Food and Agriculture
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DIETARY ASSESSMENT

A RESOURCE GUIDE TO METHOD SELECTION AND APPLICATION IN LOW RESOURCE SETTINGS




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Food and Agriculture Organization of the United Nations
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FOREWORD

Across the world today, there is increasing interest in incorporating robust nutrition information into national information systems. The aim is to inform the implementation and evaluation of nutrition-sensitive agricultural projects, policies and programmes, and to tackle all forms of malnutrition. The need for such robust information was reaffirmed at the Second International Conference on Nutrition (ICN2) in November 2014. It is therefore important that as an organization, FAO works to meet global knowledge demands and gaps in decision-making, by supporting the collection of nutrition information for surveillance, setting targets, measuring impacts, and tracking progress.

Up-to-date and valid assessment of what people eat and drink will help to generate better information and evidence that will contribute to the formulation of effective agricultural and nutrition policies and programmes. It will also benefit consumer education, which in turn will contribute to raising levels of nutrition and help to prevent undernutrition, obesity and non-communicable diseases. This increasingly rigorous approach will lead to a culture of robust dietary data collection, resulting in evidence-based decisions that are crucial to achieving the strategic objectives of the organization.

This resource guide provides an updated overview of the dietary assessment methods that can be used to collect dietary data at national, household and individual levels. The strengths and limitations of various methods are discussed in detail. Its particular focus on low resource settings makes it a valuable tool for users working in environments where resources are limited and rapid nutritional changes might take place. Taking advantage of the proliferation of digital technologies, methodologies involving the use of interactive and web-based technologies for dietary data collection have also been reviewed.

The guide will be a useful resource for programme managers, educators, health care professionals, health promotion specialists, students, extension workers and researchers: in short, anyone involved in food consumption surveys, programme planning, implementation, monitoring or evaluation. It is a one-stop shop for selecting the most appropriate methods for different contexts.

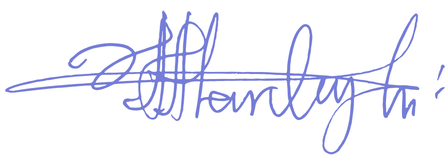
Anna Lartey

Director

Nutrition and Food Systems Division

Food and Agriculture Organization of the United Nations

Rome, Italy



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ABBREVIATIONS AND ACRONYMS

ADePT-FSM	ADePT Software
AMPM	Automated Multiple-Pass Method
ANOVA	Analysis Of Variance
ASA24	Automated Self-Administered 24-hour Recall
BMR	Basal Metabolic Rate
CARDIA	Coronary Artery Risk Development in Young Adults
DAFNE	Data Food Networking
DDS	Dietary Diversity Score
DISHES	Dietary Interview Software for Health Examination Studies
DLW	Doubly Labelled Water
DNSIYC	National Survey of Infant and Young Children
EI	Energy Intake
EPIC	European Prospective Investigation into Cancer
ESN	Nutrition and Food Systems Division, FAO
ESNA	Nutrition Assessment and Scientific Advice Group, FAO
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	FAO Statistical Databases on Food and Agriculture
FAO/WHO GIFT	FAO/WHO Global Individual Food Consumption Data Tool
FBS	Food Balance Sheet
FCD	Food Composition Database
FCS	Food Consumption Score
FFQ	Food Frequency Questionnaire
FP 24-hR	Food Photography 24-hour Recall
GDD	Global Dietary Database
HAZ	Height-for-Age Z-Scores
HBS	Household Budget Survey
HCES	Household Consumption and Expenditure Survey
HDDS	Household Dietary Diversity Score
HES	Household Expenditure Survey
HIES	Household Income and Expenditure Survey
ICN2	Second International Conference on Nutrition
IHS	Integrated Household Survey

IHSN	International Household Survey Network
INFOODS	International Network of Food Data Systems
IYCDDS	Infant and Young Child Dietary Diversity Score
LCFS	Living Costs and Food Survey
LSMS	Living Standards Measurement Studies
MDD-W	Minimum Dietary Diversity – Women
mFR	Mobile Food Record
MMDA	Mean Micronutrient Density Adequacy
MPA	Mean Probability of Micronutrient Adequacy
NANA	Novel Assessment of Nutrition and Ageing
NDNS	National Diet and Nutrition Survey
PAL	Physical Activity Level
PDA	Personal Digital Assistant
PRA	Participatory Rural Appraisal
TADA	Technology-Assisted Dietary Assessment
TEE	Total Energy Expenditure
USDA	United States Department of Agriculture
WDDS	Women's Dietary Diversity Score
WHO	World Health Organization

KEY TECHNICAL TERMS AND NOTATIONS[1]

A

Analysis of Variance (ANOVA) is a statistical analysis that allows for the comparison of means in more than two groups or in groups defined by more than one qualitative variable.

Anthropometric measurements are measurements of the variation of the physical dimensions (i.e. length, height, weight, weight-for-length, mid-arm circumference head circumference, etc.) and the gross composition (i.e. body fat, fat-free mass) of the human body.

B

Basal Metabolic Rate is the minimal rate of energy expenditure required to sustain life. It is measured in the supine position when the individual is in a state of rest (but not sleeping), mental relaxation, fasted, and in a neutrally temperate environment. It is the largest component of total energy expenditure, typically 60–75 percent when measured over 24 hours.

Biomarkers refer to a chemical, its metabolite, or the product of an interaction between a chemical and some target molecule or cell that is commonly measured in body fluids (blood, serum, urine) and tissue to perform a clinical assessment and/or monitor and predict health and disease states in individuals or across populations and in validation studies.

Bland–Altman plot also known as difference plot in analytical chemistry and biostatistics is a method of data plotting used in analysing the agreement between two different assays.

C

Chi-squared test is a statistical test for categorical variables commonly used to compare observed data with data we would expect to obtain according to a specific hypothesis. The hypothesis states that there is no significant difference between the expected and observed result.

Correlation coefficient is a measure of the interdependence of two random variables that ranges in value from -1 to +1, indicating perfect negative correlation at -1, absence of correlation at zero, and perfect positive correlation at +1. Also called coefficient of correlation.

Covariate is a variable that may be predictive of the outcome under study. A covariate may be of direct interest or it may be a confounder or effect modifier.

Cross-classification is a classification according to more than one attribute at the same time; e.g. the cross-classification of cases was done by age and sex.

D

Doubly labelled water method is a stable isotopic technique for measuring energy expenditure in free-living subjects, it is used to identify underreporting of total energy intake.

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[1] The authors used the following sources to compile the list of terms. For further information, users are directed to the original sources. Dietary Assessment Primer, National Institutes of Health, National Cancer Institute: http://dietassessmentprimer.cancer.gov/. Medical Research Council, Glossary of terms: http://dapa-toolkit.mrc.ac.uk/dietary-assessment/da-glossary-of-terms.php. (Both accessed 23 October 2015.)

E

Energy adjustment is an analytic method by which nutrient or food quantity intake is corrected for the total energy intake.

F

Fisher's exact test is a statistical test used to determine if there are non-random associations between two categorical variables.

It is commonly used when the sample size is small. Fisher's exact test is more accurate than the chi-square test of independence when the expected numbers are small.

Food consumption in the present resource-guide refers to an estimate of the quantity and/or variety of a food or group of foods consumed by an individual, household or a specific population.

Food composition table provides detailed information on the nutrient values of foods – energy, macronutrients (energy, protein, carbohydrates) and micronutrients (vitamins and minerals). Nutrient values are usually expressed in terms of the nutrient content of the edible portion of the food per 100g.

G

Goldberg cut-off is used to identify dietary underreporting and is based on the principle that an individual of a given age, sex and body weight requires a minimum energy intake. The cut-offs can be used at both the individual and group levels.

M

Measurement error is the difference between the true value of a parameter and the value obtained from reporting e.g. dietary intake.

Misreporting in self-report dietary assessment is considered to be unavoidable and can include both under and over reporting.

P

Physical activity level (PAL) is a way to express a person's daily physical activity as a number, and is used to estimate a person's total energy expenditure. In combination with the basal metabolic rate, it can be used to compute the amount of food energy a person needs to consume in order to maintain a particular lifestyle.

R

Random error is a type of measurement error that contributes to variability (reduces precision) but does not influence the sample mean or median. It generates a deviation from the correct results due to chance alone.

Regression is a statistical measure that attempts to determine the strength of the relationship between one dependent variable (usually denoted by Y) and a series of other changing variables known as independent variables (usually denoted by X).

Reliability is a quality of the measurements relating to a technical aspect of measurement noting the ability to accurately measure the real change or achievement in a consistent and comparable manner over time and space.

Reproducibility assesses the degree to which a method provides similar results when used repeatedly (on two or more occasions) in the exact same situation.

S

Sensitivity in dietary assessment (also called the true positive rate) measures the proportion of positives that are correctly identified as such (e.g. the percentage of sick people who are correctly identified as having the condition).

Specificity in dietary assessment (also called the true negative rate) measures the proportion of negatives that are correctly identified as such (e.g. the percentage of healthy people who are correctly identified as not having the condition).

Statistical significance refers to the likelihood that a difference or relationship exists or if it is caused by a mere random chance. Statistical hypothesis tests (e.g. Chi Square, t-test, ANOVA) are traditionally employed to determine if a result is statistically significant or not. Most authors refer to statistically significant as $P<0.05$ and statistically highly significant as $P<0.001$ (less than one in a thousand chance of being wrong).

Systematic error (also known as bias) is a type of measurement error in which measurements consistently depart from the true value, in the same direction. Systematic error affects the sample mean and can result in incorrect estimates and conclusions.

T

Total energy expenditure refers to the energy spent, on average, in a 24-hour period by an individual or a group of individuals. Total energy expenditure consists of three components: Basal Metabolic Rate (typically 60–75 percent of total energy expenditure), the thermic effect of food (10 percent), and energy expenditure due to physical activity (15–30 percent).

True intake is the actual intake, which usually cannot be measured among free-living individuals.

T-test is a statistical analysis to test the difference of two populations means that are normally distributed. Commonly applied with small sample sizes, testing the difference between the samples when the variances of two normal distributions are not known.

U

Usual intake is the long-term average daily intake, taking into account both consumption days and non-consumption days.

V

Validity assesses the accuracy of self-report instruments in measuring true intakes.

W

Wilcoxon Signed Rank test is a nonparametric test that compares two paired groups. The test essentially calculates the difference between each set of pairs and analyses these differences. It can be used as an alternative to the t-test when the population data does not follow a normal distribution.

Within-person variation (also known as day-to-day variation) is the difference between assessing a variable or variables collected via a single administration of an instrument, compared with a long-term average based on multiple administrations of the instrument.

EXECUTIVE SUMMARY

The present resource guide provides a comprehensible insight into dietary assessment, and into the challenges and considerations linked to the selection of the most appropriate method. The guide has been developed to provide assistance in the collection of dietary information, to be used to inform a number of programmatic decisions, as well as policy formulation, and to address diet-disease relations. The guide first provides a conceptual background of different dietary assessment methods, highlighting both indirect and direct (prospective and retrospective) methods, and providing a description of their application, validity, strengths and limitations. The guide also provides tips and methodological considerations to take into account during method selection and implementation, along with examples of forms and questionnaires used in previous studies. Lastly, the guide addresses technical and financial considerations, and looks at key factors to be taken into account prior to the selection of a direct dietary assessment method, such as the importance of identifying the study objective and selecting the appropriate study design. This is followed by a step-by-step guide to facilitate the selection of a dietary method along with a summary of the major features of direct methods. Throughout the guide, a special effort is made to include evidence from low resource settings when describing the accuracy, reproducibility, validity and applications of the methods.

The purpose of the resource guide is to facilitate and improve the quality and accuracy of nutrition information collected. The need for this improvement is reflected in international calls for the incorporation of robust nutrition data into national information systems (e.g. ICN2). Selecting the most appropriate dietary assessment method for a given purpose will in turn help generate better evidence for formulating effective nutrition projects, policies and programmes. This resource guide is written for professionals who play a role in the selection of the dietary assessment method for use in regional or national dietary and nutrition surveys, programmes and monitoring frameworks. These professionals may be programme managers, educators, health care professionals (including dietitians, nutritionists and health promotion specialists), students and extension workers. The information presented in the resource guide is intended to be used to direct and help steer the decision on the selection of the most adequate dietary assessment method according to the study objectives, population's characteristics and available resources, and should not be used as a tool to provide all the answers for the selection process. References for further reading have been included to supplement the guide and provide more advanced information for those who would like to go beyond the scope of this publication.

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1 INTRODUCTION

Strengthening and sustaining the capacity of countries to incorporate robust nutrition indicators into their information systems would help to generate better evidence for formulating effective agricultural and nutrition policies. The need for such robust information was recently reaffirmed at the Second International Conference on Nutrition (ICN2), jointly organized by the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO) in November 2014. More specifically, as stated in one of the outcome documents from ICN2 (The Rome Declaration):

"Nutrition data and indicators, as well as the capacity of, and support to all countries, especially developing countries, for data collection and analysis, need to be improved in order to contribute to more effective nutrition surveillance, policy-making and accountability[2]."

The Nutrition Assessment and Scientific Advice Group (ESNA), a branch of the Nutrition and Food Systems Division of FAO, plays an active role in providing technical support to countries in collecting food and dietary information. This support is often provided within a framework of generating evidence-based policies, implementing ICN2-related follow-up activities, and ensuring government accountability. In order to produce better evidence for formulating effective nutrition projects, policies and programmes, the most appropriate dietary assessment method first needs to be selected. This resource guide has been developed with the purpose of providing a comprehensible review on dietary assessment methods based on the latest research and development and the challenges and considerations that are linked to the selection of the most appropriate dietary assessment method, specifically focusing on low resource setting areas.

Ultimately, the guide can be used as a resource to:

- Strengthen the decision-making process for professionals when used as part of an informed process of selecting the most appropriate dietary assessment method for their particular study, and to provide a resource for those who want a review on the topic.
- Gain a better understanding on the specific challenges and needs that professionals face in

[2] Paragraph 13g, Rome Declaration on Nutrition, www.fao.org/3/a-ml542e.pdf (Accessed 23 October 2015)

low resource setting areas when they need to assess the diet of individuals and populations, such as the availability of food composition tables, estimation of portion sizes, seasonality, and the characteristics of specific populations and geographical locations.

- Complement other sources of information – such as information generated from needs assessment exercises, scientific expertise and local knowledge and experience – that influence the selection of the final method for measuring food and nutrient intakes for a given purpose.
- Direct users to ask appropriate questions that will lead to the selection of a method that properly considers data needs and the purpose of the study. In so doing, users will need to understand that compromises and more resourceful approaches are needed, especially when working in low resource settings, in order to select methods that take into account, resources required and resources actually available, culturally specific issues, time and human resources available for data collection and analysis, issues pertaining to portion size estimation and the availability of food composition tables.

The guide addresses the fundamental aspects involved in the selection of a dietary assessment method and data collection process. It also highlights the selection of methods for specific programmatic needs by providing a number of examples. It therefore aims to support, not dictate, the selection of a dietary assessment method, by being part of the informed decision-making process that results in a well-thought-out selection. The key objectives of the resource guide are:

- to provide users with practical guidance on available dietary assessment methods and to enhance users' understanding of their key features, strengths and limitations;
- to describe the main methodological considerations involved in dietary assessment, specifically in low resource settings[3];
- to outline and elaborate on the main sources of measurement errors and bias, and to explain why they occur;
- to explain and demonstrate – with a specific focus on low resource settings – the possible consequences of overlooking measurement and methodological considerations during data collection, analysis and interpretation, and their impact on overall data quality.

[3] This refers to settings with limited capacity and resources to perform nutritional assessment.

