Proceedings of the Workshop on Food-Consumption Surveys in Developing Countries

Future challenges

E-Siong Tee, Marie Claude Dop, and Pattanee Winichagoon

Abstract

The workshop "Food-consumption surveys in developing countries: Future challenges," held in Chiang Rai, Thailand, January 25–26, 2003, brought together 30 nutritionists and food safety experts from 10 Southeast Asian countries as well as from countries outside the region. It provided a forum for sharing information and experiences relating to food-consumption survey methodology. It enabled detailed discussions of the gathering of food-consumption data in developing countries for purposes of nutrition assessment, exposure assessment, and studies of diet-disease relationships. The workshop participants emphasized the need to obtain the support of policy and decision makers to establish a mechanism for conducting regular coordinated food-consumption surveys to meet these needs. The participants emphasized the importance of identifying all relevant stakeholders and involving them in the planning and conduct of these surveys. A number of technical issues related to food-consumption surveys were discussed, including food-intake methodologies. It was felt that surveys on individuals are preferred, and a combination of 24-hour recall and food-frequency questionnaire would most likely provide the required data. The workshop emphasized the need to develop, maintain, and update databases at the national and regional levels for nutrients and non-nutrients as well as contaminants and food additives. To ensure that surveys are conducted regularly and professionally, the importance of having qualified and trained personnel was emphasized. Several issues related to reports of food-consumption data were discussed, including timely reporting, effective dissemination, and appropriate usage. The participants unanimously recommended the organization of further technical meetings or workshops to follow up on recommended activities and enable continuing regional collaboration on food-consumption surveys.

Key words: food consumption surveys, nutrition assessment, exposure assessment

Background

Food-consumption surveys are indispensable tools for assessing nutrient intake. In developing countries, their traditional goal has been to assess the prevalence of inadequate intakes and trends in food consumption, mostly through large national or subnational nutrition surveys. Food-consumption data are needed to develop appropriate Food-Based Dietary Guidelines and to monitor changes in dietary behaviors and patterns. With rapid social and economic development, assessing non-nutrient intakes and exposure to additives and contaminants, as well as establishing diet-disease relationships, are becoming important additional goals of food-consumption surveys in developing countries.

The first effort in regional collaboration in food-consumption surveys was a seminar on nutrition assessment methods for National Nutrition Surveys held in Kuala Lumpur in 1997, initiated by the Institute for Medical Research (IMR) [1]. In September 2000, the International Life Sciences Institute Southeast Asia Region (ILSI SEAsia), with the support of the IMR

E-Siong Tee is affiliated with the International Life Sciences Institute (ILSI) SouthEast Asia Region. Marie Claude Dop is affiliated with the Food and Nutrition Division of the Food and Agriculture Organization of the United Nations, Rome. Pattanee Winichagoon is affiliated with the Institute of Nutrition, Mahidol University (INMU), Thailand.

Please direct queries to the corresponding author: E-Siong Tee, 46, Jalan SS 22/32, 47400 Petaling Jaya, Selangor, Malaysia; e-mail: president@nutriweb.org.my.

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and of the Nutrition Society of Malaysia, organized a follow-up workshop in Kuala Lumpur.* In October of that year, another workshop was held in Beijing in conjunction with the Third Asian Conference on Food Safety.**As a follow-up to these previous meetings, a workshop on food-consumption surveys was organized on January 25–26, 2003, as a satellite meeting of the Fifth International Conference on Dietary Assessment Methods held in Chiang Rai, Thailand.

This report contains a summary of the proceedings, including information on the organizers and participants, workshop highlights (comprising opening remarks and summaries of the two keynote lectures and six country reports), and workshop discussions and recommendations. The full text of the two keynote lectures is presented in this issue of the *Food and Nutrition Bulletin*, pages 317–329.

Organizers and participants

The Food and Agriculture Organization (FAO) of the United Nations, the International Life Sciences Institute (ILSI) Southeast Asia Region, and the Institute of Nutrition, Mahidol University, Thailand, jointly organized the workshop.

Some 30 nutritionists responsible for national or large-scale nutrition/food-consumption surveys and food safety officers from developing countries participated in the workshop. They came from all 10 Southeast Asian countries as well as from outside the region, from Burkina Faso, China, Iran, and Mexico. Experts from five other countries—France, Italy, New Zealand, Japan, and the United States—acted as resource persons. In addition, relevant key officials from FAO and ILSI SEAsia Region participated in the meeting.

Workshop highlights

Opening remarks

Dr. Kraisid Tontisirin, Director of the Food and Nutrition Division of the FAO, Rome, declared the workshop open. In his opening address, he emphasized that assessing food and nutrition situations is a very important step leading to strategic policy formulation. He called on all nations to continue to allocate sufficient resources and personnel for such purposes. Traditionally, food-consumption data are used to determine nutrient adequacy. In addition to this, food-consumption data have wider uses for nutrition purposes, including studies of the relationship between diet and chronic diseases. In recent years, such data have become recognized as vital for determining exposure to contaminants (microbiological, chemical), to food additives, and even to excessively high levels of nutrients. For this reason, Dr. Tontisirin felt that collaboration among various professionals (nutritionists, food safety experts, agriculturists, etc.) is crucial to obtain food-consumption data that will meet the needs for the above-mentioned purposes. This is particularly important for developing countries because of the limited resources available. He urged nutritionists to play a greater role in exposure assessment. He called for greater collaboration among developing countries in their attempt to provide more data for the development of global standards, e.g., for the Codex Alimentarius. Dr. Tontisirin commended the various agencies involved in the timely organization of this workshop, which is an important step in promoting future collaborative ventures to add newer dimensions to food-consumption surveys and to strengthen and refine methodologies.

Mrs. Yeong Boon Yee, Executive Director of ILSI SEAsia, welcomed the participants to the workshop. She first gave a brief outline of the organization, objectives, and main activities of ILSI. She emphasized that ILSI SEAsia is involved in several food-consumption surveys in the region, particularly among children. In recent years, the organization has also supported work on food composition in the region. She went on to highlight the series of workshops on food-consumption methodologies that have been organized in Southeast Asia in recent years. She pointed out that in order to ensure effective discussions about meeting the objectives of the workshop, the organizers invited the participation of nutritionists as well as of experts in food safety and agriculture.

Dr. Songsak Srianujata, Director of the Institute of Nutrition, Mahidol University (INMU), cohost of the workshop, also welcomed the participants to the meeting and to Thailand. He highlighted the wider use of food-consumption data in recent years, beyond nutritional assessment. He gave the example of the use of such data in risk assessment. He called for greater collaborative efforts among developing countries in the region in order to collect more and better food-consumption data.

* Tee ES. Report of the workshop on harmonization of methods for National Nutrition Surveys and dietary studies in Southeast Asia, 28–29 September 2000, Kuala Lumpur. Unpublished report of the Division of Human Nutrition, Institute for Medical Research, Kuala Lumpur; 4 pp.

** Tee ES. Report of workshop on dietary survey of methodologies in Asia, 3 October 2000, Beijing, China. Unpublished report of the Division of Human Nutrition, Institute for Medical Research, Kuala Lumpur, 5 pp.

Summaries of keynote presentations

The first keynote lecture, entitled "Methodologic considerations in descriptive food-consumption surveys in developing countries," was presented by **Dr. Gail Harrison** [2], School of Public Health, University of California, Los Angeles, California, USA. In her introduction, she mentioned the diverse uses of food-consumption data for monitoring trends in dietary patterns, developing of food-based dietary guidelines and educational tools, investigating nutrition-disease relationships, and estimating exposure to contaminants. She discussed the pros and cons of stand-alone surveys versus integrating food consumption with other types of data into common surveys. She also discussed issues related to sampling and sample size considerations, as well as seasonal variations.

The paper gave a great deal of attention to issues related to the development of survey protocols and instruments. This includes detailed discussions of the use of appropriate methods for collecting food-consumption data and the choice of the individual or the household as the sampling unit. Community acceptance and culture-specific issues were also discussed. Dr. Harrison highlighted several culture-specific measurement challenges (e.g., shared dishes, sequential eating, nonstandard serving and eating tools, intake of items added at the table, and eating outside the home).

With regard to the problem of reporting bias, Dr. Harrison emphasized that this is central to the interpretation of data from food-consumption surveys and has been very little explored in the context of developing-country environments. Cross-country and cross-region comparability are increasingly important issues, for which standardized tools are required, e.g., standardized or harmonized protocols, manuals, software, survey tools (recipes, etc.), analytical methods, and food-composition databases. She felt that there are two major types of analytical tool required: adequate, harmonized, updated, and well-documented food-composition databases; and flexible, affordable software to provide the interface among foods, ingredients, and nutrients and other components. She further outlined several desirable key features of a good food-composition database and an ideal front-end software.

