responses and general knowledge of anemia or iron-deficiency anemia were extremely poor, ranging from 9% in unit 3 to 23% in unit 4. Highly significant increases of greater than 87% in correct responses were noted in units 1, 2, and 3 at the postsurvey. Even

TABLE 5. Knowledge of anemia (% of women displaying knowledge) before and after intervention

	Unit 1: *iddli* ($n = 72$)		Unit 2: gooseberry juice ($n = 80$)		Unit 3: medicinal supplements ($n = 70$)		Unit 4: negative control ($n = 80$)	
Indicator	Before	After	Before	After	Before	After	Before	After
Knowledge								
Have heard of anemia	10	99***	14	94***	9	87***	23	35***
Stating cause of anemia correctly								
Weak blood	15	57***	21	64***	11	66***	11	30***
Deficiency in diet	1	65***	18	71***	19	66***	12	26***
Can't say	83	6***	61	18***	70	5***	89	53***
Which food makes the blood strong?								
Fruits	15	22***	11	66***	14	19***	11	36***
Vegetables	32	54***	26	58***	37	53***	16	39***
Meat	17	75***	28	65***	47	86***	13	39***
Milk	10	47***	13	33***	11	14***	18	43***
Others	8	15***	8	10 NS	0	0	13	38***

*** $p < .001$; NS, not significant.

in unit 4 (the negative control), they increased from 23% to 35%. The major stated cause of anemia was "weak blood and deficiency in the diet." Although 21 messages—not all dietary—were targeted to the subjects, those that made the greatest impression were food-related. Even in the specific intervention groups receiving fermented food (unit 1) and gooseberry juice (unit 2), all four groups were firmly convinced that meat (trotter soup) was a good dietary measure to make the blood strong. Aided recall of "eat fermented foods and fruits and vegetables" also was high on the list. Although "drinking more milk" was not in any of our IEC messages, the spontaneous responses were significantly higher at the end of the program. Milk is considered the food of the gods and the affluent, perhaps accounting for this unexpected response.

Knowledge does not necessarily translate into practice or behavioral change. The hemoglobin levels of the women in unit 4 (the negative control) did not show a change, although their knowledge levels did. Postsurvey scores were higher for fermented foods, as expected. As a result of much higher consumption of the fermented food (*iddli*) at the workplace and a somewhat higher consumption at home, the mean hemoglobin levels of the women increased significantly.

Impact on health practices

Table 6 shows that in addition to gaining knowledge, the most favored practices were to seek the help of a doctor or to take the iron supplementation.

Impact on hemoglobin status

As seen in table 7, the hemoglobin status of the women significantly improved in units 1, 2, and 3. In unit 1, which received the fermented food intervention, there was a significant increase in mean hemoglobin from 11.10 to 12.30 g/dl (1.20 g/dl increase). The greatest benefit, as viewed by the woman, was that it was basically a food with "properties of making weak blood strong." In unit 2, which received IEC plus gooseberry juice, there was a significant increase in mean hemoglobin from 11.20 to 12.7 g/dl (1.50 g/dl increase). The women viewed this intervention as a "most refreshing drink that also had the ability to make the blood strong." In unit 3, which received deworming plus iron supplementation without IEC, there was a significant increase in mean hemoglobin from 11.50 to 13.00 g/dl (1.50 g/dl increase). This intervention was most successful in eradicating worms

TABLE 6. Practices affecting the control of anemia (% of women displaying practice) before and after intervention

	Unit 1: *iddli* ($n = 72$)		Unit 2: gooseberry juice ($n = 80$)		Unit 3: medicinal supplements ($n = 70$)		Unit 4: negative control ($n = 80$)	
Practice	Before	After	Before	After	Before	After	Before	After
Go to doctor	79	96*	59	94**	50	81***	68	98***
Do nothing	22	4**	43	5***	50	29***	38	3***
Take iron tablets as prescribed	44	74***	36	63***	36	57***	48	52*

* $p < .05$; ** $p < .01$; *** $p < .001$.