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2 DIETARY ASSESSMENT METHODS

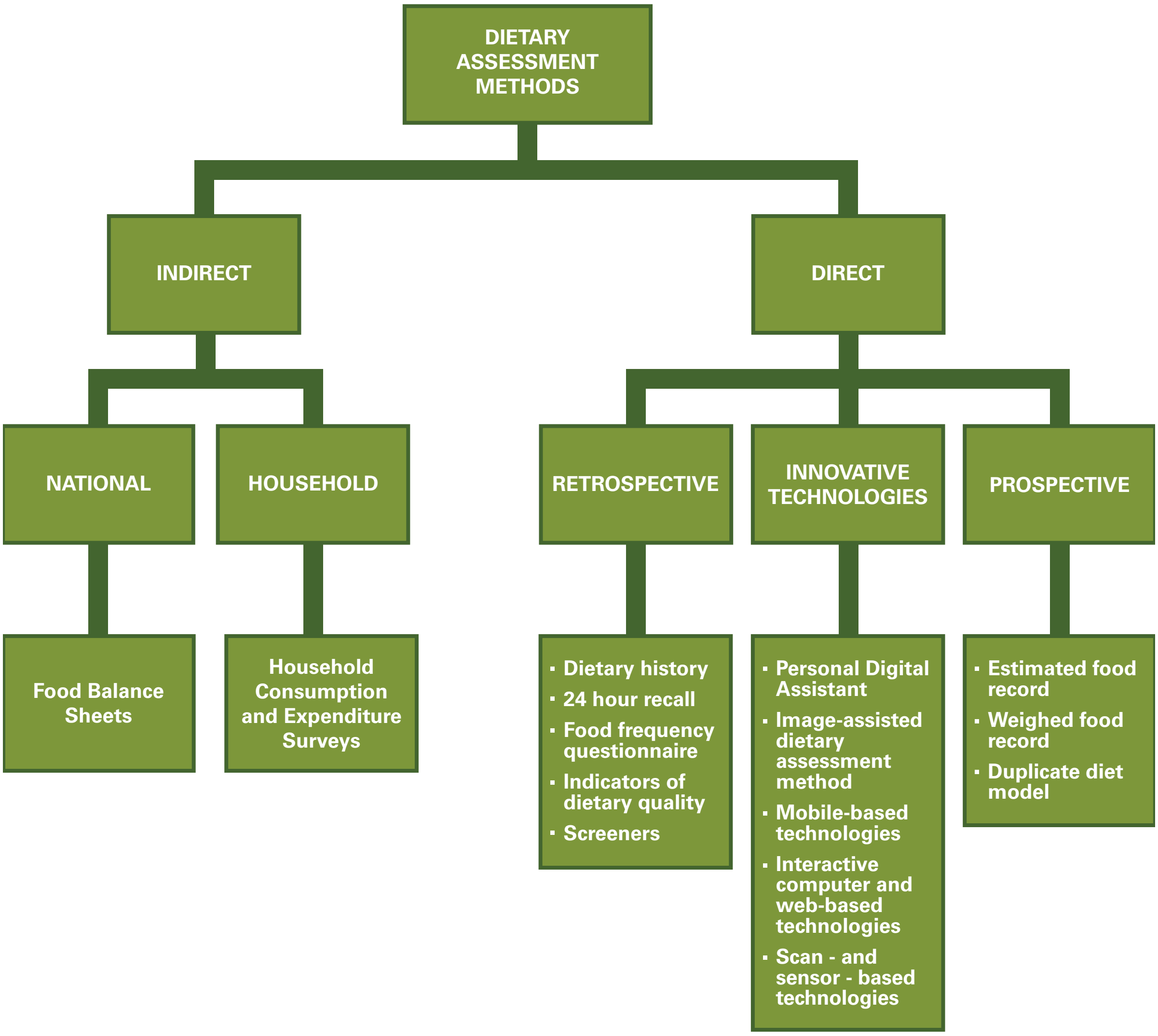
Dietary assessment is an evaluation of food and nutrient intake and dietary pattern of an individual or individuals in the household or population group over time. It is one of the four approaches in nutrition assessment to evaluating the nutritional status of individuals comprehensively. The other three are anthropometrics, biochemical parameters and clinical examination (Gibson, 2005). Dietary assessment methods are usually categorized according to the nature of the method used as shown in Figure 1. Indirect methods utilize secondary data for assessing diets, while direct methods collect primary dietary data from individuals. Prospective and retrospective methods refer to the time food consumption is recorded. Prospective methods involve recording the diet when the foods are being consumed; retrospective methods are based on a recall of food intake that have already been consumed. Furthermore, dietary assessment can be qualitative (types of food consumed) or quantitative (types and amounts of food consumed). The latter allows estimation of an individual's food, energy and nutrient intakes. Selection of an appropriate method for dietary assessment depends on the purposes of the study, which may be to measure food consumption, nutrient intake or eating habits.

2.1 INDIRECT METHODS

Indirect methods use secondary information (e.g. food supply, agricultural statistics, food expenditure) to estimate food available for consumption at the national and household levels. Firstly, we will look at the Food Balance Sheet (FBS)[4], which provides food consumption information at national level: food consumption is estimated from the point of view of food supply. Secondly, we will discuss about the Household Consumption and Expenditure Survey (HCES), which provide food consumption information *at household level:* food consumption is estimated from the point of view of food demand. Neither of the two methods directly obtain primary dietary data from individuals to evaluate dietary intake or food consumption on an individual basis. Indirect methods are useful for identifying trends in food availability and consumption across different geographical regions and time.

[4] Others terms that relate to FBSs include: "national food accounts", "supply/utilization accounts", "food disappearance data", and "food consumption level estimates". These terms reflect different methods of calculating food availability.

Figure 1 - *Overview of dietary assessment methods to estimate food and nutrient consumption at national, household and individual level*



2.1.1 FOOD BALANCE SHEETS – NATIONAL FOOD AVAILABILITY

FBS are compiled by FAO annually and are mainly based on country-level data covering a calendar year. They are used to assess national food availability for consumption. Using these data and the available information on seeds, waste coefficients, stock changes and types of utilization, a supply/utilization account is prepared for each commodity in weight terms. Besides commodity-by-commodity information, the FAO FBS[5] also provide total food availability estimates by aggregating the food component of all commodities including fishery products (FAO, 2001; FAO, 2015). The data are conventionally presented per capita, by adjusting for population size, e.g. available amount of food/energy/nutrients per person per day. More specifically, FBS present a comprehensive picture of a country's food supply over time. However, FBS provide little information on the variability of food

[5] http://www.fao.org/faostat/en/#home

intake of individuals within a population. The FBS list food items, i.e. primary food commodities and a number of processed food commodities potentially available for human consumption, including their sources of supply and utilization.

Online FBS data are compiled by FAO annually for approximately 185 countries and for a total of around 100 food commodity groups worldwide that may potentially be available for human consumption in the country. Gross national food supply in a given reference period of a country is calculated from the total quantity of food produced plus the total quantity imported, adjusted for changes at national food stock levels and exports. Net food availability is calculated by subtracting the amounts used for animal feed, seeds, industrial or other purposes and losses in the supply chain. This net value is then divided by the country's population estimate to obtain a final figure describing the availability of food commodities, expressed as kilograms per capita per year. This per capita information can also be linked to food composition data and presented as per capita energy intake (kilocalories per day), protein intake (grams per day) and fat intake (grams per day).

2.1.1.1 Applications and uses of FBS

The FAO FBS are widely used in the food and agriculture sectors to monitor global food patterns and dietary habits. This monitoring also includes trends and changes in overall national food availability, and the adequacy of a country's supply to meet nutritional requirements. Currently, the FAO FBS only provide data on annual per capita consumption of energy, protein and fat, while they do not provide data on micronutrients. FBS have also been used to set public health priorities, formulate policies, undertake intercountry comparisons, and estimate the likelihood of micronutrient deficiencies. For example, FBS data was used to identify the probability of micronutrient deficits in food supply per capita for 17 countries in the Western Pacific (Gibson *et al*., 2012). Additionally, FBS were employed to estimate the global prevalence of inadequate zinc intake (Wessells *et al*., 2012), and to examine the impact of improved nutrient supply on meeting a population's micronutrient needs etc. (Arsenault *et al*., 2015). Furthermore, (Naska *et al*., 2009) national FBS data has been used to examine the correlation with mortality statistics. More recently, FBS have been utilized in formative research to examine the nutrition transition (Mattei *et al*., 2015). Other studies have employed FBS data to analyse variation in adherence to the Mediterranean diet between 1961–1965 and 2000–2003 (da Silva *et al*., 2009). However, the actual distribution of food consumed among individuals in the population of a country as categorized by socio-economic status, age, or gender cannot be determined by using FBS.

2.1.1.2 Accuracy of FBS

The accuracy of FBS relies on the underlying accuracy and reliability of the statistics that the FBS are based on. These statistics are mostly derived from the official primary commodity production data and the primary and derived commodities trade data. Some adjustments may be required before the data can be used by FBSs. The extent to which the basic data have properly reflected the reality needs to be cross-checked with factors such as food losses and waste and unrecorded trades across national boundaries, etc. Literature on the accuracy of FBS estimates are scarce, and the available literature often focuses on the differences in the trends of food supply and availability over time. Serra-Majem *et al*. (2003) undertook a comparative analysis that evaluated three types of nutrition surveys: the FBS, the Household Budget Survey (HBS) and the individual dietary survey. They analysed inter- and intra-country comparisons of data for different stages of the food chain in Canada, Finland, Poland and Spain. It was concluded that FBS overestimated the energy, alcohol and fat intake of individuals, and the percentage of energy derived from fat (except in Poland), when compared with individual dietary surveys. FBS estimates were found to have exceeded those from the nationally representative dietary survey data collected in the Global Dietary Database (GDD) for most food groups, namely fruit, vegetables, whole grains, red and processed meat, fish and seafood, and milk, as well as total energy intake, while beans, legumes, nuts and seeds were underestimated. The differences were significant (P<0.05) ranging from 54 percent for total energy intake to 270 percent for whole grain intake (Del Gobbo *et al.*, 2015). In low resource countries, the reliability of FBS data may be further limited by the quality and representativeness of the national primary statistics, and under-reporting of food available through home grown food, hunting and gathering, non-commercial production, etc.

2.1.1.3 Strengths and limitations of FBS

The following table will provide a summary of the strengths and limitations associated with conducting an FBS.

Table 1 - *Strengths and limitations of using FBS data for assessing diets*

STRENGTHS	LIMITATIONS
• Inexpensive source of indirect nutrition data, standardized, accessible by all, relatively simple to analyse	• Cannot provide disaggregated information across different population characteristics, e.g. socio-economic, demographic etc.
• Include nearly all countries worldwide	• Estimates are derived from primary and/or basic country statistics which themselves may be subject to methodological errors
• Monitor global nutrition patterns and dietary habits, including trends and changes in overall national food availability	• Do not provide data on seasonal variations in the food supply
	• Do not provide data on foods not included in national production statistics such as game, wild animals and insects, and non-commercial or subsistence production
	• Do not provide individual-based dietary estimates
	• Statistics may be subject to incomplete or unreliable estimates of the total population in a given country
	• Food waste (domestic and retail), processed foods, home grown food production and food from non-retail sources are not accounted for
	• Time lag between data collection and availability on FAOSTAT (FAO Statistics Division)

2.1.2 HOUSEHOLD CONSUMPTION AND EXPENDITURE SURVEYS – HOUSEHOLD FOOD CONSUMPTION

Household food consumption has been defined as "the total amount of food available for consumption in the household, generally excluding food eaten away from the home unless taken from home" (Putnam *et al*., 1994). There is a wide range of multipurpose household surveys, such as the Household Budget Survey (HBS), the Living Costs and Food Survey (LCFS), the Household Income and Expenditure Survey (HIES), the Living Standards Measurement Study (LSMS), the Household Expenditure Survey (HES) and the Integrated Household Survey (IHS) – that measure food consumption or its proxies, are collectively known as HCESs. The central statistical offices in countries are usually responsible for data collection. Household members keep records on all expenses and type of foods consumed during a specific time period, usually one to four weeks, and preferably evenly distributed during different times in the year, which is then provided to enumerators. The collected data are analysed and used to assess food consumption at household level. Surveys of this type are routinely undertaken in many countries to provide information for the calculation of consumer price indices, to study household living conditions and analyse trends in poverty and income distribution (Moltedo *et al*., 2014). In some low resource settings, information generated from these surveys is the only form of food consumption data that can also be used to calculate estimates of nutrient intake. These estimates are calculated by multiplying the average food consumption data by the corresponding nutrient values for the edible portion of the food. Data on nutrient values are obtained from food composition tables (Gibson, 2005). However, household surveys do not provide information on the distribution of food consumption between family members, cooking methods or food losses. These surveys are often performed for economic reasons rather than for nutrition or health reasons.

Fiedler *et al*. (2012) provide a comprehensive review on the availability and characteristics of HCES, indicating that currently there are more than 700 published surveys. These surveys differ in terms of the nature and level of detail by country, and cover over one million households in 116 low- and middle-income countries[6]. The key findings of the review are as follows:

- The designs of the surveys were not harmonized or standardized, meaning that they differed in key characteristics such as questions used in the questionnaire, coverage, frequency, sample size and statistical accuracy[7].
- Routine information was collected including household composition, housing characteristics, income, assets, wealth and livelihood, as well as personal information such as age, sex and education. Information on food consumption was mainly collected via recalls and occasionally via diaries. The latter was reported to be a more accurate but also a more expensive method of data collection.
- The list of food items in HCES questionnaires varied in length and composition.
- All surveys asked whether a food item was purchased, homemade, received as a form of 'salary', or received from friends, relatives or a social programme.

[6] See also http://blog.usaid.gov/2014/03/the-power-of-household-consumption-and-expenditure-surveys-hces-to-inform-evidence-based-nutrition-interventions-and-policies/ (Accessed 1 December 2016)

[7] The International Household Survey Network (IHSN) provides a number of resources on HCES. It aims to improve the availability, accessibility, and quality of survey data within developing countries and to encourage the analysis and use of this data by national and international development decision-makers, the research community and other stakeholders. See: http: // www.ihsn.org/home/ (Accessed 23 October 2015)

- Some surveys captured both food quantities and costs, while others captured costs only.
- A majority of the surveys overlapped data on food acquisition and consumption, which can result in overestimating consumption.
- The surveys presented clarifications regarding food stocks, as well as information on the quality of the food composition tables (in some cases food composition information was absent, outdated or available only for a limited number of foods).

2.1.2.1 Applications and uses of HCES

HCES are recognized as an inexpensive and more readily available alternative for tracking food consumption patterns when compared to individual-based methods. HCES have been used by FAO for global monitoring of food security, e.g. for Target 1c of the Millennium Development Goal 1 ("Halve, between 1990 and 2015, the proportion of people who suffer from hunger") and the similar goal set in 1996 by the World Food Summit. Information on food consumption at the household level allows the derivation of variability parameters such as the coefficient of variation of food consumption which are used to estimate undernourishment (FAO/IFAD/WFP, 2015). Estimation of undernourishment is often conducted in partnership with national and regional institutions, in conjunction with capacity development activities.

To support the use of household surveys, FAO, in collaboration with the World Bank, developed the Food Security module of the ADePT software (ADePT-FSM)[8]. The software allows streamlined and consistent food security statistics to be estimated using HCES data (Moltedo *et al.*, 2014). Food security indicators are derived at national and subnational levels, by population groups, by food commodity groups and by food items, using standardized files as inputs. Examples of such indicators include inequality levels in calorie consumption, as well as consumption levels of macronutrients, micronutrients and amino acids. The wider acceptance of data gathered from HCES received a further boost via the formulation, implementation and evaluation of nutritional policies across Europe with the development of the Data Food Networking[9] (DAFNE) initiative. The DAFNE databank is based on information collected as part of the HCES which are periodically conducted in various EU countries. A significant achievement of this project is the development of a common classification system for food variables and socio-demographic variables in national HCES, allowing inter-country comparisons. Elsewhere, HCES[10] data have been used to assess household dietary intakes in relation to nutrition transition in Cape Verde (Dop *et al.*, 2012), and to estimate food consumption and micronutrient intakes (vitamin A, iron, zinc) in Bangladesh, thereby identifying population subgroups at risk of inadequate micronutrient intakes (Bermudez *et al.*, 2012).

2.1.2.2 Accuracy of HCES

Smith *et al.* (2007) examined the reliability and relevance of HCES data, including 100 household surveys from low and middle income countries. They concluded that nearly all surveys were appropriate when the aim was to measure the percentage of households purchasing and consuming individual foods. However, for estimating the quantities of individual foods consumed and assessing micronutrient insufficiencies it was shown that this data was useful in less than 10 percent of surveys, mainly

[8] http://www.fao.org/economic/ess/ess-fs/fs-methods/adept-fsn/en/ (Accessed 23 October 2015)

[9] http://www.nut.uoa.gr/dafneENG.html (Accessed 23 October 2015)

[10] Smith and Subandoro (2007) have produced a detailed guide for practitioners in assessing food security status in the population using HES.

because of issues related to units of measurement and the estimation of food consumed away from home. The authors appraised the reliability of the surveys in terms of how they addressed different areas of investigation: the recall period for home-bound food data collection; how food acquisition was analysed; completeness of enumeration; comprehensiveness and specificity of the home-bound food list; the quality of data collected on food consumed away from home and how seasonality in food consumption was accounted for. Recommendations to improve reliability focused on three criteria which were not met by approximately half of the surveys, i.e. seasonality, out-of-home eating and specificity of survey food lists. In Uganda, Jariseta *et al.* (2012) compared estimates of nutrient densities in the diet of women and children by HCES and by a 24-hour recall. Nutrient densities were calculated as the nutrient contents per 2 000 kcal of edible portion of food consumed (nutrient content divided by energy intake). The authors found no significant differences between the medians of energy intake in 7 out of the 14 nutrient densities (i.e. protein, fat, fibre, iron, thiamin, riboflavin, and vitamin B6) estimated by the HCES and 24-hour recall ($P<0.05$). They concluded that HCES estimates were close proxies for 24-hour recall measures of nutrient density. Whereas HCES may be less precise than individual dietary assessment methods, the relative low costs have made HCES an attractive tool for decision-makers to inform national policies and identify areas where nutritional interventions are needed.

2.1.2.3 Strengths and limitations of HCESs

The following table will provide a summary of the strengths and limitations associated with conducting a HCES.