Dr. Jean Pennington of the Division of Nutrition Research Coordination, National Institutes of Health, Bethesda, Maryland, USA, delivered a presentation entitled "General approaches to estimation of dietary exposure to contaminants" [3]. She outlined the preliminary steps to be taken: gathering the necessary expertise, clarifying the intent and purpose of the work, selecting the exposure model, gathering available pertinent information, and determining additional needs and resources. Expertise is generally needed in chemistry, agriculture, toxicology, statistics, nutritional epidemiology, and computer software development. Two basic types of data are required: the kinds of food containing the contaminants and the levels of the contaminants; and how much of these foods are consumed and by whom. The main questions that might be asked in exposure assessment are: What are the daily exposures of contaminants for people in a defined geographic region? How do the exposures compare with the acceptable or tolerable standards of intake? She emphasized that it is important to understand the unique features of each contaminant, including the chemistry, distribution, and pattern of flow through the food and water supply; the effects of agricultural, environmental, and processing variables on its levels in finished food; and its physiology (bioavailability, absorption, and body storage).

Dr. Pennington outlined five models for estimating exposure: the core food model, the directed core food model, the large database model, the raw agricultural commodity (RAC) model, and the duplicate diet model. The types of data or information to gather would include analytical data on contaminants in commodities, foods, and food products; government regulations on pesticide use and standards of intake for contaminants and residues; and food-consumption data for the population. Exposure to contaminants is expressed as the weight of substance ingested per person per day, or per kilogram of body weight per day. Biochemical measurements of contaminants or their metabolites from national health surveys may serve as a means of validating dietary exposure assessments, or they may be built in as part of the dietary exposure model. Dr. Pennington felt that progress might be more substantial if various organizations within a country or region joined together to share resources and information in exposure assessment.

Summaries of country reports

The two keynote lectures were followed by six brief reports by country representatives on experiences in conducting national food-consumption and nutrition surveys in developing countries.

Dr. Corazon Barba of the Food and Nutrition Research Institute of the Philippines spoke on "Periodic National Nutrition Surveys in the Philippines." The general objective of the surveys is to reassess the food situation and the nutritional status of the population of the Philippines approximately every five years for the appropriate formulation and modification of food and nutrition policies and intervention programs, as well as related development programs. The specific objectives include providing comprehensive data on per capita food consumption and nutrient intake and on adequacy at the national and subnational levels. Another important specific objective is to analyze trends in food consumption and other key nutrition variables in relation to the socioeconomic situation.

The first National Nutrition Survey was conducted in 1978 and the second in 1982, followed by the third in 1987 and the fourth in 1993. Dr. Barba described the sampling design and coverage of each of the surveys. For the first three surveys, a three-stage stratified sampling was used, whereas for the fourth survey, a two-stage stratified procedure was employed. At the household level, the food-consumption methodologies included food records and recalls and food inventories. At the individual level, the method used was food recall. She outlined the flow of activities in food-consumption surveys. The results obtained included mean one-day food consumption according to food group and subgroup, mean one-day per capita nutrient intake and percent adequacy, the list of food items most commonly consumed, food and nutrient intakes by selected socioeconomic parameters, percent contribution of macronutrients to energy intake, and one-day dietary patterns and food wastage.

Dr. Barba summarized the uses of food-consumption data in the Philippines, which are important in relation to the food-fortification efforts of the food industry and serve as a basis for the formulation of Recommended Dietary Allowances and Nutritional Guidelines for Filipinos as well as for nutrition advocacy. The data were also used for evaluation of the adequacy of menus of the different regions and provinces, for agricultural planning at all levels, and for formulating the Philippines Plan of Action for Nutrition. She also highlighted some areas where food-consumption data are underutilized, e.g., in the study of diet-disease relationships, monitoring of dietary patterns and lifestyle changes, and agricultural planning. She pointed out other potential uses of the data, e.g., in the assessment of food safety and pesticide exposure, and in identifying opportunities to improve the nutritional quality of products and the economic potential of food enterprises.

Dr. Juan Rivera of the National Institute of Public Health, Mexico, shared with the participants experiences gained in the Mexican National Nutrition Survey (MNNS) of 1999, which included collection of food consumption data. The survey was representative at the national level, covering both urban and rural areas and four geographic regions. The sample included 21,000 households. The groups that were studied at the individual level were children under 12 years of age and women 12 to 49 years of age. The variables studied in the whole sample were socioeconomic, demographic, and health information, anthropometry, and infant feeding. Blood and urine specimens were collected from a subsample, and physical activity patterns (among women) and dietary intake (in 4,200 households) were studied. The dietary assessment included a 24-hour recall for all groups and a food-frequency questionnaire for women.

Dr. Rivera discussed the main uses of the 1999 MNNS. These included estimating the adequacy of energy and nutrient intakes; assessing trends in dietary intake that can pose health risks; estimating the bioavailability of iron, zinc, and other minerals; identifying departure from food-based dietary guidelines; assessing the contribution of centrally processed food to the diet; and identifying candidate foods for national fortification programs. He emphasized that there is a need to share experiences from different applications of national dietary surveys in developing countries. For each national dietary survey application, there are particular methodologic as well as analytical challenges that have important practical implications for data collection and analysis.

Dr. Nabuo Yoshiike of the National Institute of Health and Nutrition, Japan, presented the "Annual Nutrition Survey in Japan." He described the historical background of the Japanese surveys. The first National Nutrition Survey was carried out in the Tokyo metropolitan area in 1945, following the end of World War II. On the basis of the Nutrition Improvement Law (1952), the survey is carried out to monitor health conditions and dietary intakes in order to guide nutrition policymaking. Under the new law (Health Promotion Law, 2003), a more comprehensive National Health and Nutrition Survey will be initiated, which will include, in addition to nutrition, cardiovascular and metabolic disease risk factors.

A total of 15,000 subjects from 5,000 households in 300 randomly selected districts were surveyed in the 1999–2001 National Nutrition Survey. Data were collected by physical examination of individual subjects (anthropometry, blood pressure, blood tests, and physical activity measured by a pedometer) and by interviews on the use of medication, smoking, alcohol consumption, and exercise habits. A dietary survey was also conducted by the use of a one-day household and individual weighed record and a questionnaire on meals eaten during the survey day (meals cooked in the family, meals taken outside, and meals skipped). An additional questionnaire on diet and lifestyle was also adminstered.

Dr. Yoshiike highlighted several problems encountered when conducting the surveys. These included the lack of a database for ready-to-eat meals, problems in converting portion sizes to weights of foods, and the lack of a database for cooking factors. He outlined the sophisticated data management and analysis system used. At the local level (client software), automated coding of dietary data is performed, as well as calculation of nutrient intake, and data are transferred by the Internet. Data analysis, tabulation, and management are handled at the central level (server software). Dr. Yoshiike outlined various uses of the dietary data. These include analyses of exposure to chemical contaminants, and establishment and evaluation of new health-promotion activities (HEALTH JAPAN 21), for the next review of the Dietary Reference Intakes (DRIs).

Dr. Vongsvat Kosulwat of the Institute of Nutrition, Mahidol University, Thailand, explained that National Nutrition Surveys have been conducted in Thailand since 1962. These surveys had an initial focus on malnutrition among high-risk groups such as children under five years of age and pregnant and lactating women. Food-consumption data, collected as part of these surveys, have traditionally been obtained for the purpose of describing patterns of food consumption and adequacy of nutrient intakes. Such data may not be in an appropriate form for assessing exposure to contaminants, additives, and food chemicals, as well as for describing food-consumption patterns in relation to the risk of chronic diseases. The challenge is to optimize the large-scale food-consumption surveys in order to address all three aspects. Nutritionists are unfamiliar with risk-assessment concepts and procedures, whereas food safety experts do not realize the technical difficulty of collecting and analyzing dietary-intake data.

Dr. Kosulwat shared with the workshop participants the preparations her project team is making for the upcoming national food-consumption survey. During the planning phase, four major tasks were identified: selection of methodology to assess food intake and improvement of the available dietary assessment methods, selection of a food classification system and review of the existing food-composition database, improving the software and statistical aspects of food-intake assessment, and establishing the logistics of the food-consumption survey.

A report on the "National Household Nutrition Survey of Vietnam" was presented by **Dr. Nguyen Cong Khan** of the National Nutrition Institute, Vietnam. The general objective of the survey was to evaluate the current food consumption of households in the different ecological regions of the country in the year 2000. The data will be used for nutrition policy planning in Vietnam. Sampling of households for the survey was undertaken by dividing the country into 8 geographic regions and sampling 30 communes from each region. From each of the 240 communes, 32 households were randomly sampled, giving a total of 7,680 households. For the study of household dietary intake, two main approaches were used: the 24-hour recall method, checked by weighing, and a study of the frequency of food consumption. Nutrient intake was calculated based on the Vietnamese food-composition table, using an in-house computer program.