TABLE 7. Mean hemoglobin values before and after intervention[a]

	Unit 1: *iddli* ($n = 72$)		Unit 2: gooseberry juice ($n = 80$)		Unit 3: medicinal supplements ($n = 70$)		Unit 4: negative control ($n = 80$)	
Hemoglobin value	Before	After	Before	After	Before	After	Before	After
Overall mean (g/dl)	11.1 ± 2.1	12.3 ± 1.0 ***	11.2 ± 1.9	12.7 ± 1.1 ***	11.5 ± 1.3	13.0 ± 1.3 ***	10.9 ± 1.4	10.9 ± 1.5 NS
Severe anemia (< 7 g/dl)	5.7 (1)	10.7 ***(1)	6.9 ± 0.1 (2)	11.2 ± 0.5 ***(2)	6.0 ± 0.0 (2)	7.5 ± 0.0 ***(2)	6.4 ± 0.0 (2)	8.9 ± 0.0 *** (3)
Moderate anemia (7–9.9 g/dl)	8.9 ± 0.7 (21)	11.3 ± 0.9 *** (21)	8.8 ± 0.9 (17)	12.3 ± 1.2 *** (17)	No cases	No cases	9.40 ± 0.70 (18)	9.7 ± 1.2 NS (18)
Mild anemia (10–11.9 g/dl)	11.0 ± 0.6 (29)	12.3± 0.6 *** (29)	11.2 ± 0.5 (36)	12.4 ± 0.8 *** (36)	10.9 ± 0.5 (37)	12.4 ± 0.5 *** (37)	10.8 ± 0.9 (44)	11.0 ± 0.6 NS (44)
Normal (≥ 12 g/dl)	13.8 ± 0.9 (21)	13.2 ± 0.6 * (21)	13.2 ± 0.9 (21)	13.5 ± 0.9 NS (25)	12.5 ± 0.3 (31)	14.0 ± 0.30 *** (31)	12.7 ± 0.7 (16)	12.8 ± 0.5 NS (16)

a. The number of subjects for each category of hemoglobin values is given in parentheses.
* $p < .05$; ** $p < .01$; *** $p < .001$; NS, not significant.

and for "making the blood strong."

In unit 4, the negative control, there was no increase in hemoglobin. However, there were significant gains in knowledge regarding the causes and consequences of iron-deficiency anemia even though no intervention was given. The questions asked in the presurvey had made the women in unit 4 curious enough to seek information on iron-deficiency anemia.

Impact on anemia

The prevalences of the different grades of anemia in the women before and after the interventions are shown in table 8. Severe anemia (hemoglobin < 7 g/dl) was totally eliminated in all the four groups, even in unit 4 (negative control). After some probing in unit 4, at the postsurvey, it emerged that the women had sought medical intervention and had been prescribed Matrae tablets containing iron by the lady doctor. Moderate anemia (hemoglobin 7 to 9.9 g/dl) was also virtually eliminated in units 1, 2, and 3, but increased from 23% to 30% (significant at p < .05) in unit 4. Mild anemia (hemoglobin 10 to 11.9 g/dl) was also significantly reduced in units 1, 2, and 3.

The impact of the supervised *iddli* intervention plus IEC on anemia is summarized in table 9. The mean total number of *iddlis* eaten over six months did not vary much from the severely anemic subjects (hemoglobin < 7 g/dl) to the normal subjects (hemoglobin 12 g/dl). The range was 224 to 283. However, the intervention had a striking effect on the severely anemic subjects, whose mean hemoglobin level increased by 5.0 g/dl. The moderately anemic subjects (hemoglobin 7 to 9.9 g/dl) had a mean increase of 2.4 g/dl, the mildly anemic (hemoglobin 10 to 11.9 g/dl) had an increase of 1.3 g/dl, and those who had normal hemoglobin values (12 g/dl) had a decrease of 0.60 g/dl. Overall, the increase in hemoglobin was 1.20 g/dl (11.10 to 12.30 g/dl).

Comparison of the effects of the intervention on unmarried working women, who generally did not have access to a kitchen, and on married working

TABLE 8. Prevalence (%) of different grades of anemia before and after intervention

Anemia	Unit 1: *iddli* (*n* = 72)		Unit 2: gooseberry juice (*n* = 80)		Unit 3: medicinal supplements (*n* = 70)		Unit 4: negative control (*n* = 80)	
	Before	After	Before	After	Before	After	Before	After
Severe (< 7 g/dl)	1	0	3	0	3	0	3	0
Moderate (7–9.9 g/dl)	29	1	21	1	0	3	23	30*
Mild (10–11.9 g/dl)	40	32***	45	25***	53	10***	55	50 NS
Normal (≥12 g/dl)	30	67***	31	74***	44	87***	20	20 NS

* *p* < .05; *** *p* < .001; NS, not significant.