Table 2 - *Strengths and limitations of using HCES data for assessing diets*

STRENGTHS	LIMITATIONS
• Inexpensive source of nutrition data since they are also collected for purposes other than nutrition, standardized, accessible to all and relatively simple to analyse, if the design of the questionnaire is appropriate	• Limits the ability of the respondent to report completely (via recall or record) all foods consumed by the household. Good training of enumerators and careful questionnaire design could help to alleviate this limitation
• Routinely conducted in a number of countries on sample populations that are nationally representative of the national demographic	• Units used to report food quantity are non-standardized
• Collect information on socio- economic and demographic characteristics of the head of household. This type of survey also enables investigation of subnational variations in consumption patterns, which can be invaluable in designing nutrition programmes	• Food wasted or food given away is not accounted for: consumption may be overestimated
• Statistically representative at the national level, and usually also at the subnational level	• Food eaten away from home is not always accounted for: consumption may be underestimated

STRENGTHS	LIMITATIONS
• Comprehensive, as they contain detailed household food consumption information that allows direct observation of the agriculture and nutrition nexus, through markets, value chains, and other pathways	• Leads to misrecording and/or misreporting of important foods when using a predetermined list of food items
• Information collected enables examination of trends and changes in overall national food availability and consumption	• The size of the household may be different from the number of people who actually consumed the food over the reference period
	• Does not collect information on individual food consumption or on the distribution of foods among household members
	• In the case of acquisitions surveys, food that is stocked up for an extended period of time remains unaccounted for
	• Nutrient estimates are dependent on the quality of the food composition table.

2.2 DIRECT METHODS

Direct methods using individual-based dietary assessment can be classified into two groups, as described in Figure 1. Retrospective methods measure food intake from the past. These methods include 24-hour recall, food frequency questionnaires (FFQ), and dietary history. Prospective methods assess current food intake. These methods include food records and the duplicate meal method. Estimates obtained from direct methods are used to identify trends in food consumption, food and nutrient intakes, eating patterns, and to evaluate diet–disease associations. Information provided by such methods can also be used to calculate relevant food-based indicators for monitoring and evaluation purposes. This section will describe dietary assessment methods used in individual-based surveys, and analyse their application, focusing mainly on low resource settings, and will also cover the issues of precision and accuracy.

2.2.1 RETROSPECTIVE DIRECT METHODS

Retrospective methods collect information on foods and beverages already consumed. Among the retrospective methods are the FFQ, 24-hour recalls and diet histories. These methods greatly depend on the memory of the respondent and their ability to recall all foods and portion sizes consumed over a reference period of time. Quantities of foods consumed can be obtained by food models, pictures of foods, standard household measuring cups, spoons, etc.

2.2.1.1 Food frequency questionnaire

FFQs assesses the frequency with which foods and/or food groups are eaten over a certain time period. The questionnaire includes a food list (usually close-ended) and a frequency category section, and can be self- or interviewer-administered. Appendix 1 gives an example questionnaire. Depending on the study objectives, data collection might be daily, weekly, monthly or yearly. Furthermore, FFQs can include information about portion sizes and/or quantity of food intake. These types of questionnaires are known as semi-quantitative, i.e. general portion sizes are described and quantified, or specific portion sizes are recalled and supported by food pictures for each item on the food list. By including portion size as part of frequency, the questionnaire allows for the estimation of food quantities eaten and of nutrient intakes. FFQs can either be developed from basic principles or adapted from existing questionnaires (Cade *et al.*, 2002). In the first case, important decisions and considerations are needed in developing the food list. Several key considerations include:

- Foods selected should encapsulate the objectives of the assessment, e.g. to measure intake of only a few foods and nutrients, or to undertake a comprehensive dietary assessment (Willett *et al.*, 2013).
- Whether to rank individuals' consumption or provide a measure of absolute nutrient intakes.
- It is often preferred to put together a comprehensive list of foods and/or of food groups to allow for energy adjustments. Aggregating foods into food groups can be used as a technique to capture specific nutrient(s) or non-nutrient(s) when these nutrients are confined to a relatively small number of foods (Gibson, 2005). However, aggregation of foods into small groups may lead to underestimation of intakes, whereas larger food groupings can lead to overestimation of intakes. Aggregating food can further lead to over counting due to difficulties in reporting combined frequency for a particular food eaten both alone and/or in mixed dishes (Cade *et al.*, 2002).
- The choice of foods in a list is partly data driven and partly a question of scientific judgment (Patterson *et al.*, 2004). Selected foods can be used to capture the major sources of energy and/or nutrients consumed by the study population, variability in food intake between persons, and of course the study objectives.
- The list of foods in the FFQ cannot be infinite as it could potentially increase the burden on the respondent. Therefore an *a priori* decision should be taken on the foods to be included, their frequency of consumption in the studied population, their cultural importance and their relative value as a specific nutrient source.

Methods for selecting food items to be incorporated into a FFQ food list may range from information obtained from previous dietary assessment reports to focus group discussions and pilot 24-hour recalls.

- A review of the literature can be used to help select the appropriate food items to include in the FFQ. This approach consists of a detailed revision of available dietary data of the target population. Data on the past dietary surveys, cultural beliefs and food choices are reviewed in order to select and confirm foods and food categories to be included in the FFQ. In a cross-sectional study designed to capture diet patterns in women in Micronesia, ethnographic data was used to develop a structured 7-day FFQ (Corsi *et al.*, 2008).
- Focus groups should consist of individuals selected randomly from the target population and be representative of the population. Individuals are asked to identify through discussions the commonly-eaten foods in the area, along with information on ingredients used, food preparation methods, the seasonal-variable of foods and culturally-specific dishes. Later on, the groups can hold an open discussion and agree on the relevant food list to construct for the FFQ questionnaire. For example, 19 focus groups were used to generate data for the FFQ development in Botswana (Jackson *et al.*, 2013). Focus group discussions were organized by home economists together with agricultural demonstrators in each region.
- 24-hour recall (for more information on 24-hour recall, see section 2.2.1.2) can be used as a tool for selecting the appropriate food

items to be included in the FFQ. This approach was used in a study conducted in Colombia, where a random subsample of 100 individuals representative of the target population were asked to record their food intake using a single 24-hour recall. The FFQ was then developed based on the most frequently reported food items, excluding foods that had a low frequency of consumption (Dehghan *et al*., 2012).

Questionnaires can be modified versions of existing one. However, caution should be employed in assessing the original purpose and validity of the parent FFQ: for example, for whom it was written, when it was developed, whether it had been previously validated etc. (Cade *et al*., 2002).

2.2.1.1.1 Applications and uses of FFQs

There is a plethora of FFQs available, and they continue to be developed or adapted for different purposes. FFQs are commonly used in large epidemiological studies (Willett *et al*., 2013) to capture data on dietary intakes and patterns (Corsi *et al*., 2008; Merchant *et al*., 2005), to assess diet–disease associations (Liu *et al*., 2001; McCullough *et al*., 2002) and to calculate correlations or relative risks (Hutanasu *et al*., 2009). FFQs can also be used to assess seasonal dietary patterns (Campbell *et al*., 2014). However, there is an ongoing debate on the use of FFQs in assessing diet, with some authors questioning the validity of results obtained from studies where FFQs were applied (Kristal *et al*., 2005). Others argue that the value of FFQs in epidemiological applications has been documented objectively by correlations with biochemical indicators (Willett *et al*., 2007). The FFQ is a time-effective method that is easy to administer and provides a simple data entry procedure. However, FFQs have limited sensitivity to changes in food supply and are not suitable for people with a wide variation in dietary intake patterns (Gibson, 2005). As an example, a semi-quantitative FFQ was used to investigate intakes of major carotenoids and tocopherols in Costa Rican adolescents. The authors suggested that when assessing the diet of adolescents it is important to ask about specific portion sizes, and to support the questions with food pictures or household measures (Irwig *et al*., 2002).

FFQs have also been used to measure year-round and seasonal dietary patterns in a large sample of rural Nepalese women (n=15 899) (Campbell *et al*., 2014). The respondents were asked to report on the frequency of foods consumed over the previous year, using day, week and month as the unit of measure for the frequency of intake. The study revealed that intakes of vegetables, fruits and animal-source foods were infrequent in certain seasons and especially among poorer members of the rural population. The authors noted that the study design could have been improved by including local farmers and resident focus groups for information on seasonal foods. In a study in Micronesia, where an FFQ was used to capture diet patterns in adult women, the authors highlighted the importance of training interviewers on accurate data collection and ensuring a good understanding of local culture and customs (Corsi *et al*., 2008).

2.2.1.1.2 Reproducibility and validity of FFQs

Methods used to validate FFQs include multiple 24-hour recalls, food records (both weighed and estimated) and biomarkers. Special attention is required to ensure that measurement days captured by the records or recalls reflect the time frame covered by the FFQ, since some FFQ time frames can cover up to one year (Willett *et al*., 2013). Though a weighed food record is the preferred validation method, it is not error free. A weighed food record is more valid and precise than 24-hour recall to validate FFQ. (see section 3.7 & 3.8: 'reproducibility and validity in dietary assessment'). However, when the study participants are illiterate, the use of multiple 24-hour recalls is more appropriate than a weighed food record, despite the weaker correlations because both FFQ and 24-hour recall rely on memory and estimation of portion size. Listed below are a number of factors related to FFQ development that could influence validity (Cade *et al.*, 2002):

- The number of food items in the list. This is partly determined by the population characteristics and study objectives.
- The order of the food list, e.g. items of particular interest should be placed at the beginning of the questionnaire.
- The frequency and portion size responses. These should be close-ended rather than open-ended, to minimize errors in coding and transcription.
- The time frame of the recall period.
- The mode of administration.
- Data entry and computation once the survey is complete.

The reproducibility and validity of a 124-item FFQ in assessing habitual nutrient intake of Malay adolescents were validated against a non-consecutive three day 24-hour recall (Nurul-Fadhilah *et al.*, 2012). For reproducibility, the correlation coefficients for energy-adjusted nutrient intakes between the two FFQ administrations ranged from 0.43 (carotene) to 0.86 (fat), indicating a good reproducibility. For validity, correlation coefficients between energy-adjusted nutrient intakes between the methods ranged from 0.22 (zinc) to 0.68 (calcium), indicating a moderate to good agreement between the two assessment methods. In both cases the correlations were weaker for micronutrients than for macronutrients.

In a study conducted in Botswana, Jackson *et al.* (2013) tested the reproducibility and validity of a quantitative 122-item FFQ – repeated after one year – by comparing nutrient and food group intakes against four non-consecutive 24-hour recalls, covering a time frame of one year. For reproducibility, correlation coefficients for energy-adjusted nutrients ranged from 0.39 (retinol) to 0.66 (vitamin E), indicating good reproducibility. Good validity in estimating most food and nutrient intakes was observed, except for iron, retinol, β-carotene and related food groups (i.e. fruits, dark green leafy vegetables and yellow vegetables). The authors suggested that this could be attributed to the seasonal availability of fruits and vegetables leading to substantial fluctuations in estimated intakes (Jackson *et al.*, 2013).

Kabagambe *et al.* (2001) assessed the reproducibility and validity of a 135–item FFQ in Costa Rican adults using seven 24-hour recalls, plasma samples (for assessment of tecopherol and carotenoid) and adipose tissue samples (for assessment of tocopherol, carotenoid and fatty acid intake). For the reproducibility study – where the administration of the FFQs was 12 months apart – correlation coefficients ranged from 0.33 to 0.77, indicating good to high reproducibility. In the validity analysis, the FFQ gave higher values of energy and nutrient intakes compared with those obtained by the recalls for all nutrients studied, except for vitamin K, iron and caffeine. The authors concluded that FFQ was a valid and reproducible tool to measure the diet of adults. They suggested that biomarkers should be used to complement the FFQ rather than substitute for it, as biomarkers did not perform better than the FFQ in this study. The study furthermore, showed that biomarkers did not give a better result than the FFQ (Kabagambe *et al.*, 2001).

In another study, the reproducibility and validity of a self-administered 130-item FFQ was assessed against biomarkers in urine (nitrogen, potassium, and sodium) and blood (plasma ascorbic acid), and compared to a 7-day food record. For validity, the correlation between urinary potassium and dietary potassium from the FFQ was 0.33 and from the food record was 0.53. The authors concluded that food record (see sections 2.2.2.1 and 2.2.2.2 for additional information on food records) provides a better estimates of nutrient intakes than the FFQ (McKeown *et al.*, 2001).

2.2.1.1.3 Strengths and limitations of FFQ

The following table will provide a summary of the strengths and limitations associated with conducting an FFQ.

Table 3 - *Strengths and limitations of FFQ*

STRENGTHS	LIMITATIONS
• Assess the usual intake over a long period of time.	• The food list cannot cover all the foods consumed by the respondent, which may lead to underreporting.
• Can be used to capture a range of foods, specific nutrient(s) (quantitative FFQ) or a specific food group, including rarely consumed food items.	• Does not give precise information on the estimated portion size consumed.
• Can capture portion size estimates (semi and quantitative FFQ), details about cooking and preparation methods.	• Requires respondents who are literate and have numeracy skills (if self-reported).
• An open section added to the end of the questionnaire can allow for addition of foods consumed that are not present in the food list.	• Self-administered FFQs can lead to misinterpretation of questions and the omission of food items that are not understood by the respondent.
• Since it is a retrospective method, it does not affect eating behaviour.	• Questionnaires need to be adapted and validated to reflect the study population and purpose. This may require a considerable amount of time and resources.
• Low respondent burden.	• Not suitable for a population where people have distinctly different dietary patterns.
• Relatively simple to administer and inexpensive when compared with other assessment methods (i.e. 24-hours recall, dietary records).	• Relies heavily on memory; therefore, declined cognitive ability can result in errors when reporting on frequency and portion size estimation.
• Interview-based FFQ questionnaire does not rely on the literacy and numeracy skills of the respondent.	• Misreporting arises when reporting combined frequencies for a particular food eaten both alone and in mixed dishes.
• Can also be self-administered via mail or internet.	
• Appropriate for large studies as it can be administered using a machine-scannable format, reducing data-entry errors.	

BOX 1. QUICK GUIDE TO USING AN FFQ

Project objectives and budget determine the study design and sample size

- √ Who is the population of interest?
- √ Do you want to collect information on specific nutrient(s), foods, food groups or the overall diets?
- √ What is the objective of the data collection, e.g. to rank respondents from low to high intakes, or to provide a measure of estimated intake?

Define the target population (elderly, children, adolescents etc.), literacy level, and cognitive ability

Frequency categories in the FFQ: times per day, times per week, times per month, rarely, never etc.

Developing a survey protocol

- √ Adapted to local cultural context, e.g. meal patterns, shared dishes, non-standard eating and serving tools.
- √ A validation exercise can be applied to test the efficiency of the protocol.

Identifying sources of information

- √ Information on foods consumed by a population can be obtained from national or regional survey data, databases, or from undertaking a focus group discussion with the target population.

Development of a food list and assigning food codes

- √ Foods selected should represent those commonly consumed by the target population and the food list should be in line with the study objectives.

Adapting an existing food list

- √ If a similar FFQ already exists, it can be used in its original form or modified/adapted by adding or replacing foods with items more commonly consumed in the target population, or by adapting the food list to target a specific nutrient. However, changes to an FFQ will require a validation study.
- √ Update the database as required to include all the food components of interest.

Assessing the need for portion size estimation (non-quantitative, semi-quantitative or quantitative)

- √ Determining if the FFQ should collect quantitative information on food intake would depend on the objectives of the study, age of respondents, homogeneity of the target population, standard units available, and the type of information to be collected.

Estimation of portion size (semi-quantitative or quantitative FFQ)

- ✓ Using food models, photographs or household measures to help estimate portion size.

Supplementary questions (about cooking methods, brand names, etc.)

Open ended section

- ✓ Respondents may record consumption of other foods that are not included in the close-ended food list.

Mode and time of administration

- ✓ Self-administered using paper or web-based formats, or interviewer administered via face-to-face or telephone interview.
- ✓ To account for seasonality, the survey can be administered at different times of the year (different foods may be available for consumption during different seasons).

Method used for recording (e.g. pen and paper, scannable format)

Length of FFQ

- ✓ To reduce respondent fatigue and reporting error, FFQ length should not be too drawn out and food items should be carefully selected.
- ✓ Increase the number of foods included in a FFQ and at the same time keep the length of the questionnaire short by grouping together items based on food classification or nutrient similarity.

Reference period for the FFQ: e.g. previous weeks, months, etc. Bear in mind that FFQ may not be suitable for recalling diet in the distant past (e.g. the previous year)

Availability of a food composition database

- ✓ Ensure that a food composition database is available which is up-to-date and complete, and includes locally available foods.