Dr. Khan highlighted the main findings of the 2000 national survey. Consumption of major food items and nutrient intake were presented by rural and urban area, and by ecological region, in addition to the national average.

Comparison of the data obtained in 1985, 1987, and 2000 showed that there was no marked difference in per capita energy intake. However, the percentage of energy obtained from fats was found to have doubled (6.2% in 1985 to 12% in 2000), whereas the percentage obtained from carbohydrates decreased from 82.6% to 74.9%.

Dr. Noël Marie Zagre of the Research Institute for Health Sciences, Burkina Faso, shared with the workshop participants his experiences with "Constraints on estimating usual intakes of vitamin A in West Africa." He first summarized the vitamin A deficiency situation in the region. Vitamin A deficiency has been shown to be a public health problem in most West African countries. According to a report in 2001, as many as 80% to 85% of children from one to three years of age in Burkina Faso had low serum retinol levels, and from 1% to 6% had night-blindness. Inadequate vitamin A intake and a host of related factors are believed to be the main causes of the problem. Strategies to overcome vitamin A deficiency are mainly based on vitamin A supplementation on National Immunization Days. Fortification is also a promising strategy at the regional level.

Dr. Zagre discussed the constraints on estimating usual vitamin A intake. Some of the main errors in estimating food intake result from the consumption of street foods and eating from shared plates, which are not taken account of by dietary survey tools. Determining the vitamin A content of foods is also a major constraint, since the available food-composition tables are not adequate. A third major constraint relates to factors influencing the bioefficacy of plant carotenoids, since plant foods are important sources of vitamin A in these communities.

Dr. Zagre then presented case studies for estimating usual intakes of potential food vehicles (oil and sugar) for fortification with vitamin A, conducted in Burkina Faso, Niger, Guinea, and Mauritania. The aim was to measure intakes of oil used in sauces and intakes of sugar from a commonly prepared and sold beverage using two survey tools. In the "volume ratio" method for estimating oil intake, the total volume of sauce was first estimated by the number of ladles of water used in making the sauces. The volume of oil used for this sauce was also estimated using water in ladles. Since the weight of a ladle of oil is known, the amount of oil in a ladle of sauce may be estimated. In the "cash technique" used to estimate the amount of sugar used, the total cash collected could be remembered as well as the number of bags of beverages sold. The amount of sugar was then derived from the cost of sugar used in the beverage. The amount of sugar per bag was then computed. These survey techniques were validated against actual weighings conducted during preparation of these foods. No significant differences were observed between the results obtained by these survey tools or the weighing method. High correlation coefficients were obtained.

Workshop deliberations and recommendations

Two sessions of group discussions were held concurrently. The participants in the first group discussed "Interagency coordinated food-consumption surveys: needs, feasibility and challenges," while the second group focused on "Major issues in food-consumption survey methodologies." The participants in both groups comprised a mixture of experts in nutrition, food safety, and agriculture.

Highlights of the discussions and the main recommendations of the working groups are summarized below.

Fostering coordination among agencies in conducting coordinated food-consumption surveys

The participants emphasized the vital importance of promoting interagency coordination from the beginning and ensuring that the planning stage is well coordinated, with a goal of integration. It was felt essential that the program be coordinated by a high-level body or agency, e.g., the Prime Minister's Office or the Planning Commission. All relevant agencies and clients should be involved at the planning stage. It is important to ensure that the technical needs for the food-consumption survey are sound and feasible to all partners involved. All operational issues and the role of each agency in the collaboration should be thoroughly discussed.

The workshop participants highlighted the importance of timely reporting of food-consumption data to relevant bodies and potential users. Reports should be disseminated to agencies involved to obtain feedback for the next reporting phase. It was emphasized that food-consumption data should be presented in "different languages" in user-friendly formats to all potential users. Good-quality databases should be made widely available for secondary use for policy-making and research through a variety of means, using information technologies. It was also pointed out that technical support should be provided to all users to avoid misuse or misinterpretation of the food-consumption data.

Diet assessment: General considerations

It was emphasized that countries need to institute a mechanism to conduct regular national food-consumption surveys for nutrition and exposure assessment, e.g., at five-year intervals. The methodologies to be used in such surveys should meet the needs for both types of assessment. Due consideration should be given to proper sampling procedures to obtain representative data at the national, urban/rural, and other relevant administrative levels. Consideration should also be given to issues of timing of surveys, taking into account seasonal variations, days of the week, and holidays. The participants also recognized that when methodologies change between national surveys, it is important to conduct calibration or "bridging" surveys in order to ensure that the results of consecutive surveys are comparable. The workshop also recommended conducting studies of the physical activity patterns of communities, if possible in the National Nutrition Surveys.

Diet-assessment methodologies and tools for surveys

The workshop participants agreed that 24-hour recall (preferably repeated over more than one day) was the preferred method, because it is quick and simple and provides quantitative data on nutrient intake. Moreover, they felt that a combination of 24-hour recall and food-frequency questionnaire (FFQ) would provide additional information on usual intake and was more likely to meet the needs of both nutrition and exposure assessment. Surveys on individuals are preferred, and household surveys should only be resorted to if the individual surveys are not possible. Within a household, an attempt should be made to sample one individual per age group, based on predetermined criteria.

Consideration needs to be given to the difficulty of estimating intakes from shared dishes (communal pots). To reduce errors in such circumstances, standardized methods or approaches should be developed. Other approaches that may be used include the "proportion method" (e.g., as used in Japan), household measures, and individual or reference recipes.

It is important to understand and document differences in recipes for a similarly named dish. Other approaches that were discussed were developing reference recipes for mixed dishes, using software that allows for entry of raw or cooked foods, and using software that includes an option for modifying recipes.

Some other issues that the participants felt were important to bear in mind included the operational definition of the household, possible sensitivities to some of the questions asked in surveys, and reporting bias. The intake of dietary supplements should be assessed where relevant. It was emphasized that standardization of methodologies between fieldworkers is vital. In this context, it is important to provide training to all members of survey teams. Supervisors should conduct quality-control and spot checks and should analyze differences between fieldworkers.

Food-composition databases

Because good food-composition databases are crucial in food-consumption studies, the workshop participants stressed the need to develop, maintain, and update databases at the national and regional levels for nutrients and non-nutrients (e.g., fiber, flavonoids and other biologically active components, and antinutrients). With the increased interest in assessing exposure to contaminants, there is a need to establish databases for contaminants and food additives at the national and regional levels. The countries agreed to share available food-composition databases wherever applicable. The participants also agreed to have closer collaboration in the region in food-composition database development, especially to standardize food codes, harmonize the analytical methods used, and conduct food-analysis activities at the regional level.

Advocacy and funding

The workshop participants emphasized the need to increase the awareness of policy and decision makers of nutritional issues and their impact on the health and economy of countries. They reiterated the need to institutionalize regular national food-consumption surveys. International organizations such as FAO, the World Health Organization (WHO), and UNICEF should advocate to governments the need for regular planning, funding, and implementation of national food-consumption surveys and for developing and maintaining food-composition databases. It is important to identify partners from government, international agencies, nongovernmental organizations, the food industry. and others to participate in and jointly fund surveys. It is also vital to ensure capacity-building to enable surveys to be conducted regularly and professionally.

Regional follow-up activities

The participants unanimously recommended the organization of further technical meetings or workshops to follow up on recommended activities and enable continuing regional collaboration on food-consumption surveys. Countries were urged to continue efforts to promote coordinated food-consumption surveys to meet nutrition purposes and assessment of exposure to contaminants and chemicals. It was proposed that training or exchange programs be set up to enable professionals involved in national food-consumption surveys to visit other countries to benefit from their experience by participating in actual surveys or observing data management and analysis activities. It was recommended that a database on the status of national food-consumption studies be established to obtain information on what has been carried out, the stage of development of these activities, plans for the future, and inputs required.

The representatives from the participating countries agreed to further promote regional harmonization of methods of dietary assessment. The preparation of a regional manual on dietary assessment procedures was recommended. There should be a mechanism for regular regional exchange of food-consumption data. There was a proposal to establish and maintain a regional network on food-consumption surveys. Regular activities that could be conducted through the network include holding regular workshops on new development of methods and reporting on the progress of ongoing surveys and survey results. It was felt that regional cooperation in conducting common ethnic group surveys, especially among neighboring countries, would be beneficial. A call was made to set up regional diets for the purpose of exposure assessment by using national food-consumption surveys. There was also a suggestion that the United Nations develop a regional software for analysis of food-consumption data that could be used by various countries.