TABLE 9. Impact of the supervised *iddli* intervention and severity of anemia before and after intervention (*n* = 72)

Indicator	Before	After	Change in hemoglobin level
Per worker			
Mean no. of *iddlis* eaten over 6 mo	121	121 + 156 = 277	
Overall mean hemoglobin (g/dl)(*n* = 72)	11.1 ± 2.1	12.3 ± 1.0 ***	+ 1.20
Severely anemic women (hemoglobin < 7 g/dl)			
Mean no. of *iddlis* eaten over 6 mo	204	204 + 156 =360	
Mean hemoglobin of the group (g/dl)(*n* = 1)	5.7	10.7***	+ 5.00
Moderately anemic women (hemoglobin 7–9.9 g/dl)			
Mean no. of *iddlis* eaten over 6 mo	114	156 + 114 = 270	
Mean hemoglobin of the group (g/dl)(*n* = 21)	8.9 ± 0.7	11.3 ± 0.9***	+ 2.50
Mildly anemic women (hemoglobin 10–11.9 g/dl)			
Mean no. of *iddlis* eaten over 6 mo	127	156 + 127 = 283	
Mean hemoglobin of the group (g/dl)(*n* = 29)	11.0 ± 0.6	12.3 ± 0.6***	+ 1.69
Normal women (hemoglobin ≥ 12 g/dl)			
Mean no. of *iddlis* eaten over 6 mo	114	156 + 114 = 270	
Mean hemoglobin of the group (g/dl)(*n* = 21)	13.8 ± 0.9	13.2 ± 0.6*	– 0.60

* *p* < .05; *** *p* < .001.

women, who did have access to a kitchen, strengthened our hypothesis that "control of the kitchen" was an important factor if the IEC recommendations were to be followed at home. The mean increase in hemoglobin levels in the 33 unmarried working women was 0.9 g/dl, as compared with 1.60 g/dl in the married women ($n = 39$). This difference was highly significant. Since the psychosocial and cultural values are unlikely to change in the near future, this finding emphasizes the importance of persuading employers to provide iron-rich lunch packages at the workplace.

Impact of the supervised gooseberry juice plus IEC intervention

The results of the gooseberry juice plus IEC intervention were analyzed as described for the *iddli* intervention (table 10). Each woman in unit 2 received 3,120 ml of gooseberry juice, at 40 ml per woman, three times a week for 26 weeks (6 months). There was also some increase in the consumption of lime pickle, occasionally of lime juice, and of lime rice. Lime was usually not used to sour the lentil soup, although this constituted one of the IEC lessons. The post dietary intake survey among women in unit 2 showed a mean increase of 8 g in the consumption of fruit, not necessarily lime. The large increase in vitamin C or ascorbic acid came almost entirely from the gooseberry juice at the workplace. There was a highly significant increase in hemoglobin of 1.50 g/dl. The more severe the anemia, the better the response, similar to the results of the *iddli* intervention. In the two cases of severe anemia, the mean hemoglobin enhancement was 4.30 g/dl. In the moderately anemic category, the mean hemoglobin enhancement was 3.50 g/dl. In those mildly anemic, the mean increase in hemoglobin was 1.20 g/dl, and in the normal category, the mean increase was a mere 0.30 g/dl. Gooseberry juice was as effective as deworming plus medicinal iron supplementation: overall the mean increase in hemoglobin in both units 2 and 3 was 1.50 g/dl.

There was no significant difference between the increase in hemoglobin values in the married ($n = 38$) and unmarried ($n = 42$) groups.

Discussion

The major strategy of this diet-based study was to determine whether the bioavailability of iron in typical fermented foodstuffs (*iddli*) could be exploited to improve the hemoglobin status of the young working woman population of Karnataka [15]. It is well known that autofermentation of cereals and pulses cleaves the phytic acid bound to the iron. Once the iron is freed, it is readily absorbed into the bloodstream [16–23]. Similarly, ascorbic acid-rich gooseberry juice is a well-known enhancer of dietary iron and makes it much more bioavailable. However, consumption of fruits in general, and of citrus fruits in particular, at the household level is minimal. This strategy was designed to be affordable by the employer at the workplace. The cost of delivering 40 mg of ascorbic acid via gooseberry juice per worker per day was approximately the cost of one cup of tea. In all offices and workplaces, the employer supplies tea ad libitum.