BOX 2. BRIEF DIETARY ASSESSMENT

For some assessment situation, a full-length FFQ questionnaire is not practical. Therefore, brief dietary instruments, sometimes referred to as screeners or short dietary instruments, can be employed in these circumstances. Screeners are used to measure the frequency of consumption without including information on portion size or dietary behaviour, via self- or interviewer-administered modes (Perez Rodrigo *et al.*, 2015). They are modified versions of longer FFQs varying in length, frequency categories and number of foods listed. An example is presented in Appendix 2. Consequently, screeners are used in situations when there is no need for comprehensive assessment. They are also used for surveillance, to screen individuals for inclusion in intervention or clinical trials, to identify and separate large numbers of individuals into groups or to distinguish individuals with low or high intakes. Depending on the specific objective of the assessment, brief dietary instruments can be referred to by different names. Instruments that assess specific nutrient and/or food group intakes are often called targeted instruments, and those that assess both dietary and non-dietary components are called brief multifactor instruments (Perez Rodrigo *et al.*, 2015; Thompson *et al.*, 2013).

Brief dietary instruments have further been demonstrated to be useful in low resource settings, specifically, by field workers with limited training in conducting large dietary assessments. Examples of these instruments include the Rapid Rural Appraisal (RRA) and Participatory Rural Appraisal (PRA), developed by Chambers (1994). These instruments are used to rapidly identify key risk factors for malnutrition or inadequate consumption patterns for specific food groups and allow for immediate action to take place (Perez Rodrigo *et al.*, 2015). Screeners have additionally been used to measure diet–disease association, as shown in a study by Jilcott *et al.* (2007). Women from impoverished and resource limited settings in the United States were asked to undertake a brief dietary instrument which included 54 questions on foods commonly eaten in the region. The results were used to provide guidance for dietary counselling.

Additionally, validation of brief dietary instruments have been conducted comparing the method with 24-hour recall. For example, this comparison was examined by Yaroch *et al.* (2012), where the performance of a 16-item screener used in a US adult population to assess fruit and vegetable intake, was compared to multiple 24-hour recalls. A Pearson correlation coefficient for the screener compared to the 24-hour recalls was low (r=0.37). The authors concluded that while dietary screeners are a less burdensome and cost-effective method for collecting information on fruit and vegetable intake, it is not recommended to use when trying to measure precise intake levels but rather to be used to obtain overall estimates, and/or to rank individuals with regard to intake levels of a particular food group.

2.2.1.2 24-hour recall

During a 24-hour recall, respondents (i.e. adults, children and their parents or caretakers) are asked, by a nutritionist or dietitian who has been trained in interviewing techniques, to recall and report all foods and beverages consumed over the preceding 24 hours. The 24-hour period starts with the first thing eaten by the respondent in the morning until the last food item consumed before he/she got up the next morning. Thus, the method assesses the actual intake of individuals. However, a single 24-hour recall is not enough to describe an individual's usual intake of food and nutrients. To achieve this objective, multiple non-consecutive 24-hour recalls on the same individual are required in order to capture daily variability (Baranowski, 2013; Gibson, 2005; Patterson *et al.*, 2004). Additionally, multiple day data collection can be used as a comparison method to validate an FFQ. Multiple 24-hour recalls can increase quality control, minimizing errors and maximizing reliability. Further information on the number of recalls required to estimate intakes can be found in section 3.1.

Information on 24-hour recall is collected using an open-ended format. Quantitative information on food intake, as described using portion size, allows for the calculation of energy and nutrient intakes (please refer to Appendix 3 for an example of a 24-hour recall form). Estimation of portion size is facilitated by the use of measurement aids such as standard household measures, photo atlases, food models, etc. To calculate energy and nutrient intakes, the estimated portion size or the amount of food intake is multiplied by the values of nutrient content in foods as found in the food composition tables or databases (for more information on food composition tables, refer to section 3.5).

As 24-hour recall is dependent on memory and cognitive functions, it can be challenging to study in young children (under the age of eight years), or in elderly and institutionalized groups. In these cases, proxy/surrogate reporters can be used to provide additional assistance during the interview. However, it should be highlighted that the use of surrogate reporters can also introduce error, especially if the respondent is under the care of multiple caregivers. The interview(s) can take place either face-to-face, by telephone, or via a self-administered computer-assisted 24-hour recall version. The latter relies on literacy and an internet connection. It is crucial that interviewers are well trained in order to gather precise, detailed and accurate information to reduce error and bias. They should be familiar with the dietary patterns of the respondents, have a list of foods commonly eaten by the target population and be familiar with composite dishes, their recipes and preparation methods, and be aware of how food is served. Lastly, they should have training on how to use standard probes and prompts properly, how to measure portion size, particularly for mixed dishes, and how to ask questions in a non-judgmental and non-influential manner during the recall.

The importance of using a standardized interview structure such as the 'multiple pass approach' has been found useful (Gibson, 2005). Currently, the United States Department of Agriculture (USDA) computerized Automated Multiple-Pass Method[11] (AMPM) uses this approach to collect dietary data in the National Health and Nutrition Examination Survey, either in person or by telephone. This approach employs five steps. **Step 1:** 'quick list' (a list of foods and beverages consumed during the previous 24 hours is collected); **step 2:** 'forgotten foods' (probes for foods possibly forgotten during step 1); **step 3:** 'time & occasion' (time and occasion for each food is collected); **step 4:** 'detail cycle' (detailed description, amount, and additions for each food is collected); and **step 5:**

[11] http://www.ars.usda.gov/News/docs.htm?docid=7710 (Accessed 1 December 2016)

'final probe' (probes for anything else consumed in the previous 24 h) (Blanton *et al.*, 2006).

2.2.1.2.1 Applications and uses of 24-hour recall

Depending on the number of days recorded, 24-hour recalls can be used to measure different outcomes. When a study aims to determine the mean intakes for a group or population, a single 24-hour recall per respondent can be carried out, especially when the sample size is sufficiently large. On the other hand, when the objective is to estimate the distribution of intakes, or to examine usual diets and correlations of individual intakes, more than one recall day per respondent is required.

A cross-sectional study examining rural Kenyan adults used two non-consecutive 24-hour recalls to investigate dietary patterns. The quantitative recall attempted to ensure reliable measurements of food and nutrient intakes by using local household measures, local food models and food composition tables (Hansen *et al.*, 2011). Due to the cross-sectional nature of the study, the authors noted that a major limitation was the inability to measure the impact of seasonal variation when assessing dietary patterns.

A non-consecutive two-day 24-hour recall has also been used to monitor household diet adequacy during three different seasons in rural Mozambique (Rose *et al.*, 2003). The decision to use 24-hour recall was related to the simple and inexpensive nature of the method when compared to other assessment methods, such as dietary history and food record. Furthermore, the authors found that conducting multiple 24-hour recalls at different times of the year was useful in accounting for seasonal variation in dietary intakes. Albuquerque *et al.* (2015) used non-consecutive three-day 24-hour recalls to evaluate the association between stature and total energy expenditure of low-income women in Brazil. Portion size was estimated by trained nutritionists with the aid of a photographic atlas.

24-hour recalls have been used in a number of other studies, including: a quasi-experimental complementary feeding intervention in Lombok, Indonesia (Fahmida *et al.*, 2015); a nutrition assessment in three specific regions of Ecuador (Sanchez-Llaguno *et al.*, 2013); a study measuring intakes of young children living in an impoverished South African setting (van Stuijvenberg *et al.*, 2015); and a study examining the impact of water intervention on beverage substitution in a randomized trial of overweight and obese Mexican women (Hernández-Cordero *et al.*, 2015). In summary, 24-hour recall has been used to assess the total dietary intake both of individuals and populations, and to examine the relationship between diet, health and other variables.

2.2.1.2.2 Reproducibility and validity of 24-hour recall

There are a number of issues to be considered when undertaking a reproducibility study for a 24-hour recall. These considerations include, but are not limited to, the following factors:

- Using non-consecutive days when conducting multiple 24-hour recalls is recommended since eating habits from consecutive days have been shown to be correlated (Hartman *et al.*, 1990);
- The effect of seasonality on the diet and changes in food availability should be taken into account;
- In repeated 24-hour recalls, action should be taken to avoid the first recall influencing the collection of data from the subsequent recall;
- Rankin *et al.* (2012) determined the reproducibility of two- to five-day repeated 24-hour recalls among urban African adolescents. This study was used to identify the optimum number of 24-hour recalls that need to be conducted in order to give the best reproducibility result. Their findings showed that conducting four or five recalls ensured higher reproducibility when compared to repeating the recall only two or three times.

There are a variety of issues to be considered when addressing the validity of 24-hour recalls. These considerations include, but are not limited to:

- The individual's accuracy in recalling or recording their consumption and estimating portion sizes;
- The comprehensiveness of the food composition tables to capture all foods available for the study;
- Types of foods frequently forgotten or overlooked, e.g. butter and salad dressing;
- Understanding that respondents are prone to over-reporting low intakes and under-reporting high intakes. This pattern is referred to as 'flat slope syndrome' (Baranowski, 2013).

It has been suggested that for the validation of 24-hour dietary recalls, the use of dietary histories or 7-day weighed records is not appropriate, due to differences in the time frame of the recall period and the potential for increasing the burden on the respondent. A single weighed food record may be considered as an alternative validation method (Gibson, 2005). A number of studies have reported good agreement between the methods of 24-hour recall and one day weighed record with trained observers and biomarkers (Thompson *et al.*, 2013).

Estimates from a multiple-pass interactive 24-hour recall in rural Ethiopian women have been compared with estimates from weighed food records (Alemayehu *et al.*, 2011). Their results showed that the median daily intakes of energy and most nutrients obtained were lower when measured by 24-hour recall than by weighed food record ($P<0.05$). Furthermore negative bias for energy and nutrient intake were confirmed by Bland–Altman plots. The authors concluded that the two methods were not comparable in this setting: a result which could be attributed to the poor portion size estimation. Thus, extra attention must be devoted to the selection of the aids and tools used to estimate portion size.

In another study, a 24-hour recall to assess the diets of Kenyan children, using mothers as proxies, was validated against a weighed food record (Gewa *et al.*, 2009). Energy intake was underestimated by approximately 6 percent by the mothers and 9 percent by the children. It was stated that further improvements were needed to allow for more accurate recalls to be collected, and to help increase recall of foods that typically go under-reported, namely, sugars, fruits, dairy products and meats. The authors remarked that assessing intakes in large-scale studies might not be feasible until improvements have been made.

Biomarkers have also been used to validate 24-hour recall. Scagliusi *et al.* (2006) conducted a study measuring the level of underreporting of energy intakes in a female Brazilian population, using the doubly-labelled water (DLW) method to validate a 3-day multiple pass 24-hour recall. The authors concluded that the energy intake measured by the multiple-pass 24-hour recalls presented a significant difference compared to energy expenditure measured by doubly-labelled water ($p<0.0001$). Therefore, 24-hour recall was shown to underestimate energy intake. The authors noted that the outcome of the study could be related to the methodological approach, i.e. number of recall days, portion size estimation, measurement aids and food composition tables.

2.2.1.2.3 Strengths and limitations of 24-hour recall

The following table will provide a summary of the strengths and limitations associated with conducting a 24-hour recall.

Table 4 - *Strengths and limitations of 24-hour recall*

STRENGTHS	LIMITATIONS
• Assesses the usual intakes of a large population (provided that the sample population is representative and the days of the week are adequately represented)	• Needs multi-day recalls to adequately represent the habitual intake of individuals and to take into account seasonality differences.
• Captures information on eating patterns, preparation methods, place of consumption, etc.	• Relies on respondent's memory.
• The mode of administration does not affect food choice and eating pattern.	• Requires well-trained interviewers with knowledge of cultural practices, eating habits, local recipes and preparation methods.
• Open-ended format used is appropriate for all eating patterns.	• Expensive due to the fact that extensive training is needed for the interviewers and the time spent on data entry and food matching with food composition data.
• Recalls intakes over the last 24-hours, therefore there is less burden on the respondents' memory, leading to better accuracy and response rates.	• Recall bias may be present, as respondents can be selective with the foods they choose to report during the recall.
• Interview-based 24-hour recall does not rely on the literacy and numeracy skills of the respondent.	• Relies on respondent's literacy and ability to describe the food and to estimate its portion size (self-reported 24-hour recall).

BOX 3. QUICK GUIDE TO USING A 24-HOUR RECALL

Project objectives and budget will determine the study design and sample size. It is important to

- √ Understand the characteristics of the target population.
- √ Define the purpose and research questions of the study.

Requires trained nutritionists and dietitians to conduct this form of assessment

Target population group

- √ Characteristics: population groups (e.g. toddlers, pregnant women, elderly, etc.), age, literacy level, numeracy skills and cognitive abilities of the respondents assessed will have an impact on the mode of administration used.

- ✓ Parents can act as a proxy for children less than eight years old and can assist older children.
- ✓ Surrogate reporters can be used as proxies for the elderly if there is evidence of cognitive decline. Note that this increases the chances of error, particularly if the individual is under the care of multiple caregivers during the day.

Food intake and meal patterns. It is important to

- ✓ Understand the food intake and meal patterns of the target population group and also identify specific subgroups of the population (e.g. shift workers, pregnant and lactating women) who may have different meal patterns.

Mixed diets (composite diets). It is important to

- ✓ Understand local recipes, identify and record all ingredients consumed and have a strong appreciation of how to measure portion sizes of mixed dishes. For more information on recording mixed dishes, readers are referred to Gibson *et al*. (2008) pp. 47 to 67 on recording mixed dishes.

Information on dietary supplements (e.g. vitamins, minerals)

Mode of administration

- ✓ Face-to-face interview, computer-assisted recall or telephone administered recall.
- ✓ The researcher should explain to the participants that the goal of this interview is to record everything that the participant ate (meals and snacks) the day before, starting with the first thing eaten by the respondent in the morning until the last food item consumed before he/she got up the next morning.

Method used for recording information (e.g. pen and paper, scannable format)

Number of recorded days

- ✓ Selecting the number of days that will allow for an appropriate estimation of an individual's usual intake.
- ✓ A single 24-hour recall does not represent an individual's usual diet (hence multiple days are needed), nor does it take into account daily, weekly or seasonal variations of an individual's food intake.
- ✓ The time frame for a 24-hour cycle needs to be defined using reference points applicable to the target population (e.g. first food/drink consumed after waking up in the morning to the last food/drink consumed before going to sleep at night).

Days selected for conducting the assessment (weekday vs. weekend)

- ✓ Non-consecutive days are preferable, helping to capture more of the variability in an individual's diet.

- √ Including one weekend day in a week is desirable, to capture variability of food intakes during weekends.

Knowledge and skills of the interviewer. Interviewers should

- √ Receive training on conducting a 24-hour recall with standardized procedures, including practice interviews prior to the start of the study.
- √ Know how to probe the respondent using standardized and non-leading questions that are specific to the food consumption patterns of the target population.
- √ Ideally have knowledge of local foods, eating patterns, food preparation methods and the specific cultural practices of the study population.

Conducting a pilot study

- √ Select subjects and geographic sites that are representative of the actual target population for the pilot study.
- √ Identify any logistical and/or technical problems in the pilot study in order to fine-tune the survey procedures and to identify problems that may occur in the interviews prior to the actual survey, such as discrepancies in interview protocol, recalling and recording of composite dishes and food matching with food composition data.

Estimating portion sizes

- √ Using food models, photographs (photographic atlas) or standard household measures to help estimate portion sizes and food intake.
- √ For liquids (e.g. soups or beverages), record quantities as volumes, preferably using the respondents' own household utensils after these have been calibrated.
- √ Conversion factors or a food composition database are required to convert household measures to weight equivalents (Gibson, 2005).

It is necessary to have access to a food composition database which is up to date, complete and includes locally available foods as much as possible for nutrient estimation

- √ Refer to sections 3.4 and 3.5 'Estimation of portion sizes' and 'Availability of food composition data'.

Assessing validity and reproducibility

Procedures to minimize errors

- √ Train interviewers prior to the recall to become familiar with the dietary patterns of the study population.
- √ Create a standardized interview protocol.
- √ Calibrate utensils in the home and use standardized methods for portion size estimates.

- ✓ Use effective probes/prompts to reduce respondent memory lapses.
- ✓ Utilize multiple-pass interviewing techniques.

Reviewing the recall data

- ✓ Check and identify errors in the dietary data with the respondent during the interview. This should be conducted at the same time as the interview in order to ensure the most accurate information is obtained and to limit missing data.

2.2.1.3 Dietary history

Dietary history is a detailed assessment to describe usual food intake and its variation over a long period of time (six months to a year). The original dietary history designed by Burke in 1947 consisted of three parts (Biro *et al.*, 2002; Gibson, 2005):

- an in-depth interview to assess usual food intake and eating patterns;
- a food list;
- a three-day record with portion size estimates used as cross-checks.

Burke used the dietary history method to assess dietary intake. During an interview, the respondent was asked about their usual eating patterns at meal times and in between meals. Food consumed was recorded in common household measures. Questions like "What do you usually eat for breakfast?" were followed by further questioning to include daily variations until a full picture of food variety was obtained for breakfast. The portion size of food was also recorded in its real food size (i.e. a big, medium or small apple) or by using household measures. The interview continued in this way until a comprehensive collection of different kinds of food and their variations was recorded. The dietary history record was subsequently cross checked with a list of food groups, where the respondent was asked the frequency and quantity of a food that was consumed over a specific period of time (Burke, 1947).