Conclusions

The two keynote lectures set the stage for the workshop sessions by providing broad overviews on a variety of methodologic issues specific to the developing countries surrounding food-consumption surveys and estimates of exposure to contaminants. The six brief country reports provided an opportunity for the participants to share experiences on conducting food-consumption surveys. The group discussions covered a wide variety of topics, and there was general agreement on a number of issues. The workshop participants emphasized the need to obtain the support of policy and decision makers to establish a mechanism for conducting regular coordinated food-consumption surveys to meet food and nutrition needs as well as for assessment of exposure to contaminants. The participants emphasized the importance of identifying partners from the government, nongovernmental organizations, and the private sector and promoting interagency coordination beginning from the planning stage. All operational issues and needs, and the role of each agency in the collaboration, should be thoroughly discussed.

A number of technical issues related to food-consumption surveys were discussed. It was agreed that due consideration should be given to proper sampling procedures and timing of surveys. The participants agreed that surveys on individuals are preferred and a combination of 24-hour recall and food-frequency questionnaire would most likely provide data that would meet the purpose of both nutrition and exposure assessment. The need was emphasized to develop, maintain, and update databases at the national and regional levels for nutrients and non-nutrients, as well as contaminants and food additives. The participants realized that it is vital to undertake capacity-building to ensure that surveys are conducted regularly and professionally. Several issues related to reports of food-consumption data were discussed, including timely reporting, effective dissemination, and appropriate usage.

Finally, various regional follow-up activities were recommended to enable continuing regional collaboration on food-consumption surveys. A recommended activity was to establish a database of the status of country national food-consumption studies. Through this workshop, an important step has been taken to reach a more coordinated approach among various agencies in the conduct of food-consumption surveys so that data collected can be used to address broader national issues (including nutrition, diet-related chronic diseases, formulation of food safety standards for trade facilitation, agricultural planning, etc.). It will be a long way to go before such mechanisms can be fully instituted in developing countries. It will require continued regional collaboration and the assistance of international agencies and foundations.

E-Siong Tee, formerly Head of the Cardiovascular, Diabetes and Nutrition Research Centre of the Institute for Medical Research, Kuala Lumpur, Malaysia, is Scientific Director, International Life Sciences Institute (ILSI) SouthEast Asia Region. Marie Claude Dop is Nutrition Officer in the Food and Nutrition Division of the Food and Agriculture Organization of the United Nations, Rome. Pattanee Winichagoon is Associate Professor and Deputy Director for Academic Affairs, Institute of Nutrition, Mahidol University (INMU), Thailand.

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Methodologic considerations in descriptive food-consumption surveys in developing countries

Gail G. Harrison

Abstract

This paper reviews some methodologic issues relative to food-consumption studies in developing countries, including sampling considerations; capturing temporal variation in food consumption; choice of dietary instruments and protocols; and food-composition databases and needs for adequate software interfaces. Increasingly, issues of cross-country and regional comparability in food-consumption data are now coming into the decision mix. Comparability of data across countries requires comparability of several fundamental systems. Specific countries and cultural contexts must tackle problems of how to estimate individual intakes when one-dish serving is the norm; how to keep up with rapidly changing food supplies; how to capture ingredients added at the table that may be concentrated sources of nutrients or other components of interest; and how to document out-of-home eating. Assumptions about error, bias, and intra-individual variation in food intake need to be thoroughly tested in developing-country contexts. There is an urgent need for improvement in the availability of appropriate food-composition databases and software interfaces for developing-country use.

Key words: food-consumption surveys, developing countries

The author is affiliated with the School of Public Health, University of California, Los Angeles, California, USA.

Please address queries to the author: Gail G. Harrison, UCLA Center for Health Policy Research, 10911 Weyburn Avenue, Suite 300, Los Angeles, CA 90024, USA; e-mail: gailh@ucla.edu.

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Introduction

Food-consumption surveys in developing countries, as anywhere, serve a number of different objectives and have a diverse set of users. Data on food consumption—sometimes integrated with measures of nutritional status, food security, morbidity, and health risk factors—provide the basis for monitoring trends in dietary patterns and nutritional risk for agricultural, economic, and health policy. The same data can provide the basis for the development of food-based dietary guidelines and nutrition education materials. Researchers utilize these data to investigate nutrition-disease relationships, and those charged with oversight of food safety require information on food consumption to estimate exposure to contaminants in the food supply. There is wide variation from country to country as to who is responsible for collecting food-consumption data, constructing and maintaining the supporting technical databases, making data available and accessible, and analyzing, interpreting, and reporting the information. Further, there is no consistency across countries in terms of the stability or adequacy of resources to accomplish these critical tasks. This paper will review a number of questions and issues facing investigators in developing countries whose responsibility it is to design the best possible survey systems with limited resources, and articulate the need for common systems to facilitate timely and accurate analyses of food-consumption data.

Integrated versus stand-alone surveys

Integrating food consumption with other types of data into common surveys, such as combined health, nutritional status, and food-consumption surveys or combined household expenditure and food-consumption surveys, has some advantages in terms of cost and utility. This approach allows the analyst to relate food-consumption patterns to other variables, a considerable advantage for many purposes, and has the further strength of automatically creating wider, more diverse constituencies of users of the data. The disadvantage of integrated surveys, which can be substantial, is that food consumption and nutrition must compete with other priorities in survey design. Since food intake usually contributes the single largest share of respondent burden in integrated surveys, it is highly vulnerable to abbreviation in the context of a complicated, multipurpose survey.

Sampling considerations

There are a number of issues surrounding the nature and size of the sample for food-consumption surveys, and the decisions that are made with respect to sampling are among the most important, not only in determining the cost and efficiency of the survey design, but also in setting the limits of conclusions that ultimately can be drawn from the data. For example, must the data be nationally representative or should they be representative of smaller administrative units, such as provinces? Depending on where policy decisions based on the data will be made, there may be good reasons for sampling strategies that represent the smaller units. Should the sampling frame be stratified by rural/urban or other key structural variables? Will the household or the individual be the unit of sampling? The long history of household-level food-consumption surveys in many parts of the world argues for continuity at the household level; newer interest in exploring diet-disease relationships across varying cultures and environments places emphasis on individual-level data. Linking data on individuals within households requires a more complex survey design but may be worth doing when both purposes need to be served. Are there subgroups of the population that should be oversampled? Where there are ethnic minorities or other important subpopulations that would have too few numbers in a simpler sample to allow conclusions to be drawn, oversampling of population subgroups makes sense. Similarly, where fertility rates are low, there may be too few pregnant or lactating women to allow conclusions to be drawn about their food consumption unless they are systematically oversampled. Last, who is outside the sampling frame, and how important are they? Individuals without residential addresses, members of the military, and individuals residing in any kind of institutional facility are typically outside of national sampling frames. Particularly in the case of individuals or families who cannot be identified by a residential address, there may be particular nutritional vulnerability, and there may be consideration of a supplemental survey or other mechanism for obtaining data on these groups.

The total size and geographic distribution of the sample is one of the most powerful determinants of survey cost. Thus, calculations of sample size need to be done carefully, with attention to survey objectives. Key questions include: What is the most limiting prevalence that must be estimated accurately, and for what subsets of the population? Are the central tendency and dispersion of key variables sufficient for intended uses, or is it important to estimate the extremes of the distribution (i.e., the 10th or 90th percentile of intake)?

Seasonal variation in food intake is an essential issue to consider in sampling and survey design. The first question to ask is whether seasonal variation is important in the particular local or national context. If it is important with regard to food availability and/or food-consumption patterns, then seasonality must be taken into account in survey design. There are several options. The survey can be divided into two or more discrete surveys conducted in different seasons. The survey can be spread over a calendar year in each primary sampling unit—an ideal option, but one that requires a staffing pattern that allows for long-term, lower-intensity data collection. When there is no choice but to conduct the survey within a particular season, the investigators must recognize not only the loss of data on variability that is a consequence, but also the fact that future surveys will have to be conducted in the same season if data are to be comparable.

Development of survey protocols and instruments

The choice of specific instruments and protocols depends on the survey objectives (which may include continuity and comparability with earlier data), the resources available, and specific cultural considerations. The early development of household food-consumption survey methods, led by the Food and Agriculture Organization (FAO) of the United Nations, emphasized weighed records and observations of household food supplies and the preparation and consumption of food [1, 2]. Since the advent of computers capable of handling large amounts of data in reasonable time frames, it has been possible to think about and implement surveys that include relatively large, and representative, samples with less labor-intensive data-collection methods. Current uses of food-consumption data argue heavily for including individual-level data collection, whether the individual or the household is the sampling unit. Intake records pose a heavy respondent burden and are reactive (that is, they may change the very behavior they are documenting), and they also require literacy across all segments of a population. Much more feasible are recalls (single or multiple) if whole-diet quantitative data are required, food-frequency questionnaires if more stable estimates of food-consumption patterns are desired at the individual level, or targeted recalls or food-frequency instruments if only a few foods or nutrients are of interest.