TABLE 10. Impact of the supervised gooseberry juice intervention plus IEC and severity of anemia before and after intervention ($n = 80$)

Indicator	Before	After	Change in hemoglobin level
Overall			
Gooseberry juice consumed over 6 mo (ml)	—	3,120	
Mean hemoglobin (g/dl)($n = 80$)	11.20	12.70***	+ 1.50
Severely anemic women (hemoglobin < 7 g/dl)			
Gooseberry juice consumed (ml)	—	3,12	
Mean hemoglobin of the group (g/dl)($n = 2$)	6.90	11.20***	+ 4.30
Moderately anemic women (hemoglobin 7–9.9 g/dl)			
Gooseberry juice consumed (ml)	—	3,120	
Mean hemoglobin of the group (g/dl)($n = 17$)	8.80	1,230***	+ 3.50
Mildly anemic women (hemoglobin 10–11.9 g/dl)			
Gooseberry juice consumed (ml)	—	3,120	
Mean hemoglobin of the group (g/dl)($n = 36$)	11.20	12.40***	+ 1.20
Normal women (hemoglobin ≥ 12 g/dl)			
Gooseberry juice consumed (ml)	—	3,120	
Mean hemoglobin of the group (g/dl)($n = 25$)	13.20	13.50 NS	+ 0.30

*** $p < .001$; NS, not significant.

The bioavailability of iron in a typical Indian meal is extremely low. A meal of ragiballs, potato, and tea has an iron bioavailability of only 0.9%. A meal of rice, dal, potato, and milk raises the bioavailability of iron to 4.5 % [16]. To our knowledge there are no studies on the bioavailability iron in Indian fermented foods, such as *iddli*, *dosai, appam*, or *dhokla*. Our study found that the mean hemoglobin status of the women increased by 1.20 g/dl when an average of 20 to 30 *iddlis* were consumed per subject per week. It would be desirable to determine whether intermittent or once-weekly consumption of *iddlis* would be sufficient to raise hemoglobin levels.

It is well known that cereals have a high content of phytic acid, a significant inhibitor of dietary iron. We, therefore considered a culturally accepted, habitually practiced, and traditional food-processing procedure, namely, autofermentation of cereals and pulses. Fermented foods such as *iddli*, *dosai*, and *appam* are eaten practically every day as a breakfast food or as a tiffin (snack food) at tea time in affluent South Indian households. Our surveys revealed that the poor households made *iddlis* only once or twice a week, but in large quantities. Hence, we decided to capitalize on this established food practice in this region of India.

Gibson et al. [17, 18] in Malawi described several dietary interventions to prevent zinc deficiency, of which fermentation was the simplest and most effective at the household level. Several other studies, mostly conducted in Africa, have shown the effectiveness of reducing the phytic acid content of maize, sorghum, other millets, or dry pulse grains by the simple process of soaking the cereals in water for a few hours to overnight [19, 20].

Iddli, a fermented food which is eaten daily for breakfast, is very simple for most South Indians to prepare. Generally, one measure of raw rice, one measure of parboiled rice, and one measure of black gram dal (*Phaseolus mungo* Roxb.) are the main ingredients for *iddli*. The rice and black gram dal are washed and soaked separately in about two inches of water for about 6 to 8 hours. The rice is coarsely ground and the pulse is finely ground, and both are mixed well. Salt and baking soda (sodium bicarbonate) are added to taste. The batter is allowed to ferment overnight (10 to 12 hours), which makes the batter sour and lowers its pH. The batter is poured into greased molds and steamed in either a pressure cooker or *iddli* steamer for 8 to 10 minutes. The steamed dumplings are served with spicy lentil soup and coconut chutney. Raw ingredients of 2 kg of rice grain plus 1 kg of blackgram dal would yield about 60 to 70 *iddlis*.

The low-income families use much less of the expensive pulse but add more baking soda. It would be useful to conduct *in vitro* and *in vivo* studies on the bioavailability of iron from different *iddli* recipes. The most practical, cost-effective, and sustainable recipe could then be promoted to the employers as their contribution to the employees' lunch at the workplace.

Since the women claimed to eat from two to eight *iddlis* at once, the equivalent of 100 g of raw rice plus pulse (for two *iddlis*) to 400 g of raw rice plus pulse (for eight *iddlis*) would be consumed per *iddli* meal. At presurvey, *iddlis* were the packed Monday lunch for most of the women. At postsurvey, *iddlis* were still a Monday treat, but the quantity consumed was far greater.

An even simpler method to increase the bioavailability of iron for cereals would be to soak the cooked rice in water overnight, drain off the water the next morning, add curd (yogurt), and take it to work as a packed lunch. Although, as stated earlier, this was considered to be something that very poor people did, our IEC poster to promote this practice did not find favor. We were told that all the cooked food was consumed on the same day so that there was no leftover cooked rice. Our advice to cook more rice for steeping later was not well received.