The original method by Burke (1947) was however, considered impractical because it relied heavily on trained staff to perform the interviews and to code and enter the data. Modified versions of dietary history have since been developed and used to assess individual food intakes and meal patterns over a predefined period of time. The main difference between these variants and Burke's original design is that the three-day record is often disregarded. Additionally, computerized versions have been developed to simplify the process, which can be self- or interviewer-administered. However this can still lead to high levels of respondent burden, usually associated with the long duration of conducting dietary histories (Gibson, 2005). When carrying out a three-part dietary history a trained nutritionist is needed to perform the interviews. Please find an example of a dietary history in Appendix 4.

2.2.1.3.1 Applications and uses of dietary history

Dietary histories were originally developed for clinical use, e.g. dietetic counselling, and are not often used in low resource settings, because they require well trained nutritionists with experience in dietary assessment. Computerized dietary history questionnaires, such as the Dietary Interview Software for Health Examination Studies (DISHES 98), have been shown to be useful in assessing dietary intakes and help to reduce the average interview and coding time.

DISHES 98 was used in the German National Health Interview and Examination Survey of 1998. It was designed to assess the usual dietary intake over a 4-week period in a subsample of an adult and elderly German population (Mensink *et al.*, 2001). Dietary history has also been used to study the relationship between early growth and diets and its link to the development of obesity and hyperlipidaemia in Hong Kong children. The dietary assessment was carried out by trained research dietitians to estimate portion size by using standard household measures such as bowls, cups and spoons to indicate the amounts consumed (Leung *et al.*, 2000). The Coronary Artery Risk Development in Young Adults (CARDIA) study employed an interviewer-administered dietary history to collect reliable quantitative data on the intake of young adults from the United States of America (Carnethon *et al.*, 2004). The assessment included a short questionnaire on general dietary practices, an FFQ on the usual intake of foods during the last month, and lastly a follow-up on the portion size and frequency of consumption of each food item selected. The data gathered by the researchers resulted in the collection of detailed information on the habitual eating habits and patterns (McDonald *et al.*, 1991). Dietary histories have also been used to determine the relationship between dietary patterns and tooth decay in a low-income African-American population. The dietary history revealed a high level of sugar and fat intake, with a low level of fruit and vegetable consumption in the study group that contributed to an increased incidence of tooth decay (Lim *et al.*, 2008).

2.2.1.3.2 Reproducibility and validity of dietary history

Compared to other assessment methods, there are a limited number of studies in validating dietary history as it is often used as a reference method to validate other methods of dietary assessments, e.g. 24-hour recall and FFQ (Thompson *et al.*, 2013). A validation study by Mensink *et al*. (2001), compared the results from the computerized version of dietary history, DISHES 98, with results from a 3-day weighed dietary record and 24-hour recall. This study, described above in *Application and uses of diet history*, provides a good example of how the dietary history method has been validated. For most nutrients measured, the mean intakes recorded by DISHES 98 were lower than those measured by the 3-day weighed food records with an average Pearson's correlation coefficient of 0.51. A similar outcome was noted by the authors when the results from DISHES 98 were compared with a 24-hour recall, presenting an average Pearson's correlation coefficient of 0.46. The similarity observed could be due to the tendency of 24 hour-recall and dietary history to be influenced by similar error sources, since they both rely on the memory of the respondent. The authors concluded that the validity of DISHES 98 was deemed comparable to those of other dietary histories and the method was valid for assessing dietary intake (Mensink *et al.*, 2001).

Comparison of results between dietary history and biomarkers have also been demonstrated. Hagfors *et al*. (2005) conducted a validation study to compare the results of a dietary history to estimate energy, protein, sodium and potassium intakes against bio-markers. Protein, sodium and potassium estimates were compared with respective markers from a 24-hour urine sample and good agreement was observed (r=0.58). Overall, the authors noted that dietary history methods are adequate in assessing dietary intake, however, due to the small sample size of the study, (n=32), results could not be generalized.

The validity of the dietary history questionnaire was also tested against biomarkers to measure urinary excretion of nitrogen and plasma levels of carotenes, vitamin E and vitamin C. The subjects were adult males and females from the Spanish arm of the European Prospective Investigation into Cancer and Nutrition (EPIC) study. The correlation coefficient between the dietary history questionnaire and nitrogen excretion was 0.58. The validation revealed that the correlation between the questionnaire and the plasma levels of vitamin C, β-carotene and carotenoids, and dietary intake, were 0.46, 0.33 and 0.42 respectively. From these results, the authors concluded that the dietary history method is able to provide reliable information on usual intake of the nutrients measured in the study (Gonzalez, 1997).

2.2.1.3.3 Strengths and limitations of dietary history

The following table will provide a summary of the strengths and limitations associated with conducting a dietary history.

Table 5 - *Strengths and limitations of dietary history method*

STRENGTHS	LIMITATIONS
• Provides details of meal patterns, individual foods consumed and usual food intake after completing a single interview	• Relies on respondent's memory, can lead to recall bias
• Provides quantitative estimates of energy and nutrient intakes	• Labour-intensive, time-consuming, may not be suitable for young children and elderly respondents
• Useful to describe usual food or nutrient intake over a relatively long period of time. It can be used to estimate prevalence of inadequate diets	• To obtain detailed information on food intake, longer interview times are needed, resulting in high respondent burden
• Does not rely on the literacy of the respondent	• Portion size estimation of past meals can be difficult, even with the use of aids
• Provides information on foods that are not regularly consumed	• Requires trained personnel with knowledge of local food culture and eating patterns (inter-view-based dietary history)
• Does not interfere with normal eating habits	• Requires literate respondents with the ability to estimate portion size (self-administered dietary history)
	• Expensive to administer
	• Data entry and coding is time consuming and requires trained personnel

BOX 4. QUICK GUIDE TO USING A DIETARY HISTORY METHOD

Project objectives and budget determine the study design and sample size

- ✓ Understanding the specific target population, and the purpose and guidelines for the study.

Population characteristics

- ✓ Age (e.g. toddlers, adolescence, elderly, etc.), pregnant/lactating, literacy level and cognitive abilities of the respondents will have an impact on the mode of administration.

Food and meal patterns

- ✓ Understanding the food and meal patterns of the target population and identifying specific subgroups of the population who may have different meal patterns (e.g. shift workers, pregnant and lactating women).

Mixed diets (composite diets)

- ✓ It is important to have an understanding of local recipes and to identify all ingredients consumed.

Information on dietary supplements (e.g. vitamins, minerals)

Mode of administration

- ✓ Face-to-face with an interviewer or computer-administered (interviewer-based or self-administered).

Length of assessment

- ✓ To reduce respondent fatigue and over-reporting, interview length should be kept short.

Reference period for the interview, e.g. previous weeks or months. Keep in mind that recalling diets from the distant past (e.g. previous year) may result in recall bias

Recording method

- ✓ Use of food models, photographs and/or standard household measures.
- ✓ Brand names, a complete description of the method of preparation and cooking, and the recipes for composite dishes should all be recorded.

Capacity of the dietary assessment coordinator

- ✓ A trained nutritionist is needed to conduct the interview.

- √ The nutritionist should have experience in gathering detailed information on the consumption of food and drink, and information related to the respondents' food habits, e.g. food allergies, seasonal variations and dietetic preferences, etc.
- √ They should know how to probe the respondent using standardized and non-leading questions.
- √ The dietitian or nutritionist needs knowledge of local foods (including brands), preparation methods, recipes and portion size. For more information, readers are referred to Gibson *et al*., (2008) on recording mixed dishes.

Availability of a food composition database

- √ Ensure a complete and up-to-date food composition database is available which also includes locally available foods.

For practical tips on how to conduct an FFQ, see Box 1: 'Quick guide to using an FFQ'. For practical tips on how to conduct a three-day food record for verification, see Boxes 5 and 6: 'Quick guide to using an estimated food record', and 'Quick guide to using a weighed food record'.

2.2.2 PROSPECTIVE DIRECT METHODS

In the prospective methods, diet, including all food and beverages consumed, is recorded at the time of consumption, therefore allowing for current food intake to be recorded. These methods include a weighed food record, an estimated food record and a duplicate meal method. Prospective methods can be more labour intensive depending on the objectives of the study (i.e. the weighed food record and duplicate meal method) than retrospective methods and rely heavily on respondents having good literacy and numeracy skills.

2.2.2.1 Estimated food records

When conducting an estimated food record, respondents are instructed to document all foods and beverages consumed during a predefined period (e.g. 1 to 7 days). The number of days included in the assessment depends on the purpose of the study (Gibson, 2005). If the objective is to collect information on an average intake of a population group, then one record day will suffice. However, if the purpose of the assessment is to obtain habitual intakes for individual respondents, then more than one day is needed, including one weekend day (Gibson, 2005). During the record period, specific details such as brand names, time of day the food or beverage was consumed, the location and sometimes a description of the occasion should be documented as well. Estimation of the food portion or food weight consumed is normally aided by using standardized household measures, food photographs or models (please refer to Appendix 5 for an example of an estimate food record form). Furthermore, food recording taking place during meal time should take place simultaneously in order to minimize reporting errors due to fading memory. Prior to data collection, respondents are often provided training and practice on recording, in order to become familiar with the steps of the assessment, especially for foods eaten outside the home. Moreover, ways to record food preparation, cooking methods and mixed dishes will also be covered prior to starting the assessment method. Complete instructions should be given to the participants prior to the start of the project in an effort to minimize errors. In cases where respondents cannot record their consumption, trained interviews, parents, family members and/or caregivers might provide assistance to record intake. To ensure that data collection is accurate, a home visit by trained interviewers on the first day of recording is helpful. In addition to home visits, at the end of the recording period, skilled interviewers should go through the records, clarify the entries, and ask the respondent for any omitted items. After data collection is completed, calculation of nutrient intake is done using a food composition database.

2.2.2.1.1 Applications and uses of estimated food records

Estimated food records are useful in assessing detailed food and nutrient intakes at individual level. A cross-sectional study on obese adolescents in Malaysia examined the role of diet and physical activity on adult morbidity and mortality (Rezali *et al.*, 2012). A self-reported 3-day estimated food record was applied, the respondents were trained on how to use the food record form and how to estimate portion size using standard household measures to assess all food and beverages consumed along with the descriptions of brands and methods of food preparation. The authors commented that a major limitation of the method was the self-reported nature of the study, which can result in under-reporting of dietary intake due to incomplete reporting of the type or frequency of foods and snacks consumed.

Furthermore, estimated food records have been used in large-scale monitoring studies, including the National Diet and Nutrition Survey (NDNS) and the National Survey of Infant and Young Children (DNSIYC) (Stephen *et al.*, 2013). The former is designed to assess the nutritional status of babies aged 18 months or more, living in private households in the UK, while the latter is a single survey of infants and young children throughout the UK. As part of the survey, a 4-day estimated food record – including two weekend days – was collected to replace a previously used repeated 24-hour recall. The decision for the replacement was based on the fact that energy intake was found to be similar for both methods when compared to DLW. 24-hour recall, however, showed more over-reporting in young children and respondents reported excess burden when conducting 24-hour recalls (Stephen *et al.*, 2013).

2.2.2.1.2 Reproducibility and validity of estimate food record

Methods used to validate estimated food records have included weighed food records and biomarkers. Chinnock (2006) validated a 3- and 4-day estimated food record against those obtained from a 7-day weighed food record in Costa Rican adults from both rural and urban areas. Interviewers visited the respondent's homes during meal preparation and consumption, and observed the weighing of ingredients, and recording of food intakes, as well as left-over food. Training of subjects on data collection was provided before the study. Energy and nearly half of the nutrient intakes were underestimated by the food records obtained. Correlation coefficients ranged from 0.68 for polyunsaturated fats to 0.87 for calcium, indicating good to high agreement. The authors concluded that the results were comparable with other similar studies (Bingham *et al.*, 1994; Bingham *et al.*, 1995; Bonifacj *et al.*, 1997). They supported the use of estimated food records in dietary surveys among Costa Rican adults and also noted that there was a greater difference between weighed and estimated food record estimates for energy in rural residents, where energy intake was underestimated by 312 Kcal. They speculated that subjects in rural areas underestimated the amount of rice and beans consumed. As a result, the authors recommended the use of additional aids in estimating intakes of these two specific foods in subjects living in rural areas (Chinnock, 2006).

Biomarkers have also been used to validate estimated food records. In the EPIC Norfolk cohort (described earlier in the dietary history section), the performance of a 7-day estimated food record was assessed against biomarkers of urine (nitrogen, potassium and sodium) and blood (plasma ascorbic acid). Reproducibility was also measured by comparing one 7-day food record with a second 7-day food record. Results of the reproducibility study did not show a significant difference ($p<0.001$). For validity, the average correlation coefficients between urinary nitrogen and dietary nitrogen were relatively high ($r=0.57$–0.67); between urinary potassium and dietary potassium they were good, ($r=0.51$–0.55); and between plasma ascorbic acid and dietary vitamin C they were more moderate ($r=0.40$–0.52). The authors concluded that the food record used in the study was a suitable method to estimate dietary intake (McKeown *et al.*, 2001).

2.2.2.1.3 Strengths and limitations of estimated food records

The following table will provide a summary of the strengths and limitations associated with conducting an estimated food record.

Table 6 - *Strengths and limitations of estimated food records*

STRENGTHS	LIMITATIONS
• Provides estimates of actual instead of usual diet. This is dependent on the number of measurement days	• Requires literate and motivated respondents with numeracy skills
• Open-ended format appropriate for all eating patterns	• In low-resource countries, a trained investigator/interviewer is required to collect data
• Provides a high level of specificity and details regarding foods consumed and occasion	• High cost for administration and data analysis
• Gives detailed information on eating patterns	• Time consuming and can result in a high level of respondent burden and lower cooperation
• Allows for the collection of information from respondents with sporadic eating habits	• Respondents may forget to record specific food items or whole meals
• Does not rely on respondent's memory, since information is recorded at the time of consumption	• Portion estimation can be difficult to compute if inadequate information is recorded by the respondent
• Allows for real time portion size estimation, reducing errors in the estimation of intake	• May interfere with normal eating habits
	• Reliability of records decreases over time, due to increased respondent burden
	• Missed or less accurately recorded food intake in children when foods are eaten when the child is not in the presence of parents or caregivers

STRENGTHS	LIMITATIONS
	• May not capture foods eaten less frequently • Data entry and coding can be time consuming and requires trained staff

BOX 5. QUICK GUIDE TO USING AN ESTIMATE FOOD RECORD

Project objectives and budget determine the design of the study and sample size

- ✓ Understanding the specific target population, purpose and guidelines for the study.

Population characteristics

- ✓ Age (e.g. toddlers, adolescence, elderly, etc.), pregnant/lactating, literacy level and cognitive abilities of the respondents assessed will have an impact on the mode of administration.

Mode of administration

- ✓ Can be completed by the respondent, parent or caretaker.
- ✓ Investigators are advised to conduct home visits during the study period to ensure proper recording procedures.

Number of recorded days

- ✓ Should be selected based on the objectives of the dietary assessment.
- ✓ A single-day food recording is not sufficient to capture a typical diet and does not take into account daily, weekly or seasonal variations in food intake.
- ✓ A standard 3–7 day food record is typically used. Recording periods of more than seven consecutive days can lead to respondent fatigue.
- ✓ Repeated food records conducted at different times of the year or in different seasons will give a better picture of habitual intake.

Days selected for conducting the assessment (weekday vs. weekend)

- ✓ Non-consecutive days are preferable to capture more of the variability in an individual's diet.
- ✓ Including one weekend day in a week is helpful in capturing variability of food intakes during weekends.

Recording methods

- ✓ Use of food models, photographs and/or standard household measurements (cups, tablespoons, etc.), supplemented with measurements using a ruler (e.g. meat and cake) and counts (e.g. bread slices).
- ✓ Food intake can be recorded at the time of consumption or using a portable recording device.
- ✓ Brand names, the method of food preparation and cooking, and recipes for composite dishes should all be recorded.

Capacity of the dietary assessment coordinator

- ✓ Trained dietitians or nutritionists with knowledge of local foods (including brands), preparation methods, recipes, food ingredients and portion size. For more information, readers are referred to Gibson and Ferguson, 1999, pp. 47-67, on recording mixed dishes.
- ✓ To check with the respondent to identify forgotten foods using standardized and non-leading questions.

Capacity of the respondent

- ✓ Understand the instructions for the study (supplied with an instruction booklet to be used during food recording period).
- ✓ Investigators provide training before the study for participants to practice food recording.

Availability of a food composition database

- ✓ Ensure a food composition database is available, up to date and complete, and includes locally available foods.