Not surprisingly, the most common protocol in use today is the quantitative 24-hour recall of food intake. In sufficiently large samples, single recalls of high quality can yield accurate estimates of mean and median intakes, or at least comparably accurate estimates for population subgroups, which can therefore be compared. There are constraints, however, on going beyond this basic objective. A distribution of single recalls of intake overestimates the variance in intake, since it will be composed of both the true between-person variation and the within-person variation that derives from the day-to-day and other time-related variability in intake for individuals [3]. The result of this overestimation of variance is to systematically overestimate the prevalences of low and high intakes when cutoffs are applied to the distribution. Further, because the magnitude of intra-individual variation in intake is nontrivial, a single recall cannot be used to represent an individual's usual intake in analyses that relate food or nutrient intake to other variables. Various statistical adjustments have been proposed and utilized to compensate for the overestimation of variance, all relying on the collection of data on multiple days for at least a subsample of individuals in the survey population [3–6]. The number of replicate days required varies with the nutrient or food component of interest, but available evidence indicates that even a single replicate (i.e., two recalls) can substantially reduce the error in estimating the prevalence of low or high intakes [3]. The assumption that intra-individual variability in food intake is lower in developing countries than in more industrialized settings because of the monotonous diets in developing countries is not supported by evidence; it remains critical to investigate and document the extent of intra-individual variability in each specific survey setting.

Various visual aids for estimating portion size can be used, including foods purchased at a local market and weighed, as well as standardized two- or three-dimensional models of various kinds. For infants and young children, specific targeted or qualitative instruments designed to capture key variables are essential.

Besides the protocol or instruments to be used, the survey design must include attention to designation of the survey respondent, selection of interviewers, selection and testing of visual aids for estimation of portion sizes, and a myriad of other details. Each of these decisions may be critical in determining the ultimate quality of the data.

Community acceptance and culture-specific issues

Issues of informed consent, feedback and benefit to communities, obtaining of government and other approvals, publicity about the survey, and information provided to households and communities are basic. Nonresponse and refusal rates may be determined in large part by how well and thoroughly attention is given to these issues, beyond the requirements of governments.

Survey protocols must be developed in and adapted to local cultural contexts, and this task can be particularly challenging where quantitative information on total dietary intake by individuals is the objective. It is often necessary to carry out small-scale validation exercises to test the efficiency of protocols developed. Examples of these issues include how to estimate individual intake from shared serving dishes; how to account for the change in composition of the food served brought about by sequential eating by different members of the family; how to estimate quantities from nonstandard eating and serving tools (including hands); how to account for the contribution to intake of items added at the table, such as condiments and sauces (which may be concentrated sources of nutrients of interest); and how to estimate food intake away from the home.

A further issue in which there is large cultural variation is the extent to which food is regarded as a private or sensitive topic [7]. In some cultural contexts, talking about one's dietary habits to a stranger is neither problematic nor threatening; in fact, food may be a welcome topic for a social exchange. In others, food may be regarded as a rather private affair within the family, and opening the domain to inspection by strangers is fraught with discomfort.

Reporting bias

Issues of reporting bias are central to the interpretation of data from food-consumption surveys, and they have been very little explored in the context of developing-country environments. Reporting bias can arise from the nonrandom characteristics of nonrespondent individuals or households; from systematic bias in reporting socially desirable or undesirable items; and from individual underreporting or overreporting of intake. Nonresponse rates need to be reported, and screening data collected on sampled but nonrespondent units (households or individuals) and compared to that of respondents. Individual reporting bias can be selective (underreports of socially undesirable items such as alcoholic beverages, overreports of socially desirable items such as meat in many contexts) or general.

The most studied individual bias is the phenomenon of underreporting of intakes in surveys, which is consistent and substantial in surveys in North America and Europe. For example, in the United States, 31% of adult respondents in the National Health and Examination Survey II (NHANES II), and 18% of men and 28% of women in the NHANES III, had "implausible intakes," i.e., less than 0.92 BMR (basal metabolic rate) as estimated from anthropometry [8, 9]. The apparent underreporting is systematically greater in obese than in nonobese respondents and may be due to a variety of causes, including deliberate fabrication, failure to remember food items or eating events, lack of knowledge about the composition of mixed dishes, inability to estimate portion size accurately, and truly low intakes due to dieting behavior. The problem of underreporting has prompted a great deal of methodologic work to improve 24-hour recall methodology, with some success [10, 11]. There have been few studies of the issue in developing countries, but the limited available evidence, from Egypt and Indonesia [12, 13], shows less apparent underreporting in developing-country settings. The implications for design of surveys are clear: it is essential to collect information on anthropometry (heights and weights) and (ideally) some estimate of physical activity level within food-consumption surveys if underreporting is to be examined and reported.

Recent work using biomarkers for energy and protein intake indicates that there is additionally individual-specific bias in reporting of food intake, which further complicates the interpretation of data [14, 15].

Cross-country and cross-region comparability

Food supplies today are increasingly global, mobile, and rapidly changing, and nutrition-related health problems are increasingly similar across populations. There is a need across the globe to be able to compare food-consumption patterns, nutrient-intake patterns, and health outcomes across populations. Such comparability requires the development of food-composition databases, analytical methods, protocols, and software that meet global needs and can be shared at relatively low cost. FAO has traditionally taken the lead in the development of food-consumption survey methodology for developing countries and through its support of INFOODS is continuing that leadership. The earliest manuals of food-consumption surveys originated from FAO [1, 2]; these were followed much later by works, useful but not widely utilized, from other investigators [16, 17]. Most of the recent effort in developing comparable systems has gone into the task of harmonizing food-composition databases and making them accessible. In the 1980s, the Collaborative Research Support Program on Nutrition and Human Function (Nutrition CRSP) resulted in comparable systems for three countries (Kenya, Mexico, and Egypt), which investigators at the University of California Berkeley then developed into a six-country database called WORLDFOODS, designed to make accessible relatively complete nutrient information on foods representative of the core food supplies in important parts of the developing world [18]. Although widely used, the WORLDFOODS system has no current technical support available, and most users take advantage of the database without the entry system, which is DOS-based, and develop their own data-entry system. More recently, the International Network of Food Data Systems (INFOODS) program has made continuing efforts to create harmonized, adequately documented, and accessible food-composition databases [19]. The European Food Consumption Survey Methods group (EFCOSUM) has done impressive recent work in developing harmonized systems for the European Union countries [20, 21]. Nevertheless, many developing countries, including some very large ones, currently rely on systems hybridized from older local data and accessible international data including commercial software not suited to population-level studies.

The ideal food-composition database for use in developing countries would have several characteristics. It would include all locally important food and beverage items; it would include complete information on nutrients and non-nutrient components of interest; it would be continuously (or at least regularly) updated; it would provide information on foods both "as consumed" and "as acquired"; it would clearly differentiate between missing values and real zeros; and it would provide documentation of the ultimate source of the information. Additionally, it would be arranged hierarchically to allow for food-based analyses; it would allow the addition of new food items and the adaptation of nutrient information for local use; and it would allow the linkage of ingredients through recipes to mixed dishes.

In addition to adequate and accessible food-composition databases, we all urgently need another tool that currently does not exist: a flexible, affordable software system to provide the interface among foods, ingredients, and nutrients or food components. Such software can be developed *de novo* or from existing systems, and this development is an urgent need. The ideal front-end software would provide for data entry in the local language; allow creating of new, locally appropriate portion-size models and terms; allow entry and open-ended querying for new or unknown foods; provide for recipe modification, including changes in fat and water retention and retention/loss factors in nutrient content with cooking; and allow analyses at the levels of nutrients and food components, food, and ingredients.

None of these improvements in the toolkit is impossible, given the work that has already taken place in INFOODS, in Europe, and in the United States, and they could vastly improve the amount, timeliness, and quality of data available to solve urgent and important problems of nutritional vulnerability, food security, and improvement of human health through understanding of diet-disease relationships in developing countries.

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General approaches to estimation of dietary exposure to contaminants

Jean Pennington

Abstract

The initial steps in estimating dietary exposure to contaminants include gathering the necessary expertise, clarifying the intent and purpose of the work, selecting a dietary exposure model, and gathering available pertinent information. Expertise is generally needed in chemistry, agriculture, toxicology, statistics, nutritional epidemiology, and computer software development. The goal might be to determine the average exposure of a population to contaminants, to identify demographic groups within a population that are especially vulnerable to a contaminant, to evaluate the regulation of agricultural and food-manufacturing practices, or to determine compliance with standards for local and/or imported foods. Examples of dietary exposure models include the core food model, directed core food model, large database model, raw agricultural commodity (RAC) model, regional diet model, duplicate diet model, and total diet composite model. Each model has advantages and disadvantages and different costs and resource requirements. Consideration of the sources and flow of selected contaminants though the food supply may help identify the best exposure model to use. Pertinent information that may already be available includes analytical data on contaminants in foods or commodities, government regulations pertaining to the levels of contaminants in foods, food-consumption data, data on the average body weights of age-gender groups (to express exposure on a body weight basis), and biochemical measures of contaminants or their residues/metabolites. Collecting available information helps to clearly define what critical information is missing so that the planned research can be most effective. Careful documentation of decisions and assumptions allows for recalculating exposure estimates with the same model using different decisions and assumptions; documentation also allows others to understand what was done and how to use the resulting intake estimates properly. Clearly identifying the limitations of the exposure model may provide justification for additional resources to further refine and improve the model.