Gibson et al. [17, 18] recommended soaking maize, the staple cereal of Malawi, as the most practical method of reducing the level of phytic acid. Svanberg [21] lists the advantages of soaking and fermentation of nontannin and high-tannin cereals, which supported our IEC attempt to popularize the "curd-steeped rice lunch" for working women in South India.

Most plant-based foods contain some phytase enzymes, which hydrolyze phytic acid to inorganic orthophosphate and myoinositol, However, phytase is in a dormant state in dry grains and pulses and is activated by moisture. Phytate reductions may be as high as 98% for a variety of fermented products based on cassava, cocoyam, maize, sorghum, rice, soybeans, cowpeas, and lima beans consumed in West Africa, depending on the conditions of preparation, storage, and cooking [22].

According to Gibson and Ferguson [17], other advantages of fermentation are that it reduces the amount of fuel required for cooking, improves the safety of food by inhibiting the growth of diarrheal pathogens, and produces antimicrobial substances. Commercial phytase enzymes can be prepared from *Aspergillus oryzae* or *A. niger* that are stable over a fairly wide range of pH (3.5–7.8) and temperature. However, they are extremely expensive [23].

We found that an enhancer such as gooseberry juice is an excellent way to increase the mean hemoglobin levels of our target working women. Other recent studies have shown that guava fruit was successful in raising the hemoglobin levels of college women in a short time [24]. In fact, in the present study, gooseberry juice proved to be superior to the fermented food, producing a mean hemoglobin increase of 1.20 g/dl, as compared with 1.50 g/dl in the group receiving gooseberry juice. All dietary sources of vitamin C are very expensive and beyond the economic reach of our subjects.

Enhancers such as ascorbic acid form soluble or chelated complexes with iron that prevent the iron from precipitating or polymerizing. Ascorbic acid also reduces ferric iron to ferrous iron at pH values greater than 3, such as are found in the duodenum and small intestine. Apparently ascorbic acid is dose-related and can act even in the presence of inhibitors [25]. Although the consumption of lime and lime juice did increase at the household level, it is a matter of conjecture whether the level of ascorbic acid would have been sufficient to have resulted in a mean increase in hemoglobin of 1.50 g/dl in the working woman population.

Ethiopian children who were given food cooked in iron pots had an increase in hemoglobin of 1.7 g/dl over a 12-month intervention period, a significantly higher value than the increase of 0.4 g/dl in children given food cooked in aluminum pots [26]. The subjects in our study rejected outright the idea of replacing aluminum cooking utensils with iron ones because food cooked rapidly in aluminum pots and the pots were easy to clean and easy to maintain. Pressure cookers were made of aluminum. In unit 2, 75% of the working women were intrigued by our IEC poster advising them to put an iron key into the lentil soup as it cooked and had tried to do so a few times at their homes. However, the men in the household objected strongly, stating that the food tasted "strange" and "bad."

Conclusions

Employers should be first targeted and informed about the concept of a workplace lunch plus IEC. Behavioral change will be immediate or not at all.

Concrete dietary or medicinal interventions at the workplace, if given free of cost, appear to give the best results as far as reduction in iron-deficiency anemia is concerned.

The young working woman, especially if she is unmarried, has very real constraints of money and time, and has no control over her kitchen.

Both the employer and the employee need organizational and managerial help to implement and sustain such a program.

The employees appreciate the IEC and implement the dietary recommendations to the extent possible. However, their time and economic constraints are the real limitations to total behavioral change or sustainability.

In urban India, aluminum cooking utensils have come to stay. Hence, iron woks will not be used.

Although the intervention with fermented food (*iddli*) did not increase the mean hemoglobin levels (1.20 g/dl) as much as the gooseberry juice or the medicinal supplementation interventions (1.50 g/dl), it was the food-based *iddli* intervention that was most appreciated.

Enhancing the hemoglobin levels of young working women makes good economic sense. Such a strategy brings about good labor relations apart from the established rewards of greater productivity, better reproductive health, better cognition, and an all-round better working atmosphere.

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Discussion paper 116. A multiple-method approach to studying childcare in an urban environment: The case of Accra, Ghana

Marie T. Ruel, Margaret Armar-Klemesu, and Mary Arimond

There are increasing concerns about the impact of rapid urbanization and the growth of urban poverty on access to adequate food and nutrition by the urban poor. The high dependence on cash income, the exposure to high levels of air, food, and water contamination, and the increasing necessity of women to participate in income-generating activities are examples of some of the constraints faced by the urban poor.