2.2.2.2 Weighed food records

The weighed food record is often regarded as the most precise method for estimating the food and nutrient intakes of individuals. This approach adopts the same methodological principles as the estimated food record method. However, in this method respondents are asked to weigh using weighing scales (e.g. a digital electronic scale with a tare button to facilitate food weighing). The subjects directly copy the weight of an individual food from the scale while conducting additive weighing without the necessity of manipulating figures, and thus avoiding errors (Marr, 1971). All food and beverages consumed are weighed and recorded, along with a description of portion size, brand names and details on food preparation (please refer to Appendix 5 for an example of a weighed food record form). Similar to the estimated food record, a predefined measurement period (between 1 to 7 days) needs to be set, where the number of days included in the assessment will depend on the purpose of the research question and again, weekend days should be included to account for changes in food intake during weekend days. To obtain even more precise data, leftovers can also be weighed or estimated. For studies requiring a very high level of accuracy it may be necessary to weigh and describe all raw ingredients separately before cooking, and this is especially important for mixed dishes (Gibson, 2005). For foods consumed away from home, the respondents are asked to provide a full description of the foods consumed, the occasion and location. Depending on the design of the study, respondents can be asked to weigh foods consumed outside the house, or the researchers will purchase the particular food from a shop or restaurant to weigh the described portion size at a later time. Prior to the recording period, the respondents should be provided with instructions for recording, with sufficient time for practicing and reminders about maintaining typical dietary habits during the recording period. Furthermore, sufficient supervision during the study is a prerequisite to obtain accurate and reliable data. Hence home visits are normally arranged during the study period to ascertain that the procedures are carried out properly (Bingham, 1987).

As with estimated food records, in cases where respondents are unable to record their own consumption, interviewers, parents, family members and/or caregivers might be required to weigh and record the food intake. To ensure the accuracy of data collection, home visits on the first day can be arranged to ascertain that procedures are carried out properly (Thompson *et al.*, 2013). It must also be noted that due to the increased respondent burden with the weighed food record, motivated individuals are needed to collect accurate data and avoid changes in usual eating patterns to simplify the measurement procedure. Once all the information from the weighed food record has been completed, food consumption data will need to be converted to nutrient intakes, which requires both a food composition database and an analysis programme.

2.2.2.2.1 Applications and uses of weighed food record

Weighed food records have been shown to be useful in collecting information for different purposes. This method has been used to collect data on group mean intakes, where a single record is sufficient, or to measure the distribution of individual intakes, where multiple record days are needed. The measurement of individual nutrient intakes has been shown in a study investigating pregnant subsistence farmers in rural Malawi using a 4-day weighed food record (Nyambose *et al.*, 2002). Enumerators living in the villages visited the homes of respondents during the study period, from the time they woke up until after the evening meal and weighed all food and beverages consumed. The raw ingredients of all dishes were weighed before cooking, followed by weighing the final cooked dish and the remaining uneaten foods. Furthermore, plates and cups were supplied to all participants to assist with food weighing. The data were subsequently entered into a nutrient analysis programme updated with additional locally consumed foods. The authors noted a large within-person variation in nutrient intakes, which poses a challenge for dietary assessment and suggests that additional replicate days are required to estimate the mean intake of individuals in subsistence farming.

In addition, weighed food records have also been used to assess micronutrient intakes for example, vitamin A, folate, iron and zinc among young children in Bangladesh. Trained nutritionists recorded all food and beverages consumed, recipe ingredients and preparation methods and any leftover foods over a 12-hour recording period (Arsenault *et al.*, 2013).

2.2.2.2.2 Reproducibility and validity of weighed food record

Reproducibility studies conducted on weighed food records have presented good agreement amongst group mean values for energy and the majority of nutrients. These results have been presented in a study by Willett *et al.* (1995), where the reproducibility of a 7-day weighed food record was tested, using Pearson's coefficient and interclass correlation coefficients. The authors showed that the interclass correlation coefficients were between 0.41 and 0.79, with the lower number referring to vitamin A. The study concluded that 7-day weighed food records are sufficient for providing reproducible results (Willett *et al.*, 1995). Weighed food records are considered the gold standard against which other dietary assessment methods are validated; therefore, their relative validity cannot be assessed via other direct assessments (Gibson, 2005). Duplicate meal methods (explained further in section 2.2.2.3) have instead been used as a reference method to validate weighed food records (Gibson *et al.*, 1982; Gibson *et al.*, 2015). A 1-day weighed record was compared with a duplicate meal composite collected on the same day from a group of rural Malawian women measuring iron intakes ($p<0.001$). The authors concluded that the intake levels calculated from food composition databases were underestimated since they did not take into account iron contamination in the soil, which the duplicate meal composite was able to capture. Furthermore, recovery biomarkers like the DLW method and urinary nitrogen excretion have also been used to validate energy and nutrient intakes. The validity of a 16-day weighed record to measure habitual food intake was compared against the 24-hour urine nitrogen technique in women aged 50–65 years in the UK. Correlation between dietary and urinary nitrogen estimates was 0.69. In addition, the relationship between weighed records and other potential biomarkers (i.e. potassium and vitamin C) showed relatively high correlation between 24-hour urine potassium excretion and dietary potassium intake ($r=0.73$), and between plasma vitamin C and dietary vitamin C ($r=0.86$), among others. The authors concluded that weighed food records provided an accurate estimate of energy and nutrient intakes (Bingham *et al.*, 1995).

2.2.2.2.3 Strengths and limitations of weighed food records

The following table will provide a summary of the strengths and limitations associated with conducting a weighed food record.

Table 7 - *Strengths and limitations of weighed food records*

STRENGTHS	LIMITATIONS
• Assess the actual or usual intakes of individuals, depending on the number of measurement days	• Requires literacy, motivated respondents with numeracy skills (if self-reported) to weigh out foods and record food intakes
• Is more accurate than other dietary assessment methods. It has been considered the gold-standard method for dietary assessment	• In communities with low literacy and numeracy, a trained field investigator is required to collect reliable data
• Does not rely on memory, since information is recorded at the time of consumption	• Time-consuming and labour-intensive for both respondent and researcher
• Provides exact portion sizes, and does not rely on estimation	• High level of respondent burden when compared to the other assessment methods
• Provides a high level of specificity and details regarding food consumed and meal patterns	• Respondents may alter eating habits to simplify the procedure due to study fatigue, especially if multiple days are recorded
• Provides information on foods eaten regularly	• Costly in both equipment and staff required to provide training and supervision
	• Errors resulting due to difficulties in weighing foods eaten away from home
	• Requires a suitable environment for weighing foods
	• May not capture foods eaten less frequently

BOX 6. QUICK GUIDE TO USING A WEIGHED FOOD RECORD

Project objectives and budget determine the study design and sample size

✓ Understanding the specific target population, purpose and guidelines for the study.

Population characteristics

✓ Age (e.g. toddlers, adolescence, elderly, etc.), pregnant/lactating, literacy level and cognitive abilities of the respondents will have an impact on the mode of administration.

✓ Characteristics (e.g. toddlers, pregnant women, elderly, etc.), age, literacy level and cognitive abilities of the respondents assessed will have an impact on the mode of administration.

Mode of administration

- ✓ Can be completed by respondent, parent or caregiver.
- ✓ Investigators are advised to conduct home visits during the study period to ensure proper recording and weighing procedures.

Number of weighing days

- ✓ Should be selected based on the objective of the dietary assessment.
- ✓ A single day food weighing is not sufficient to capture typical diet and does not take into account daily, weekly or seasonal variations of food intake.
- ✓ A 7-day weighing record period is historically most common. A period less than seven days may underestimate the daily variations, while a period greater than seven consecutive days can lead to respondent fatigue.
- ✓ Repeated food records conducted at different times of the year/season will give a better picture of habitual intake.

Weighed recording method

- ✓ A scale (typically a digital electronic scale with a tare button) to weigh all food, drinks and non-foods (e.g. water, dietary supplements, alcohol) at the time of consumption, using a record sheet or a digital audio recorder.
- ✓ Brand names, description of the cooking method and recipes for composite dishes should be recorded. Plate waste is weighed and recorded separately.

Capacity of the dietary assessment coordinator

- ✓ Trained dietitian or nutritionist with knowledge of local foods, preparation methods, recipes and portion size.
- ✓ Ability to check with the respondent to identify forgotten foods using standardized and non-leading questions.

Capacity of the respondent

- ✓ Understanding of the instructions for the study (respondents are supplied with an instruction booklet and visual demonstrations).
- ✓ Competency on how to use weighing scales correctly to measure food and drinks and record composite dishes (weighing of raw ingredients). For more information, readers are referred to Gibson and Ferguson, 1999, pp. 47-67, on recording mixed dishes.
- ✓ Receive instruction and hands-on training prior to the start of the study on how to properly weigh and record foods and drinks.
- ✓ A phone hotline should be made available to provide technical support for the respondents during the study period.

Availability of a food composition database

- √ Ensure that a food composition database is available, up-to-date and complete, and includes locally available foods.

2.2.2.3 Duplicate meal method

The duplicate meal method involves setting aside duplicate portions of all foods and beverages consumed throughout a specific time period. These retained duplicate portions are set aside, weighed, either by the respondent or fieldworker, and then sent to a laboratory for chemical analysis to determine nutrient content. During the assessment period, respondents also maintain a weighed food diary to record details of the foods and beverages consumed during the assessment period and provide information on portion size expressed in weights or household portions. The food diary can help to verify the comprehensiveness of collecting duplicate foods and accuracy of the portion sizes of the duplicate meal (Lightowler *et al.*, 1998). In some cases, such as the study by Hurst *et al.*, (2013), enumerators resided in the household during the study period to weigh and create duplicate samples of all beverages and food items consumed, which are then subject to chemical analysis to measure nutrient content. A comparison of nutrient intakes can be made between the values of analysed nutrients and the nutrient intake which is calculated based on the reported portion size and data from a food composition database.

2.2.2.3.1 Applications and uses of duplicate meal method

The duplicate meal method is often used in institutional and metabolic balance studies (where subjects do not control the portions selected) (Pennington, 2004), and is considered the best method for assessing trace element intake (Abdulla *et al.*, 1981). This approach is especially useful to assess the intakes of nutrients/contaminants without nutrient composition databases, and/or if the nutrients of interest are affected by soil concentrations, e.g. selenium, iodine and zinc. It is suitable for use in developing countries, especially for population groups with low literacy rates or in cases where a substantial portion of food is prepared at home. However, it is costly to purchase and prepare duplicate meals and to analyse nutrient contents by chemical analysis. Furthermore, it imposes a high burden on the respondent and is therefore unsuitable for large-scale studies. Examples of its application in a low resource setting area include a cross-sectional study investigating the risks of iron and zinc deficiency in women aged 15–50 years from six rural villages in Malawi (Siyame *et al.*, 2013). Trained research assistants collected a one-day weighed duplicate diet composite, along with recordings of the type of foods consumed. Diet composites were then transported to the laboratory for processing and analysis of trace elements. To help capture the variability of an individual's diet, weekdays and weekend days were proportionally represented. The authors described how the use of duplicate diet composites improved estimates of trace elements. However, due to the single day nature of measurement, usual intake level could not be obtained. Dietary exposure and assessment of trace elements, specifically the dietary fluoride intake of Ethiopian children was measured using a duplicate portion technique. Mothers were asked to prepare a duplicate portion of food and drink, identical in content and volume to the portion taken by the child, for four consecutive days including one weekend day. The portions were then collected and analysed for fluoride content (Malde *et al.*, 2004).

2.2.2.3.2 Reproducibility and validity of duplicate meal method

Duplicate meals are validated by comparison with biomarkers. However, since this method usually serves as a reference method, few studies have carried out reproducibility and/or validity studies to date. A validation study, conducted on women in Sweden, measured the extent to which the duplicate meal method estimates true dietary intake. Comparisons were made between the results from the duplicate portions and biological markers (urine and faeces collection). The duplicate meal method underreported the diet by 14 percent, specifically underestimating the intakes of protein, sodium, potassium and calcium. The authors concluded that the method provided a good measure of dietary intake (Johansson *et al.*, 1998).

2.2.2.3.3 Strengths and limitations of duplicate meal method

The following table will provide a summary of the strengths and limitations associated with conducting a duplicate meal method.

Table 8 - *Strengths and limitations of duplicate meal method*

STRENGTHS	LIMITATIONS
• Provides the most precise information on nutrient intake, and it is not affected by the limitation of food composition data	• It is costly to prepare duplicate meals and conduct the chemical analysis of foods
• Omission of foods consumed is minimized, when compared to other assessment methods	• Time-consuming and burdensome for respondents
	• Requires literate and motivated respondents with numeracy skills (if self-reported)
	• In low-resource countries, a trained field investigator is required to collect reliable data
	• Impractical to use in a large scale study population
	• Expensive for the participants to purchase and prepare extra food, relies on respondents to provide a complete duplication of foods consumed
	• Interferes with normal eating habits and may lead to underestimated intakes
	• Data entry and coding is time consuming and requires trained staff

BOX 7. QUICK GUIDE TO USING A DUPLICATE MEAL METHOD

Project objectives and budget determine the study design and sample size

- √ Understanding the specific target population, purpose and guidelines for the study.

Population characteristics and project setting

- √ Age (e.g. toddlers, adolescence, elderly, etc.), pregnant/lactating, literacy level and cognitive abilities of the respondents will have an impact on the mode of administration.
- √ Study conducted in a controlled environment (e.g. hospital) or unrestricted setting (e.g. home-based assessment).

Mode of administration

- √ Weighed record can be completed by the dietary assistant coordinator or by the respondent, parent, caregiver, etc.
- √ Investigators can conduct home visits during the study period to ensure proper recording and weighing procedures are followed.

Recording method

- √ Food items consumed are weighed, non-edible/non-consumed parts are removed, and duplicate samples are made for laboratory analysis.

Capacity of the dietary assessment coordinator

- √ Dietitian or nutritionist with knowledge and understanding of preparation foods for laboratory analysis.

For additional information please refer to the Box 6: 'Quick guide to using a weighed food record'.

2.3 INTEGRATION OF INNOVATIVE TECHNOLOGIES TO IMPROVE DIETARY ASSESSMENT

There is a growing need for more specific and accurate dietary assessment methods. High quality data are essential for research on the association between diet and health, as well as being decisive to understanding dietary patterns and nutrition-related health problems such as micronutrient deficiencies, diet-related chronic diseases, obesity, cancers, etc. Given its importance, continuous efforts are being made to improve existing dietary assessment methods, as well as to develop more innovative alternatives that are less demanding.

A review published by Poslusna *et al.* (2009) indicated that the main factors influencing misreporting in traditional methods (i.e. dietary recalls, food records) were the reliance on respondents' memories and their poor ability to estimate portion sizes. New information and communication technologies – i.e. personal digital assistants, mobile phones, interactive computer software – aim to overcome the limitations of a pen and paper method and to obtain more accurate and reliable dietary information. In addition, innovative technologies aim to reduce the cost of collecting and processing dietary information. Compared with traditional dietary assessment methods, new technologies have several advantages: they do not rely on the respondents' memory; they can automatically process data and provide real-time personalized dietary feedback advice. However, they also have a series of limitations: in particular, the feasibility and cultural suitability of integrating the latest innovative technologies in rural areas and in low resource settings, particularly among low-literacy populations, is still limited. This guide provides information on the most recent technologies used to improve dietary assessment in more developed settings, as well as some examples of new technologies used in low resource settings. Based on recent reviews (Forster *et al.*, 2015; Gemming *et al.*, 2015; Illner *et al.*, 2012; Stumbo, 2013), innovative technologies to improve dietary assessment have been classified into four key groups: personal digital assistant (PDA), image-assisted methods (i.e. digital cameras, mobile phones, tablets, etc.), interactive computer and web-based technologies, and scan and sensor-based technologies. In particular, this guide takes a detailed look at image-assisted methods, given their potential use in low resource settings.

2.3.1 PERSONAL DIGITAL ASSISTANT (PDA)

A PDA is a handheld computer that can be used for various purposes. For dietary assessment, a PDA has a specially-designed dietary software program that can be used to register and self-monitor dietary intake. It allows for the evaluation of short-term dietary intake, facilitating real-time data collection. Prior to data collection, participants must receive training on how to handle the device. They are required to record their food intake right after consumption by selecting appropriate food items from a predefined list of foods. Early PDAs provided users with a selection of about 180 food items; current PDAs offer a much higher number, between 400 and 4 000 items (McClung *et al.*, 2009). However, it has been reported that PDAs increase the respondent burden compared with pen and paper reports, on account of their increasingly extensive list of foods (Welch *et al.*, 2007). PDAs can also provide some type of aid for measuring portion sizes, i.e. electronic prompts, discrete food photographs, picture books or food models, and household measures. These will help participants quantify the amounts of food consumed. For example, one PDA may display colour photographs of each food item together with a default amount (in grams); subsequently the participant can adjust the predefined portion size to the correct consumed amount. Data is then uploaded to be reviewed by dietitians and matched with food composition tables for further analysis (Beasley *et al.*, 2009; Illner *et al.*, 2012; McClung *et al.*, 2009).

2.3.2 IMAGE-ASSISTED DIETARY ASSESSMENT METHODS

Image-assisted dietary assessment methods refer to any method that uses images (i.e. photographs, videos) of food collected during eating episodes to enhance accuracy and reduce respondent burden. The purpose of using images is to support traditional self-report methods (24-hour recalls or records) or as a stand-alone method to provide the primary record of dietary intake (Gemming *et al.*, 2013; Lassen et al., 2010; Lazarte *et al.*, 2012; Martin *et al.*, 2014).