Key words: contaminants, core food model, dietary exposure, exposure models

Introduction

It is unlikely that resources will be sufficient to make dietary exposure estimates in an optimal or ideal manner. Therefore, it is important for developers of exposure models to be creative, resourceful, and efficient. Compromise is usually necessary, but the outcome should fulfill the original objectives. Approaches for estimating dietary exposure to contaminants have been the subject of several Food and Agriculture Organization/World Health Organization (FAO/WHO) publications [1–3]. The approaches to dietary exposure estimates discussed here utilize information on the levels of contaminants in foods and information on the consumption of foods. These approaches are not as sophisticated as those of risk assessment and risk management for foods, which serve as the basis for developing food safety standards [4].

Definition of contaminants

The group of chemical compounds that are consid-

The author is affiliated with the Division of Nutrition Research Coordination, National Institutes of Health, Bethesda, Maryland, USA.

Please send queries to the author: 6707 Democracy Boulevard, Room 629, Bethesda, Maryland 20895-5461,USA; e-mail: jean.pennington@nih.hhs.gov.

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ered to be *food contaminants* is quite diverse. The same chemical component may at times be classified as a contaminant, a nutrient, an intentional food additive, or an unintentional food additive. Intentional food additives are deliberately added during plant or animal growth (pesticides, antibiotics) or food processing (humectants, emulsifiers) and are expected to end up in the finished food. Unintentional food additives get into foods, usually during processing, and may come from conveyer belts, contact with machinery, packaging materials, etc. For purposes of this paper, food contaminants will also be referred to as *food components* (although some may argue that the term *food component* should be reserved for those chemicals that are inherently present in foods or that are potentially beneficial to humans).

Food components that have been referred to as contaminants include pesticide residues (e.g., organohalogen or organophosphorus pesticides/metabolites), industrial chemicals (e.g., polychlorinated biphenyls, carbamates), heavy or toxic metals (arsenic, cadmium, lead, mercury), radionuclides (e.g., strontium-90, cesium-137), antibiotics, hormones, other drugs, nutrients in excess (e.g., selenium, iodine, zinc), naturally occurring toxins (e.g., mycotoxins, nitrites), filth (e.g., dirt, insect parts, rodent droppings), illegal fillers or food additives, and excessive levels of food additives. Food contaminants may be inherent in a plant or animal (i.e., obtained by the living plant or animal through food, water, feed supplements, or injection and incorporated into the plant or animal tissues) or incorporated into crops during growth (i.e., fertilizers, pesticides) or acquired during processing (e.g., food additives). Some contaminants may become incorporated into plant and animal tissues; others remain on the outside surface of the food material.

Overarching thoughts

When determining dietary intakes of contaminants, the goal is usually to provide accurate, valid, and reproducible exposure estimates. However, the reality is that there are resource constraints in terms of time, people, laboratory facilities, reagents, equipment, and money, which prevent optimal or ideal exposure estimates. Therefore, it is important for researchers to be creative, resourceful, and efficient and to make the best possible use of available resources and of previously acquired information. It is usually necessary to make compromises in the research plans, but the outcomes of the research should still meet the initial objectives.

Detective work to trace contaminants

Model development for exposure estimates requires detective work to trace and follow a given contaminant through the food system from its initial point of entry to the amount present in foods as consumed. The point of entry may be the living plant or animal, or it may be during harvest, storage, transport, or processing of the food. Model development requires knowledge about the unique chemical and physical features of the contaminant to trace its distribution and pattern of flow through food, water, and air; the effects of agricultural, environmental, and processing variables on the concentration of the contaminant in finished foods; and the physiological characteristics of the contaminant with respect to human bioavailability, absorption, and body storage. The concentration of a contaminant may increase, decrease, or remain the same through various phases of food production and processing. The unique features of a contaminant include its stability, volatility, ability to bind with other atoms or molecules, pervasiveness, and conversion to other metabolites in foods or in the body after consumption.

For example, pesticides are applied directly to crops, and the pesticides and their residues may remain on the outside of plant parts or be incorporated into plant tissues. The concentration of pesticide residues in grains, fruits, and vegetables may be reduced by rainfall or other environmental factors. Residue levels on grains are reduced by refining, i.e., removing the germ and bran, and grinding into flour. Hence, the residues on whole-grain wheat may be higher than those on white wheat flour. Residue levels may also be reduced by the rinsing, peeling, and cooking of fruits and vegetables. Thus, processed and highly processed foods may be lower in residues than the original commodity from which the foods are made.

Although pesticides are applied directly to crops, they can also leach into soil and runoff water so that crops subsequently grown on the soil (whether fed to humans or animals) may contain residues, and runoff water may bring residues to other crops, fish, land animals, and drinking water. If pesticide-treated crops are fed to animals, the residues may appear in animal tissues (meat, organs, milk, dairy products, eggs) that are consumed by humans.

Metal and mineral contaminants have different and varied routes of entry into the food supply. Lead in foods comes primarily from foods in metal containers in which the soldering process is old or incomplete. The primary source of mercury in the food supply is from fish, especially larger, older fish that have accumulated mercury from contaminated waters. High levels of iodine in foods may come from unintentional additives used in the dairy industry, such as iodine feed supplements fed to cows and iodophor cleaning solutions used in dairies. Other potential sources of iodine are iodate dough conditioners (found in breads) and the red food dye, erythrosine (found in some red-colored pastries, breakfast cereals, and candies). Excessive levels of selenium are found in isolated locations in the soil and water. Crops grown in these areas and wildlife living in these areas have been found to be excessively high in selenium.

One might map the course of the food component through the food and water supply to help plan the developmental exposure model. Because there is usually an interest in measuring trends, it is important to keep the models for contaminants as consistent as possible over time. Otherwise, changes in exposure estimates may reflect changes in the model rather than actual changes in exposure.

Preliminary steps

The following are the preliminary steps for building a dietary exposure model for contaminants:

» Gather together the pertinent expertise
» Clarify the intent and purpose of the work, i.e., determine the specific question(s) to be addressed
» Review previous models and select an appropriate one, modify an existing one, or develop a new one
» Gather available pertinent information and document sources
» Determine additional needs and resources
» Identify possible limitations of the model

Pertinent expertise

The development of a dietary exposure model requires expertise in chemistry, agriculture, toxicology, statistics, nutritional epidemiology, and computer software development. Chemists provide knowledge of the unique physical and chemical properties of contaminants, their residues, and their metabolites, as well as the methods for analyzing contaminants in foods. Agricultural experts contribute their knowledge of the use of fertilizers and pesticides (i.e., which ones are used in which crops), government regulations regarding permitted use levels, and knowledge of permissible levels of contaminants in imported foods. Toxicologists have knowledge of the toxicology of contaminants, their residues, and their metabolites; the effects of the contaminants on human health and environmental health; and the standards of acceptable intake set by government and international agencies.

Two types of statistical expertise are needed to design dietary exposure models: expertise in food sampling, and expertise in human population surveys and studies. Statistical expertise with regard to foods is essential to develop sampling designs so that the analyzed commodities or foods are representative of those available to the population. Statistical expertise is also helpful in making decisions about analyzing individual foods or food composites. Statistical expertise in human populations is needed to use data from food-consumption surveys and studies and apply weighting factors to achieve data that are representative of the population and population subgroups.

Nutritionists or nutritional epidemiologists are needed because of their knowledge of the dietary patterns of the population and population subgroups. They understand the important demographic variables that are needed to identify vulnerable subgroups with respect to contaminant intake. They have knowledge of the methods used to assess food-consumption patterns and the limitations of these methods. They are also knowledgable about the various food-consumption surveys and studies carried out by government agencies and academic institutions.

Expertise in computer software development is necessary to store and organize the data, perform calculations, merge food composition and food consumption data, and present results in various formats.

Questions to be addressed

It is important to clearly specify which contaminants are of interest and the specific goals of the dietary exposure model. Some questions may be answered by data from food analyses. Other questions require data on both food composition and food consumption (and usually the merging of these two types of data). A typical question may be “What is the daily exposure of a given contaminant for the people who live in a defined geographic region, and how does the exposure compare with the acceptable or tolerable standards of intake?” Table 1 provides examples of questions that may be answered through analysis of commodities or foods, and examples of questions that require both food-composition and food-consumption data.