The Accra Urban Food and Nutrition Study (AUFNS) was conducted to investigate the nature of urban poverty and the interrelationships among urban poverty, food insecurity, and malnutrition in a major urban African center (Accra, Ghana). The ultimate goal was to provide high-quality information to policymakers and to promote appropriate policies for programs for intervention in urban poverty, food security, and malnutrition. The AUFNS consisted of three types of data collection: a participatory rapid appraisal (PRA), a representative quantitative survey of Accra, and a small observational study.

Purpose of this paper

This paper focuses on one of the subthemes addressed by the AUFNS: the role of care as an input into child nutrition and the relative contribution of a number of maternal and household resources to the provision of care. The main goal was to integrate the findings from the three primary data sources and to specifically address the following questions: Is care an important input into child nutrition in Accra? Which care practices are most crucial for child nutrition? Which maternal and household resources contribute the most to enhancing care in Accra? What are the program and policy responses to promote optimal childcare practices in this urban context? How do the three research approaches used to measure childcare complement each other?

Methods

The research was carried out in three stages and was preceded by an initial roundtable seminar convened in Accra to elicit the views of key stakeholders. The first stage involved a series of qualitative data-collection activities to identify key issues to be followed up in the quantitative phase, to guide the design of a survey questionnaire, and to build up an understanding of the Accra urban context from the point of view of the poor. The second phase was a representative quantitative survey of 556 households, and the final stage was an observational study of a small subsample of households. The main purpose of this last component was to gain a more in-depth understanding of aspects of childcare that could not be explored through recall techniques, such as intrahousehold processes involving food and nutrient distribution, maternal time and child feeding, and care practices.

Is care an important input into child nutrition in Accra?

The Accra study provides unequivocal evidence of the crucial role of childcare practices as a key input into children's nutritional status. Children whose mothers had poor childcare practices were up to three times more likely to be stunted than those whose mothers had good care practices. Care was more critical for children whose mothers had less than secondary schooling and for children from households of lower socioeconomic status. Good care practices appeared to mitigate the negative effects of low maternal education and poverty.

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What care practices are most crucial for child nutrition?

Findings from the observational study confirmed the suggestions from the quantitative survey that optimal feeding practices during the first six months of life contribute to the prevention of growth faltering among young infants in Accra and that the benefits may linger beyond the first year of life.

Which maternal and household resources contribute the most to enhancing care in Accra?

Education was the characteristic most strongly associated with good childcare practices. For the majority of women, employment did not seem to be a severe constraint for childcare and nutrition in this context. However, early return to work by the mother after delivery—usually a response to economic constraints—may entail risks for children. There was no evidence that poor feeding practices resulted from severe poverty, food insecurity, or economic constraints. These socioeconomic factors, however, did affect hygiene practices, confirming the well-documented fact that good personal, household, and environmental hygiene are particularly difficult to maintain in the absence of a minimum level of services and resources.

What are the program and policy responses to promote optimal childcare practices in this urban context?

Our findings support the universal consensus on the importance of investing in girls' education. In the short term, effective nutrition education and behavioral change interventions can simulate some of the benefits of formal education. In Accra, promotion of exclusive breastfeeding, particularly among women with little or no education, could have major payoffs. Support for working women in the form of low-cost community-based childcare facilities should also be given a priority, as well as policies to address poverty alleviation, income generation, hygiene and sanitation, and quality control of street food sales.

How do the three research approaches for the measurement of childcare complement each other?

Each method provided unique information but also enriched and informed interpretation of other study components. This "triangulation" of findings also helped generate additional hypotheses that could be tested by using an iterative process of analysis. This allowed a richer and more complete picture of the role of care as an input into child nutrition in Accra to be obtained.

The full texts of this document and other FCND Discussion Papers are available at the IFPRI website: www.ifpri.org/divs/fcnd/dp.htm or via B.McClafferty@cgiar.org

Letter to the editor

Dear Sir,

Community-based salt iodization program administered by hand sprayers: A trial in Mongolia since 1999

Salt iodization is the most commonly accepted strategy for the control of iodine-deficiency disorders in more than 100 countries that have launched salt iodization programs [1]. WHO/UNICEF/International Council for Control of Iodine-Deficiency Disorders (ICCIDD) recommends a national usage rate of iodized salt of at least 90% for the effective prevention of iodine-deficiency disorders [2]. Mongolia began its salt iodization program in 1996 with nine salt companies, and by 1998, its national coverage had only reached the 42% level [3], in spite of nearly 100% coverage in the capital, Ulaanbaatar.