To make use of image-assisted methods, participants should use handheld devices or wearable cameras to shoot images of food and meals, before and after consumption. It is recommended that participants are provided with a fiducial marker (i.e. a fork or pen), and/or a marked tablecloth, which should be placed close to or beneath the food items before taking the images. The marker is useful to facilitate portion size estimation. Additionally, for increased accuracy the participants can be asked to write down or verbally record a description of food/meals that cannot be captured from images; this is particularly important for obscured images. Alternatively, a 24-hour recall can be conducted to collect further information such as the cooking method, hidden foods and added condiments.

In some cases, if Internet connection is available, respondents are requested to send the pictures immediately after the eating periods (Martin *et al.*, 2012). The images are reviewed by nutritionists and the consumed portion size can be estimated by different methods: from the digital images alone or by comparing them with images of reference portions for known food quantities, the latter being displayed on a computer screen or depicted in a printed food atlas (Lazarte *et al.*, 2012; Martin *et al.*, 2012). Calculation of nutrient intake is based on data from the corresponding food composition tables or databases, and the amount of consumed food (in grams).

Results of image-assisted methods showed that images combined with 24-hour recalls or food records enhanced self-report dietary assessment by revealing unreported foods and identifying misreporting errors not captured by traditional methods alone. This approach helps to reduce memory bias (Gemming *et al.*, 2013; Lassen *et al.*, 2010; Lazarte *et al.*, 2012; Martin *et al.*, 2012).

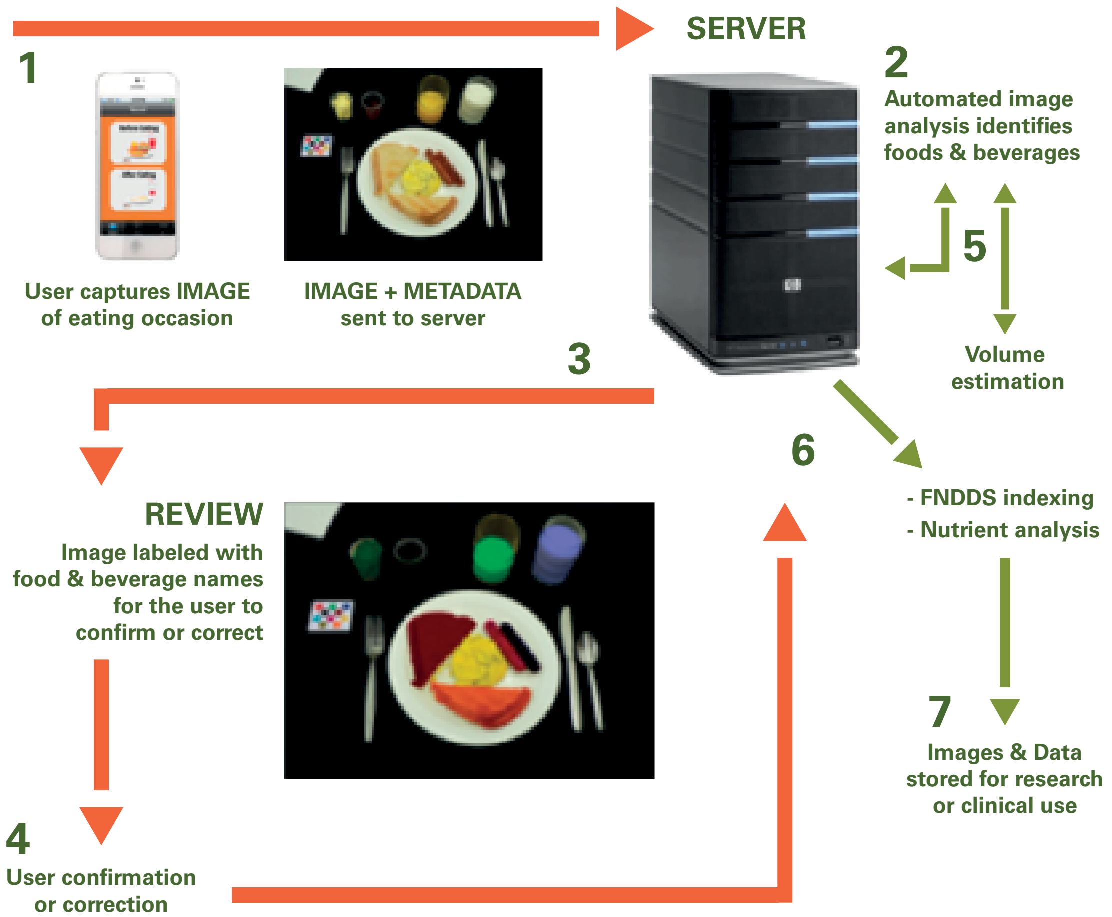
2.3.3 MOBILE-BASED TECHNOLOGIES

Mobile-based technologies are becoming increasingly accessible and have the potential to address some of the burdens associated with collecting accurate dietary data, allowing users to shoot images or make voice records using a smartphone or tablet. Moreover, the rapid advance of mobile technology encourages researchers to develop dietary assessment methods based on this technology. This method is especially appealing for children and adolescents, who are often more motivated to use technology and therefore can become potential users (Boushey *et al.*, 2015; Casperson *et al.*, 2015).

Mobile-based technologies allow short-term dietary assessment, i.e. it is possible for these assessments to be conducted in real-time. Participants are asked to take photographs, video or voice records of all the foods and drinks they consume on eating occasions. The identification of foods in the images and portion size estimation can be carried out by the respondents or dietitians. One of the first devices developed with these characteristics was the Wellnavi instrument (Kikunaga *et al.*, 2007), which was initially a personal digital assistant (PDA) with camera (Wang *et al.*, 2006). Then, the Wellnavi was upgraded to a mobile phone with a camera for capturing images of meals. It included a display on which to write the names of the ingredients of the meal in the digital photograph. The images and the written information were then sent to dietitians for portion estimation and data analysis (Kikunaga *et al.*, 2007). Also with the rapid development in mobile technologies, many mobile applications ('apps') have been developed to record food intake on mobile devices. New technologies have been developed as well for food identification and portion size estimation based on automatic analysis of the food depicted in images through a system of digital image segmentation and analysis.

An example of this innovative technology is the mobile food record (mFR) based on the mobile application mFR–Technology Assisted Dietary Assessment (TADA) (Khanna *et al.*, 2010). The mFR–TADA method has the potential to identify foods automatically and estimate portion sizes via the estimation of food volume from the before-and-after-eating images (Boushey *et al*., 2015; Zhu *et al*., 2010). A fiducial marker is included in the images as a measurement reference to help with the reconstruction of a three-dimensional image that allows for estimation of the volume of foods and drinks consumed (Chae *et al*., 2011; Khanna *et al*., 2010). A diagram of the mFR–TADA system indicating each step involved in capturing an image is shown in Figure 2. The image analysis is linked directly to food composition databases for calculating the energy and nutrient content of the foods and drinks consumed. A similar approach is the food record mobile application (FRapp) (Casperson *et al*., 2015). To date, these technologies have only been tested in terms of the usability of the mobile application among adolescents, and their willingness to do so (Boushey *et al*., 2015; Casperson *et al*., 2015). The use of mobile technologies as a stand-alone method of primary recording of dietary intake appears to be promising. However, methods that rely on automated image analysis can be prone to underestimation if users do not capture images of adequate quality before and after intake of food and drink, and on account of missed meal images which cannot be recorded retrospectively (Casperson *et al*., 2015).

Figure 2 - *Diagram of the Technology Assisted Dietary Assessment (TADA) system that starts with capturing an image with the mobile food record (mFR)*



(1) A user captures an image of an eating occasion; the image is sent to a server. (2) The image is analysed to identify the foods and drinks. (3) The labelled image is returned to the user for the 'review process', as shown by the dotted green line. (4) The user confirms the automatic labels or corrects the labels. (5) The image is returned to the server for final identification and volume estimation. (6) Identified foods and amounts are matched for nutrient analysis to the Food and Nutrient Database for Dietary Studies. (7) Images and data are stored in a server for use by researchers or clinicians. Source: Boushey *et al*. (2015), reproduced.

2.3.4 INTERACTIVE COMPUTER AND WEB-BASED TECHNOLOGIES

Interactive computer and web-based technologies involve the use of interactive dietary assessment programs installed on a desktop or portable computer; the 'web-based' moniker refers to these devices being connected to the Internet. The aim of these technologies is to collect dietary data during a specific period in the recent or distant past (short- or long-term dietary assessment). The methods associated with these technologies are based on pen and paper traditional methods which are introduced into a computer program together with a series of multimedia attributes, i.e. colours, food photographs, audio narration, animated guides, graphics and/or touch screens, pop-up functionalities and webcams. Several authors have developed interactive computer-based dietary assessment methods from pen and paper traditional methods such as FFQ (Wong *et al.*, 2008), 24-hour recall (Kirkpatrick *et al.*, 2014; Zoellner *et al.*, 2005), food records (Timon *et al.*, 2015) or dietary history (Beasley *et al.*, 2009). For data collection, participants are asked to report their food intake during a specific period, and add this information to the previously-developed computer software. The software can also include a comprehensive system for probing forgotten items. Once the food items are introduced and coded, the system calculates the intakes by means of multimedia features. Web-based technologies also include several software components, e.g. adjustable images of portion sizes. An advantage of web-based technologies is that they allow data collection to take place at any time – i.e. real-time data collection and analysis – and at a location and in a language that are more convenient for the participants (Holm *et al.*, 2015; Illner *et al.*, 2012). Nevertheless, to handle an interactive computer and/or web-based technology, the users may need to possess a high level of literacy and computer skills (Illner *et al.*, 2012).

As an example, an interactive computer-based method called Novel Assessment of Nutrition and Ageing (NANA) was developed to assess the dietary intake of the elderly. NANA consists of a touch-screen computer-based food record, plus a fixed webcam for capturing any foods and drinks participants consume, in real time. The touch-screen button selections allow participants to navigate and select food items from 12 high-level food groups. The subsequent determination of portion size is carried out by nutritionists rather than participants (Timon *et al.*, 2015). Another example is the web-based Automated Self-Administered 24-hour Recall (ASA24), which consists of a respondents' website used to collect data either in English or Spanish, and a researchers' website used to manage logistics and undertake data analysis. The ASA24 system presents a series of audio-visual aids to help respondents complete the 24-hour recall, and has shown results comparable with an interviewer-administered 24-hour recall (Kirkpatrick *et al.*, 2014). However, web-based technologies such as ASA24 require high-speed Internet access for optimum performance, as well as a high level of literacy in the respondents. These requirements may limit their viability in low resource settings.

2.3.5 SCAN- AND SENSOR-BASED TECHNOLOGIES

Scan-based technologies allow participants to scan the barcodes of purchased food items; therefore, the applications of this technology is restricted to commercial or institutional settings (Illner *et al.*, 2012). A more innovative approach is sensor-based technologies, which are designed to be memory-independent and almost entirely passive for the participants. This approach also minimizes intrusion to avoid alteration of participants' eating habits. A sensor-based technology named eButton consists of a small electronic device to record food intake automatically. It contains a miniature camera, a microphone, a memory card and several other sensors. Participants are requested to wear the device around their neck during eating occasions. The device collects visual data immediately in front of the participants, storing the data on its memory card. The data are constantly transferred to the dietitians' computers for data analysis (Sun *et al.*, 2010).

Estimation of portion size takes one of two approaches. First, servings of food with different portion sizes consumed in the participant's home can be estimated via automated image analysis using fiducial markers, such as a marked tablecloth and/or reference pictures and known dimensions of plates; these measurements are made by the participant prior to the study. Second, where food intake occurs outside the home, the device emits lights – small beams produced by laser diodes – to project a dimensional referent into the visual field that allows for calculation of portion sizes (Sun *et al.*, 2010). Once the food and portion sizes are determined, the system is linked to a food database for calculation of nutrient content.

Counting of chews and swallows has also recently been incorporated into sensor-based devices. These are a precise measure of biological movements related to eating activities, and as such are a new method for detecting and quantifying food intake (Fontana *et al.*, 2015; Sun *et al.*, 2015). These innovative technologies suggest a more objective dietary assessment. They may offer a promising alternative to overcome some of the limitations of traditional self-report methods. However, these are still emerging technologies that need to be adapted and validated before they can be deemed both feasible and suitable in different settings and populations.

2.3.6 APPLICATIONS AND USES OF INNOVATIVE TECHNOLOGIES TO IMPROVE DIETARY ASSESSMENT

Innovative technologies have been shown to be useful in assessing current dietary intakes, as most of them are simple and non-invasive. The majority of reported innovative dietary assessment methods or technology-assisted dietary assessment methods have been used to quantify participants' food intake behaviour in a variety of controlled settings such as schools, colleges and university cafeterias (Wang *et al.*, 2006; Williamson *et al.*, 2003), or in hospitals and community centres (Kikunaga *et al.*, 2007; Ptomey *et al.*, 2015; Rollo *et al.*, 2011). Fewer studies have been carried out in free-living conditions (Gemming *et al.*, 2013; Lassen *et al.*, 2010; Martin *et al.*, 2009; Martin *et al.*, 2012) and in low income populations (Fowles *et al.*, 2008; Lazarte *et al.*, 2012).

PDAs have been widely used in industrialized countries and controlled settings (Forster *et al.*, 2015). However, their application is still limited to low resource settings. PDA food records require high literacy in the respondents; as such, children and older or less literate populations might have difficulties in using a PDA for recording food intake (Fowles *et al.*, 2008; Ortega *et al.*, 2015).

Image-assisted methods were used to assess dietary intake in children (11 months to 8 years) from remote communities in Australia (Liberato *et al.*, 2015), in adolescents (12–17 years) with intellectual disabilities (Ptomey *et al.*, 2015), and in overweight and obese adults (Martin *et al.*, 2012). Mobile-based technologies were used to address difficulties reported by adolescents (11–15 years) on conducting dietary assessment (Boushey *et al.*, 2015; Casperson *et al.*, 2015) and for recording dietary intake in adults with type 2 diabetes (Rollo *et al.*, 2011). The results of these studies have shown that image-facilitated dietary assessments can be suitable in different populations and settings. One study (Lazarte *et al*., 2012) showed the feasibility of using images in the rural areas of a low resource country, where the characteristics of the population (i.e. low level of literacy) and the resources they possessed (i.e. lack of Internet connection) were taken into consideration for the development of the method.

The interactive computer-based food record NANA has been used to assess the dietary intake of older adults (Timon *et al*., 2015). Meanwhile a web-based FFQ has been used to evaluate eating practices and diet quality in a large sample size of 7 531 people from Norway, Denmark, Sweden and Finland (Holm *et al*., 2015). In all cases, the use of PDAs, mobile applications, interactive computer and web-based technologies has been shown to require an adequate level of literacy and technical skills on the part of the participants. These requirements might limit their usage in some low literacy populations. Adequate training can facilitate the use of some technologies, especially in selected population groups such as adolescents and adults in some low-resource settings, who may already have access to mobile phones and computers. Sensor-based technologies may be easier to administer, but these are still limited in both industrialized and low resource settings. As mentioned earlier, while some of these technologies are promising, they are also emergent and at a developmental phase.

2.3.7 VALIDATION OF INNOVATIVE TECHNOLOGIES TO IMPROVE DIETARY ASSESSMENT

Validation studies have been carried out comparing results from innovative dietary assessment methods with results from traditional dietary assessment methods. Comparisons undertaken have included weighed food records (Kikunaga *et al*., 2007; Lassen *et al*., 2010; Lazarte *et al*., 2012; Schap *et al*., 2014; Wang *et al*., 2006), estimated food records (McClung *et al*., 2009; Yon *et al*., 2006), 24-hour recalls (Gemming *et al*., 2013) and a few comparisons with more objective methods such as DLW (Gemming *et al*., 2015; Martin *et al*., 2012).

Gemming and colleagues evaluated whether 24-hour recall using the wearable camera SenseCam could reduce under-reporting of energy intake by providing visual aids (Gemming *et al*., 2013). Their findings showed that images increased self-reported energy intake by approximately 12.5 percent ($P = 0.02$) compared with the 24-hour recall alone. The improvement was mainly explained by the reporting of forgotten food items and the adjustment of some portion sizes. The validity of SenseCam-assisted 24-hour recall was also assessed against the DLW technique (Gemming *et al*., 2015). Energy intake was assessed in free-living conditions by three multiple-pass 24-hour recalls alone, and by SenseCam-assisted 24-hour recall. The results compared total energy expenditure (TEE, from DLW) with energy intake calculated from the multiple-pass 24-hour recalls alone and from the SenseCam-assisted 24-hour recall. They found that underestimation of energy intake was significantly reduced ($P<0.02$), in the range of 6 to 8 percent, when the wearable camera assisted the 24-hour recall. The authors concluded that wearable cameras enhanced the accuracy of self-report methods such as 24-hour recalls.