Models to estimate contaminant exposure

Most of the models used to estimate exposure to contaminants require the merging of food-composition and food-consumption data. The composition data are essential because they differentiate between the foods that are sources of the contaminants and those that are not sources. In addition, the data provide information on the levels of contaminants that are present, along with ranges and variations. Data on the consumption of foods are necessary to identify the foods that are typically consumed and the quantities typically consumed (along with ranges and variation) for the population and population subgroups. It is most useful if the data from food-consumption surveys also supply detailed demographic information (age, gender, body weight, urbanization, income, education, geographic region, etc.) so that these variables may be used to more accurately identify contaminant exposure.

The five general exposure models that require merging of food-composition and food-consumption data are the core food model, the directed core food model, the large database model, the raw agriculture commodity (RAC) model, and the regional diet model. The core food model requires collection of the primary foods in the food supply and analysis of these foods for contaminants. The directed core food model requires collection and analysis of only the core foods known to contain the contaminants. The large database model includes all foods consumed by a surveyed population and estimates of the levels of contaminants in each food. The RAC model collects and analyzes RACs for contaminants and then estimates the levels that might be in the foods and food products available to consumers. The regional diet models were developed to predict dietary intakes of pesticide residues and other chemicals in RACs [5].

In addition to the above models that merge food-composition and food-consumption data, there are two models that require analysis of sample diets or diet composites. The first is the duplicate diet model, which requires the collection and analysis of daily meal composites for contaminants. The second is the total diet composite model, which is a single composite of core foods to represent the daily intake for a selected age-sex group. The daily composite is analyzed for contaminants.

TABLE 1. Examples of dietary exposure questions

Questions answered by analyses of commodities or foods

- Are farmers adhering to regulations regarding use of fertilizers and pesticides?
- Are contaminant levels safe and acceptable
  - in food commodities?
  - in prepared foods as consumed?
  - in imported foods?
- Which contaminants and foods are of concern to public health?
- Which foods are highest in contaminants?
- What are the trends and changes over time in the levels of contaminants in foods?
- Are changes in government regulations needed to make or keep the food supply safe with regard to contaminants?

Questions answered by food-composition and food-consumption data

- What are the average intakes of contaminants for a population and subpopulations?
- What are the distributions of intakes for a population and for subpopulations?
- Which foods are major sources of contaminants?
- How do exposures vary by demographic variables?
- Which subgroups are most vulnerable with respect to age, gender, geographic location urbanization, ethnic group, education, and income?
- Are demographic variables good predictors of intakes?
- Do imported foods contribute excessively to contaminant exposure?

Core food model

Core foods are those most commonly consumed by a population, and they may be identified from the results of national or regional food-consumption surveys. The US Food and Drug Administration (FDA) uses the core food approach in its Total Diet Study [6–9]. Approximately 200 to 300 foods are selected from the approximately 8,000 foods listed in the database of national food-consumption surveys. This is done by an aggregation process in which similar foods are grouped and one item (the core food) is selected to represent each group.

Table 2 provides a simple example of a core food, cooked carrots, from one of the US national food-consumption surveys. These carrot-based foods were grouped together, and the total daily intake of each food was determined. The foods are listed here in descending order of their percent contribution to total carrot intake. Note that the total intake of raw carrots is about 36% of carrot intake, and the intake of cooked carrots is about 64% of carrot intake. In the absence of other information, *cooked carrots without added fat* was selected as the core food. The consumption of all these carrot-based foods was then assigned to *cooked carrots without added fat*. This consumption figure for cooked carrots would then be merged with composition data for contaminants in cooked carrots to estimate the exposure from this food.

Each core food takes on the consumption level for all foods within its group. The core foods in the FDA Total Diet Study are purchased four times per year using a regional sampling design. The foods are prepared for consumption and then analyzed in the laboratory for about 200 pesticide residues, radionuclides, industrial chemicals, heavy metals, and nutrient minerals [10, 11]. The food-composition data are then merged with data on food consumption, and estimates of daily intakes of the food components are made for 14 age-gender groupings.

The advantages of a core food model are that the most important foods consumed in the population can be analyzed in the laboratory on a routine basis. Thus,

TABLE 2. Core food example

Food	% of intake of carrot foods
Carrots, raw	33
Carrots, cooked without fat	30
Carrots, cooked with fat	24
Carrots, cooked, no information about fat	10
Carrot salad	3
Carrots, glazed	0.12
Carrots, creamed	0.11
Carrot salad with apples	0.01

the data are current and allow for determination of trends and changes in the contaminant levels of individual foods and the effect on trends and changes in daily intakes. The model also allows for prediction of the effects of policy changes on exposure estimates (e.g., how a change in permitted use levels of a pesticide would affect the daily intake of specific age-gender groups).

The disadvantages of the model are that it is expensive to collect, transport, prepare, and analyze the foods and that only a limited number of foods available to the population can be analyzed. Another disadvantage is that because this method focuses on average intakes, individuals in the population with unusual or atypical eating patterns will not be captured or identified. This model usually provides one average intake estimate for each age-gender group, without consideration of distributions of intakes. Many countries have Total Diet Studies that use similar or other unique approaches [12].

Directed core food model

Contaminants are usually present in certain foods or types of foods rather than in all foods. With the directed core food model, only those core foods of a population that are known to contain contaminants are collected and analyzed on a routine basis. Therefore, this model requires knowledge of which foods contain the contaminants. It might be useful to use the original core food model initially to identify which foods contain contaminants and thereafter use the directed core food model. The number of directed core foods for a population might be as few as 50 or 100, or it might be higher. The food-composition data can be merged with food-consumption data to obtain measures of exposure. This model has an advantage over the core food model in that it is more efficient, as it focuses time and resources only on the foods that contain residues.

Large database model

This model includes all the foods (e.g., 8,000–15,000 foods) consumed by the participants in a food-consumption survey. Countries with a large market in processed foods, especially canned, frozen, packaged, and restaurant mixed dish items, will probably have many more foods in their database than countries with a more traditional food supply. The task for this model is to find representative values for the levels of contaminants in all the foods in the database. Analytical data will only be available for some foods, so assumptions will have to be made for other foods. Daily intakes of the contaminants are estimated by merging the food-composition data with the food-consumption information. The disadvantage of this model is that it requires considerable estimation and imputation to fill in missing values for concentrations of contaminants in the database. The accuracy of the model depends on how carefully all the contaminant concentrations for the individual foods are selected.

RAC model

In this model, RACs are analyzed for contaminants, and this information is used to estimate the levels of contaminants that would be present in each food as consumed. This model is used for contaminants that originate in crops (e.g., pesticide residues), and it requires knowledge and estimation about what happens to contaminant levels during harvest, transport, and processing (e.g., milling, grinding, rinsing, peeling, cooking, etc.). The levels of some contaminants (e.g., pesticide residues) would be diminished by these processes. For recipe foods (e.g., bread, crackers, pasta with sauce, fruit salad, mixed vegetables), estimates need to be made of the amount of contaminant from each RAC in each food (e.g., the amount of wheat and other grains in a mixed-grain bread). If a crop is consumed by animals, the contaminant may be present in animal tissue (meat, organs, eggs, milk), and it will be necessary to include these animal products in the database. A database is developed that lists all the foods and the estimated levels of each contaminant. The database is then merged with information on food consumption to provide estimates of contaminant intake. The disadvantage of this method is that mistakes might occur in the mathematical estimations and assumptions. Some of the estimated contaminant levels should be confirmed by laboratory analysis of the finished foods.

Regional diet model

The WHO Global Environment Monitoring System/Food Contamination Monitoring and Assessment Programme has developed regional diets for five regions of the world: Middle East, Far East, Africa, Latin America, and Europe [5]. These diets were derived from FAO food-balance sheets and other expert knowledge. Daily intakes are provided for whole RACs in the groupings of cereals, roots and tubers, pulses, sugars and honey, nuts and oilseeds, vegetable oils and fats, stimulants, spices, vegetables, fish and seafood, eggs, fruits, milk and milk products, meat and offal, and animal oils and fats. These consumption data may be merged with data on the contaminant composition of these food commodities to get a rough estimate of daily exposure. The advantage of this model is the availability of the food-balance sheet data from FAO; the main disadvantage is that the data represent food disappearance rather than true consumption.

Duplicate diet model

This model requires that researchers go into homes and collect foods as prepared for consumption. The homemaker is asked to prepare an extra amount of food (the amount that would be consumed by an adult in one day), and that food is taken in a container as an analytical sample and later analyzed in the laboratory for the contaminants. The method can be highly accurate for the households included in the study. It is necessary to obtain a sufficient number of duplicate diets from households and to select the households so that they are representative of the community, region, or nation that they represent. The method is expensive and time consuming for the researchers; it is also burdensome for the participants to purchase and prepare extra food. Because the collected foods are analyzed as a one-day diet, this method will not identify the specific food sources of the contaminants when they are detected. There is also the problem of the dilution effect, where a contaminant could be detected if an individual food were analyzed, but it remains undetected in a diet composite because the amount of the contaminated food in the diet composite is too small. This method could be useful for small populations or population subgroups where a problem with a contaminant is suspected.