We figured that the high price of iodized salt in comparison with natural salt and its poor distribution in rural areas were the main obstacles to popularizing the use of iodized salt. The price of the iodized salt was twice that of natural salt in Ulaanbaatar and three to seven times in outlying areas. Out of 3,660 tons of iodized salt produced in 1998, we found that less than 40% was consumed in rural areas, which have 75% of the population.

We also inferred that the program would not make much progress under current economic and political constraints. Therefore, it was time to develop and introduce a new program, supplementary to the current salt iodization program, which focused on community ownership. We developed the safe-spray method, which iodized 1 kg of salt to 30 ppm with three sprays of a measured solution of potassium iodate (KIO_3) by using durable hand sprayers. The procedure was to measure 1 kg of salt into a plastic bag, put the sprayer nozzle into the plastic bag with the tightly closed mouth of the bag around the nozzle, spray once and shake well, and then repeat the same procedure two more times. In 10 random samplings of 1 kg of the sprayed salt, the iodine content was constant, ranging only from 29.6 to 32.8 ppm (n=300).

Uyanga, Taragt, and Zuiil, three villages with a high prevalence of goiter (31.1% to 41.3%) in Uvurkhangai Province 430 km southwest of the capital, agreed to participate in the program. The spray-method community initiative program (SMEP) in the three villages was approved by the Ministry of Health, which agreed to provide potassium iodate until 2002. The village committees then registered with the provincial government as iodized salt production sites. The SMEP officially started in August of 1999.

Quality control of iodization was done by a field test kit (MBI company, India) to check the iodine content in 10 random samples per day. We established a laboratory for a titrimetric method in the Provincial Health Center, which examined 30 samples per month from each village.

The local iodized salt was sold in the village hospitals for Tg. 120 (US$1.00 = Tg. 1,087, 1999) per kilogram of salt, and the prices of natural salt and iodized salt from Ulaanbaatar in retail shops were Tg. 100 to 130 and Tg. 350 to 400, respectively. When the hospital staff visited remote areas, they brought the sprayers and iodized natural salt to each household; the charge was Tg. 20 per kg.

A baseline survey to assess iodine-deficiency disorder status and the use of salt was carried out in 1999. One hundred fifty-eight children aged 8 to 12 years and 64 women aged 15 to 45 years were selected randomly and examined. The median values of urinary iodine excretion indicated that they were at moderate risk for iodine-deficiency disorders. Iodized salt coverage in three villages increased from 10% in 1999 to 30% in 2000. Although iodine intake among the 300 children and 300 women was not yet adequate, those in village centers showed greater usage rates and urinary iodine excretion values than those in remote units. We found the reasons that residents in remote units did not use iodized salt were that many of them did not know about iodine-deficiency disorders or iodized salt or that they preferred to exchange their livestock for natural salt that was provided by salt sellers. Quality control systems in the villages and the provinces met standards after guidance that was provided in March 2000.

The village committees secured their initial funding to purchase natural salt from a low-interest fund of foreign organizations to be repaid after one year. The village committees were eager to utilize the benefits from the salt for their health education activities and to distribute the salt to remote areas in their villages. However, because the low return from selling the salt, they could barely repay the loans after insufficient implementation of health education and distribution programs and had to ask for additional loans.

To establish a sustainable program, initial funding, without repayment, for purchasing natural salt will be critical for success. For example, the estimated annual sum needed for the purchase of natural salt in the three villages is US$5,900. If this amount can be secured, the villages could continue and expand the activities, even when the benefit is small. Community sharing of this fund has been discussed. A next step in securing the initial funding would be to intensively publish health education information about iodine-deficiency disorders and promote iodized salt usage in order to achieve universal salt iodization.

We will continue monitoring and supervising the intervention for a few more years. We have formulated a plan to expand this program to other disadvantaged areas in Mongolia after the intervention has been fully accepted by the communities, and we consider that this program will serve as a model for other countries in need.

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Books received

Nutritional health: Strategies for disease prevention. Edited by Ted Wilson and Norman J. Temple. Humana Press, Totowa, N. J., USA, 2001 (ISBN: 0-896-03864-5) 333 pages, hardcover. US$69.50.