Total diet composite model

This model requires information on the amount of each food in the average diet of a selected age-gender group for a population. The consumption data for core foods may be used for this purpose. Each food is purchased, and the specified amount of each food is put together into a single composite that is analyzed for contaminants. The model has the same disadvantages as the duplicate diet methods regarding the inability to determine the source of any contaminants found and the dilution effects that prevent detection of some contaminants.

Averages versus distributions

Those who design dietary exposure models should consider whether they need average exposures or distributions of exposures. To estimate the average daily exposure to a contaminant, one sums the individual exposures for each food. This is achieved by multiplying the average concentration of the residue in each food by the average daily consumption of each food by the surveyed population. This could be repeated for subpopulations identified by demographic variables (age, gender, etc.).

To estimate the distributions of exposure to a contaminant for a population, one needs to calculate the exposure for each person in the survey separately. This allows one to look at distributions among the demographic groups and the whole population. For each person, one sums the average concentration of the residue in each food by the average daily intake of the food consumed by each person. Then the distributions by demographic variables are evaluated, and the mean exposures may be calculated.

Although averages are useful for monitoring purposes, they do not provide accurate exposure estimates for population extremes or vulnerable population groups. The levels of contaminants in foods do not usually follow a normal (Gaussian) distribution, and they may be highly variable. If outlying values are included in the calculation of a mean value, the mean value for the pesticide may be skewed. If high concentrations of a contaminant in a food skew the average value, this could lead to overestimates of exposure.

Likewise, the distribution of food intakes for a population is not usually normal, and again, the inclusion of outlying values may result in skewed mean values. For example, if only part of a population (a certain geographic area or certain age group) is exposed to a food with a high contaminant concentration, then the average exposure will be underestimated for the population group at risk and overestimated for the population group not exposed.

If the average values for both food-composition and food-consumption data are accompanied by standard deviations, ranges, and distributions, then the information is more useful for making decisions for exposure models. It is important to look at distributions for both food-composition data and food-consumption data, so that the information used in exposure estimates is not artificially skewed. Evaluation of distributions will help make decisions about including outlying values (high or low) and about using mean values, median values, or modes in exposure calculations.

For some contaminants, the food-composition data may show many zeros and a few positive values. Averaging such results may result in zero average values. In these cases, researchers may want to calculate a worst-case scenario, i.e., take the highest level of a contaminant in a food and estimate its consumption. If the consumption of the contaminant is below acceptable standards, there will be no concern.

Collecting available, pertinent information

To be efficient and timely and make the best use of available resources, it is best to check for available information, such as the following:

» Analytical data for contaminants in commodities, foods, and food products
» Government regulations regarding fertilizer, pesticide, and food additive use levels and standards of intake for contaminants and residues
» Food-consumption data for the population
» Body weights by age and gender
» Biochemical measures of contaminants or their metabolites

This information may provide answers or estimates to some questions regarding contaminant exposure. The information may also provide justification for resources to do additional work. Gathering available information helps to clearly define what critical information is missing, so that the planned research can be most effective.

Food-composition information

Previous laboratory data on contaminants in commodities and foods may be available from the following sources:

» Government agencies involved with foods, agriculture, and pesticides
» Universities with graduate research on foods, agriculture, and pesticides
» Companies that manufacture or distribute pesticide residues
» Private laboratories that analyze RACs and foods for clients
» Published data (culled through computer searches), such as the scientific literature, previously compiled databases, and academic theses
» Food companies, agricultural organizations, and food trade associations
» Data or databases developed in other countries that have similar food supplies, agricultural and manufacturing practices, and food patterns

For imported crops, foods, or food products, data may be available from the country of origin, such as its government agencies, the import companies, or the food companies.

It is important to document the sources of food-composition data for each contaminant level in each food so that they can be traced (especially if they are later shown to be questionable) or replaced by newer or more appropriate data as they become available. It is best to have data on individual foods, but data on food composites, meals, and daily diets may also be useful in developing dietary exposure models.

Information on government regulations

This includes information on government regulations regarding the use of fertilizers and pesticides on food crops and standards for tolerable levels on individual crops; pesticide residues and other contaminants in imported foods; levels of antibiotics, hormones, and nutrient supplements in animal feed; and tolerable levels for individual intake (expressed as weight of contaminant per person per day or weight of contaminant per kilogram of body weight per day).

Food-consumption information

Information on the food-consumption patterns for the geographic area of concern may be available from national or regional government dietary assessment surveys, research or academic dietary assessment surveys, and sales or marketing data from food companies. Other sources of information about food consumption include national food-production data along with government import and export data for RACs, foods, and food products. Another source could be information from nearby countries that have similar food systems and food-consumption patterns. In general, food-intake information from household food-consumption surveys and from food purchase and production reports will be higher than food intakes from 24-hour dietary recalls and diet records. This is because the former methods may not consider food waste or food loss during preparation and cooking. Therefore, household food-consumption data and food-purchase and -production data should be used with caution in dietary exposure models, as they will tend to overestimate exposures. Likewise, data from 24-hour dietary recalls and diet records have been shown to underestimate total food intake and total energy intake, and this should be taken into consideration.

Demographic variables

Although exposure estimates for pesticide residues are usually stratified by age and gender, they may also be stratified by other demographic variables such as geographic region, education, income level, ethnic group, urbanization, or other variables that are believed to affect food-consumption patterns or exposure estimates for the population.

Body weights

Exposure to contaminants may be expressed as the total weight of contaminant ingested on a daily basis or the weight of contaminant ingested per kilogram of body weight per day. Expressing exposures per kilogram of body weight may help to identify vulnerable populations such as infants, children, and the elderly. To express exposures per kilogram of body weight, it is necessary to obtain information on body weights by age and gender of the individuals participating in the dietary surveys or to otherwise obtain national or regional data on the average body weights of the population according to age, gender, or other demographic variables.

Biochemical measurements

Biochemical measurements of contaminants or their metabolites from national health surveys may serve as a means of validating dietary exposure assessments, or they might be built in as part of the dietary exposure model. Biochemical measurements may also be the impetus for initiating a dietary assessment and monitoring program. If the contaminant results in a metabolite that is measurable in the blood or urine, then it would be possible through a series of human dietary studies to determine what level of dietary intake produces a given level of the metabolite in the blood or urine. Generally, biochemical measures of a food component give a better indication of dietary exposure than dietary assessments alone. In the United States, the National Health and Nutrition Examination Survey (NHANES) conducted by the Centers for Disease Control and Prevention includes serum analysis for persistent organochlorines and urine analysis for nonpersistent pesticide residues from chlorpyrifos, 2,4-D, diazinon, permethrin, ortho-phenyl phenol, methyl parathion, and organophosphate pesticides.

Value of collecting and maintaining data in a database

Collecting and maintaining the above types of information in a database may provide direct answers or estimates for some questions that arise. Such a database helps to clearly define what critical information is missing so that the planned research can be most effective. Thus, the database may provide justification for resources to do additional work. In developing a dietary exposure model, one can begin with the available information and then determine the additional information that is needed and the process and resources required to obtain it. The next step is to determine how the available resources can be used to provide the information that is needed, but not available. If resources are not sufficient to obtain the information needed for the exposure model, the options are to modify the model to meet the resources, use another model, modify the question(s) to be answered, or put the work on hold until the resources are obtained.

Documentation

Careful documentation is important to make it possible to retrace decisions and assumptions. It might be possible to recalculate exposure estimates with the same model using different decisions and assumptions. Careful documentation provided with the reported exposure estimates allows others to understand what was done and to use the estimates properly. Clear identification of the limitations of the model and the effects of the limitations on estimates of exposure is also important. Such information may also provide justification for the use of additional resources to further refine the model.

Organizations working together

Progress may be more substantial if various organizations within a country or region join together to share resources and information. For example, in the United States the missions and responsibilities of various government agencies are rather clearly defined; however, resources are shared and agencies provide financial support to help each other. The FDA, which is responsible for the Total Diet Study, uses national food-consumption survey data from the NHANES, which is conducted by the Centers for Disease Control. The NHANES relies on the food-consumption methodology developed by the Agriculture Research Service of the US Department of Agriculture. The Agriculture Research Service conducts and supports analysis of food for nutrients and other food components and maintains the food-composition database used by NHANES for its food-consumption surveys. The National Institutes of Health (NIH), which needs food-consumption survey data and food-composition data to design human research studies, provides some financial support for both the NHANES and the Agriculture Research Service food-composition database. The sharing of resources and information is essential to conduct government studies and surveys, and it helps to promote knowledge that leads to improved public health.

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