This volume in the Nutrition and Health series focuses on the potential role of diet in achieving maximum health throughout the life span. The critical role of nutrition and individual nutrients from fetal life to the senior years is reviewed, with special concern for obesity and chronic diseases, especially including osteoporosis, cancer, diabetes, and cardiovascular disease. The roles of dietary components, including antioxidants and omega-3 polyunsaturated fatty acids, as well as soy isoflavones, phytochemicals, and other compounds not considered dietary essentials, are well covered. Biotechnology in the food supply and the impact of nutritional epidemiology are new topics in this kind of book, as well as the emphasis and space devoted to disease prevention. It is timely, authoritative, and clearly written, with appropriate referencing and index. It will be particularly useful for university-level courses on nutrition and health.

Lifestyle nutrition. Edited by Johanna T. Dwyer and James M. Rippe. Blackwell Science, Malden, Mass., USA, 2001 (ISBN 0-632-04508-5) 232 pages, paperback. US$29.95.

This volume too focuses on nutritional strategies for improving health at all ages, but from a different perspective and for a different audience, those responsible for public health nutrition policy and its implementation. It is a concise review of public health nutrition topics in the areas of current policy and practice in public health funding, medical care, and health delivery in the United States. It discusses nutritional status assessment, nutrition for adolescents and adults, cardiovascular disease risk, management of obesity, approaches to changing health-seeking behavior, communicating nutritional messages, and changes affecting nutritional needs of the elderly. It will be a useful reference and guide for clinical and public health nutrition workers in the United States and other industrialized countries and in those developing countries that are increasingly experiencing a demographic transition.

News and notes

2001 World Food Prize Laureate

On October 18, 2001, Dr. Per Pinstrup-Andersen, a citizen of Denmark and Director-General of the International Food Policy Research Institute (IFPRI), received the 2001 World Food Prize for his contribution to agricultural research and food policy and for uplifting the status of the poor and starving citizens of the world. Dr. Pinstrup-Andersen's work has been characterized by a dedication to alleviating the suffering of persons without sufficient nutritious food, particularly malnourished and starving children. His early research at IFPRI demonstrated that in many countries, government policies and the structure of food subsidy programs often inadvertently contributed to keeping the poorest members of society mired in poverty; and without a change in governmental policies, no breakthrough in agricultural technology or other scientific advances could lift up those most in need.

For nearly a decade, Dr. Pinstrup-Andersen has been the Director-General of IFPRI, a Future Harvest Center, which is funded by the Consultative Group on International Agricultural Research (CGIAR). Under his leadership, IFPRI has become the world's leading think tank on hunger issues, taking on numerous groundbreaking research projects, including breeding staple crops for higher nutrition, improving the effectiveness of food for education efforts, and computer modeling using IFPRI's IMPACT computer system projections to determine the effects of government policies on child malnutrition and food security.

Dr. Pinstrup-Andersen has been the driving force in pressing forward a global effort, the 2020 Vision Initiative, to assist world leaders to focus on the potential for food security crises in the twenty-first century. He has personally led research efforts that enabled the governments of several developing countries to transform their policies, thus dramatically increasing the amount of food available to the poorest in each country.

Editorial Announcement

All manuscripts submitted to the Food and Nutrition Bulletin after January 1, 2002 will be subject to a charge of US$60.00 per printed page. It is assumed that this will be paid by the funding source for the study submitted. In the case of developing country authors whose research did not have sponsorship able to pay this charge, the page charge may be waived. An affidavit to this effect will be required. Studies acknowledging major financial sponsors will not be eligible for waivers. For the cost of special issues or supplements, the editorial office should be consulted.

Beginning immediately, we ask all authors who can to submit their manuscripts electronically, but tables and figures should not be imbedded in the text. In addition one hard copy of the manuscript and the original figures should be forwarded by mail.

The Bulletin welcomes paid announcements of appropriate professional opportunities, courses, and publications. To arrange for these contact the editorial office.

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Secretariat: Dr. Chu-Sing Koh, 2nd Floor, Bangunan Porla, Lot 6 SS6, Jalan Perbandaran, 47301 Kelana Jaya, Selangor Darul Ehsan, Malaysia

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2. Committee on Enzymes of the Scandinavian Society for Clinical Chemistry and Clinical Physiology. Recommended method for the determination of gammaglutamyltransferase in blood. Scand J Clin Lab Invest 1976;36:119–25.

Book or other monograph reference

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3. Brozek J. Malnutrition and human behavior: experimental, clinical and community studies. New York: Van Nostrand Reinhold, 1985.

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4. American Medical Association, Department of Drugs. AMA drug evaluations. 3rd ed. Littleton, Mass, USA: Publishing Sciences Group, 1977.

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5. Medioni J, Boesinger E, eds. Mécanismes éthologiques de l'évolution. Paris: Masson, 1977.

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