Image-assisted methods have also been validated against the weighed food record – the so-called 'gold-standard' – in free-living conditions in industrialized countries (Kikunaga *et al*., 2007; Lassen *et al*., 2010) as well as by one study in free-living conditions in low resource settings (Lazarte *et al*., 2012). When the results were compared with the reference method, small differences were shown (Kikunaga *et al*., 2007; Lassen *et al*., 2010; Lazarte *et al*., 2012). Lazarte and colleagues (2012) developed a food photography 24-hour recall (FP 24-hR) to evaluate food consumption among women in rural areas in Bolivia. When FP 24-hR was validated against the weighed food record, the authors found small differences in nutrient intakes: from 0.90 percent for vitamin C to 5.98 percent for fat (P<0.05). Furthermore, Lassen and colleagues (2010) have developed an image-based food record. Their method was validated against weighed food records of evening meals, with a negative difference of 11.3 percent for energy intake (*P*<0.001) (Lassen *et al.*, 2010). In these studies, high correlations between the image-assisted methods and weighed food records were reported (Lassen *et al.*, 2010; Lazarte *et al.*, 2012). However, high correlations did not necessarily imply good agreement between the methods; a better approach was to examine the Bland–Altman plots. In this analysis, acceptable limits of agreement between the methods were found for both energy and nutrient intakes. This indicated that differences were random without systematic bias (Lassen *et al.*, 2010; Lazarte *et al.*, 2012). It was suggested that by improving the quality of the photos it might be possible to reduce the differences. Image-assisted dietary assessment methods are promising to enhance the accuracy of some traditional self-reported dietary assessment methods, although there is still room for improvement in accuracy.

A PDA technology named MiHealthLog (McClung *et al.*, 2009) was compared with traditional written food records and validated against DLW. The authors found that energy intake estimated by food records (difference of 3 percent) and PDA (negative difference of 8 percent) were similar to energy expenditure calculated by DLW (*P*>0.05), concluding that estimation of energy intake is similarly biased for both PDA and food records (McClung *et al.*, 2009). Another PDA named DietMatePro (Beasley *et al.*, 2009) was compared with food records and validated against DLW. Beasley and colleagues reported comparable correlation between DietMatePro (*r*=0.41 to 0.71) and written food records (*r*=0.63 to 0.83). It was concluded that DietMatePro may improve diet adherence compared with participants adhering to a written food record (*P*=0.039). However, it does not appear to produce more valid data than the pen and paper approach (Beasley *et al.*, 2009).

The computer-based method NANA (Timon *et al.*, 2015) was validated against written food records and against biomarkers of nutrient intake. Good correlations were found between these dietary assessment methods for energy (*r*=0.88) and macronutrient intakes (*r*=0.80). The authors also found positive correlations between urinary urea and dietary protein using either written food records (r=0.56) or NANA (*r*=0.47). They concluded that NANA compared well with written food records and offered a potential alternative for estimating dietary intake in community-living older adults (Timon *et al.*, 2015). Nevertheless, the different technologies and alternatives available in the literature need to be adjusted according to the characteristics of each study area and validated before their actual application.

2.3.8 STRENGTHS AND LIMITATIONS OF INNOVATIVE TECHNOLOGIES TO IMPROVE DIETARY ASSESSMENT METHODS

The strengths and limitations of innovative technologies to improve dietary assessment methods are presented in Table 9, based on information extracted from the latest reviews published on this topic (Gemming *et al.*, 2015; Illner *et al.*, 2012; Martin *et al.*, 2014; Ngo *et al.*, 2009; Stumbo, 2013).

Table 9 - *Strengths and limitations of innovative technologies to improve dietary assessment methods*

METHOD	STRENGTHS	LIMITATIONS
All innovative technologies used in dietary assessment	Costs for data collection can be lower (less need for person-to-person interaction)	Larger up-front investments (i.e. purchase of mobile phones, cameras, computers, software development, etc.)
	Convenient for users, good acceptability, may improve compliance	Risk of losing devices
	Do not rely on respondent's memory	Risk of technical problems (i.e. low battery, loss of Internet connection) could impede data collection
	Record of qualitative information (e.g. date and time of recording)	A backup method is required to collect information, if technical problems occur
	Significantly cut down data processing time	
Personal Digital Assistant (PDA)	Is portable and can be easily carried by study participants	Face-to-face training of the participants is required
	Facilitates real-time data collection, entry and coding	Low level of dietary data details because of pre-coded food listings
	It is possible to set an alarm within the PDA to alert participants to record their food intake	Increases the respondent burden compared with pen and paper records, due to the extensive list of foods (depending on each PDA)
	Can be programmed to allow participants strict access to the dietary intake software only	Reports of difficulty using the search function and inability to find certain foods
Image-assisted methods, i.e. digital photographs	Easy to use	Participants may forget to take some images
	Suitable for low literacy populations (if the technologies are easy-to-use, e.g. digital cameras)	Not all information can be captured with a single photograph/image
	Quality of digital cameras keeps improving and pictures with higher resolutions can help improve the accuracy of analysis	Difficulties in estimating portion size of food consumed from common mixed dishes
	Suitable for subjects with memory impairments and for children	Lack of details about cooking methods

METHOD	STRENGTHS	LIMITATIONS
	Lower under-reporting compared with some traditional methods	Probably more limited accuracy for countries with a wide range of mixed dishes (e.g. Asia)
		Still needs a written record of foods obscured in photos, and when details of ingredients are required
Image-assisted methods, i.e. mobile-based technologies	Possible higher quality control of data because of shorter delays and real-time responses	It is costly and time-consuming to develop the application as an interface, and the software for automated portion size estimation
	Possibility of sending reminders	Certain types of foods, such as mixed dishes (soups, stews, casseroles, etc.) can be difficult to analyse with automated image analysis
	Internet access would allow respondents to send instant photos, thereby minimizing systematic mistakes	Requires certain level of literacy
		Requires network/Internet access (for real-time data collection)
Interactive computer and web-based technologies	Efficiency in terms of recording information and data processing (i.e. reduced costs and interviewer workload)	Some imaging algorithms are not sufficiently advanced to identify foods correctly and to accurately estimate the quantity of food in the computerized images
	Increased levels of quality control	Need adaptation of the software to local settings
	Include interactive visual and audible aids	Require high levels of literacy and computer skills from the participants
	Suitable for large, geographically dispersed samples; can include different countries/languages (web-based)	Possibility of collecting less food details (i.e. ingredients, methods of preparation, etc.)
	Data processing can be finalized at any time and location (web-based)	Require Internet access (web-based)
	Can provide personalized dietary feedback (web-based)	
	Possibility of sending interactive reminders (web-based)	

METHOD	STRENGTHS	LIMITATIONS
Scan- and sensor-based technologies	Incorporation of barcode scanning and PLU (Price Look Up) codes allows automatic identification of foods	Scanning barcodes is applicable to packed food only
	Objective dietary assessment (sensor-based)	Have only been used in controlled settings to date
	Passive for the participants, reduces burden (sensor-based)	Their application to date has been restricted to small test studies

The applications of innovative technologies in dietary assessment are subject to constraints such as cost, location, available resources, literacy level of the population and number of interviews. Therefore, some of these technologies remain relatively costly for implementation in large-scale epidemiological studies. As mentioned earlier, innovative technologies may be used as stand-alone dietary assessment methods, or can be added as an aid to improve data collection in conventional dietary assessment (i.e. 24-hour recall, dietary record and FFQ). Using innovative technologies along with a conventional dietary assessment may reduce the up-front cost of the stand-alone innovative methods and avoid some technical drawbacks, i.e. problems with data transfer and storage, battery life, Internet access, etc. For the dietary assessment methods used in epidemiological studies, Shim and colleagues reviewed the strengths and limitations of innovative technologies incorporated into conventional dietary assessment methods, found in Table 10 below (Shim *et al.*, 2014).

Table 10 - *Strengths and limitations of innovative technologies integrated into conventional dietary assessment methods*

	24-HOUR RECALL	DIETARY RECORD	FOOD FREQUENCY QUESTIONNAIRE
Required technology	Software, Internet, mobile phone, digital camera, etc.	Software, Internet, PDA, mobile phone, application, etc.	Skip algorithms, questions that ask for multiple details, pictures of foods, etc.
Strengths	Standardized data collection is possible (reducing interviewer bias); probable reduced time and cost; improves feasibility	Standardized, real-time data collection is possible; probable reduced time and cost; improves feasibility	Able to collect complex information and highly accurate data
Limitations	Inherent bias related to self-reporting	Inherent bias related to self-reporting; requires participant training on how to use the technology	Measurement errors related to methodology remain

Adapted from Shim, Oh and Kim (2014) with permission.

The limitations discussed in Table 10 may restrict the usage of some innovative technologies (i.e. computer web-based methods, scan- or sensor-based methods) for dietary assessment in rural areas, in low resources settings and among low literacy populations. These limitations might be overcome with the addition of new and evolving technologies and better ways to control bias. Currently, image-assisted methods (i.e. digital cameras, mobile phones) may be the most suitable for low-resource settings, and could have a positive impact on dietary assessment in these settings.

BOX 8. QUICK GUIDE TO USING INNOVATIVE TECHNOLOGIES FOR DIETARY ASSESSMENT

To integrate innovative technologies in supporting conventional methods (dietary records and 24-hour recalls)

Define the project objectives, the design of the study, the sample size and the budget

Take into consideration the specific characteristics of the population and settings: e.g. literacy level, computer skills, eating from a common pot, highly mixed dishes, availability of electricity and Internet connectivity

Choose the technologies that will be used for dietary assessment, e.g. digital cameras, mobile phones, tablets, computers, mobile applications, computer software, etc

Select the method for estimating portion sizes

- √ Only digital images;
- √ Photo atlas with standardized food portion sizes (printed or digital) for comparison with the digital images;
- √ Automatic analysis of food identification and portion size estimation, e.g. FRapp (Food Record application), ACTi Pal (www.actipal.com), mFR app, TADA system (www.tadaproject.org).

Define the number of days to be recorded: three days or more is recommended when the aim is to evaluate the individual's usual diet

Define the time frame, and days selected for conducting the method (e.g. weekdays vs. weekend days, consecutive vs. non-consecutive). It is recommended to include one weekend day

Compile information on composite dishes (e.g. soups, stews) and/or dietary supplements (e.g. vitamins, minerals). This information is difficult to extract from images, so the following alternatives are suggested

- √ *In case of image-assisted record methods*, the respondent should keep a record with the description of the composite dishes, including lists of ingredients and quantities, given that these may be difficult to identify in the images.

- ✓ *In case of image-assisted recall methods*, the interviewer should ask for a description of the composite dishes, including lists of ingredients and quantities.

Establish the procedure to follow in case of obscured or missing images of food events

- ✓ Train the respondent to review the images after taking them and to take a second image if necessary.
- ✓ Ask the respondent to write down a description of the consumed foods if the images are not clear or if he/she forgot to record the images.
- ✓ Innovative technologies assisting 24-hour recall allow the interviewer to ask for information necessary to clarify obscured images and to obtain detailed information on food ingredients.

Capacity development for the respondents

- ✓ Training in the appropriate use of digital cameras, smartphones, mobile applications and/or other devices used to collect dietary information.
- ✓ Computer skills (required for computer-based and web-based methods).

For innovative technologies used as stand-alone methods, keep in mind the following aspects

Be aware that images, if used as the only source of information, could not describe food ingredients in composite dishes. Thus, the method may increase the likelihood of under-reporting.

- ✓ Additional voice or writing records would be needed in case of obscured images.

Stand-alone innovative methods may not be suitable to estimate portion size for certain populations, for example

- ✓ When the family eats from a common pot;
- ✓ When the majority of the meals are mixed dishes such as soups and stews, or have sauces served on top of the other ingredients.

2.4 QUALITATIVE RETROSPECTIVE PROXY TOOLS FOR ASSESSING DIETARY DIVERSITY

The Dietary Diversity Score (DDS) is a proxy tool based on the concept that 'dietary diversity is a key element of diet quality and a varied diet helps ensure adequate intakes of essential nutrients that promote health' (Ruel *et al*., 2013). DDS is easy to use, inexpensive, practical, and can be utilized to quickly obtain results. Hence, it can be used for rapid assessment of dietary diversity in selected population groups, in contexts where resource and capacity constraints might restrict the use of more detailed dietary assessment methods. DDS provides a simple score which represents a number of different foods and/or food groups consumed over a given reference period (Hoddinott *et al*., 2002). There are various DDSs published and used for different purposes. They differ in the number and definition of food groups or food items, reference periods and units of analysis (i.e. household or individual level), and are as follows:

- *At household level:*
  - Household Dietary Diversity Score (HDDS) (FAO, 2010; Swindale *et al.*, 2006) is based on the count of 12-food groups. The information is extracted from one qualitative 24-hour recall, excluding foods consumed outside the home. It accesses the quality of food access at household level. Additionally, it is useful for identifying emergencies related to food security and malnutrition (Ruel, 2003a). Studies have shown that an increase in dietary diversity at household level was positively associated with household food security (Hoddinott *et al.*, 2002).
  - Food Consumption Score (FCS) (WFP, 2008) is based on the count of 9-food groups. The score is calculated taking into account the frequency of consumption of different food groups over a period of 7 days, before the survey, and the relative nutritional importance of the food groups. The results of the analysis categorize each household as having either poor, borderline or acceptable food consumption. It aims to reflect the quality and quantity of food access at household level.
- At individual level:
  - To assess dietary diversity and micronutrient adequacy of the diet at individual level, many indicators have been developed varying in the number of food groups, target population and cut-off point (FAO/FANTA/IRD, 2014). On account of their importance, the indicators Minimum Dietary Diversity – Women (MDD-W) and Infant and Young Child Dietary Diversity Score (IYCDDS) (WHO/UNICEF, 2010) are presented in further detail below.

2.4.1 MINIMUM DIETARY DIVERSITY –WOMEN (MDD-W)

The MDD-W indicator (Martin-Prével *et al.*, 2015, 2017) aims to be used as a global indicator of dietary diversity, and was recently developed from the Women's Dietary Diversity Score (WDDS) (FAO, 2010). WDDS (FAO, 2010) was constructed with the simple count of a 9-food group indicator, but it did not have an established cut-off value. There is an increasing need for a dichotomous indicator that is useful for target-setting purposes and advocacy (FAO, 2015b). As a result, WDDS was updated to the MDD-W indicator. MDD-W has been defined as a dichotomous indicator of whether or not women who are 15–49 years of age have consumed at least five out of ten defined food groups during the previous day and night. The proportion of women of 15–49 years of age who reach this minimum dietary diversity (five or more food groups) in a population can be used as a proxy indicator for micronutrient adequacy, which is one important dimension of diet quality (FAO/FHI360, 2016; Martin-Prével *et al.*, 2015). MDD-W was developed through secondary analysis of dietary intake (from multiple 24-hour recalls) of nine data sets from rural and urban areas in six countries: Bangladesh, Burkina Faso, Mali, the Philippines, Mozambique and Uganda (Martin-Prével *et al.*, 2015). The nine datasets were used to calculate the mean probability of micronutrient adequacy (MPA) for 11 micronutrients – vitamin A, thiamine, riboflavin, niacin, vitamin B6, folate, vitamin B12, vitamin C, calcium, iron and zinc – using the probability of adequacy approach. This approach is based on information or assumptions about both the distribution of nutrient requirements in the population and the day-to-day variations (intra-individual) in nutrient intakes (Barr *et al.*, 2002). The 10-food group indicator and the cut-off of the MDD-W were chosen by examining the sensitivity, specificity and total misclassification of the MDD-W with several cut-offs and thresholds of MPA (i.e. 0.50, 0.60, and 0.70). Each one of the

10-food group indicator holds the same weight. The food groups are as follows:

1. all starchy staples
2. beans and peas
3. nuts and seeds
4. all dairy
5. flesh foods
6. eggs
7. vitamin A-rich dark green leafy vegetables
8. other vitamin A-rich vegetables and fruits
9. other vegetables
10. other fruits

A cut-off point of five was established as the 'best cut off' since it performed accurately in a sufficient number of data sets (six out of nine data sets) and at different MPA levels. The cut-off of five was, furthermore, recommended as a reasonable predictor of an MPA >0.60 (for more details on the MDD-W cut off selection process, refer to Martin-Prével *et al.*, 2015). The performance of food group indicators was evaluated through a sensitivity–specificity analysis, examining error rates of classification across a range of cut-offs and for various MPA cut-offs. Low sensitivity was found in cases of very varied diets containing small quantities of nutrient-rich foods, e.g. diets in Asia. In addition to the low sensitivity, the authors reported that results from the secondary analysis were consistent enough that MDD-W could be recommended for global use in population-level assessment and advocacy (Martin-Prével *et al.*, 2015, 2017).

It is generally agreed that dietary diversity is a key element of diet quality. Thus, dietary diversity should be measured as reliably as possible. MDD-W data is relatively simple to collect and the score is easy to calculate. Food consumption of individuals during the preceding 24 hours is recalled using a qualitative 24-hour recall questionnaire, including foods that have been eaten outside the home. Alternatively, the information can be collected with a list-based questionnaire (a form of FFQ), where the interviewer asks the respondent if she has eaten foods from different food groups, using a culturally-adapted food list (i.e. common food names, local foods). The information on food consumption, collected either by 24-hour recall or list-based questionnaire, that matches the items in the 16-food group list are underlined. To create the MDD-W score, the preliminary list of the 16-food group is aggregated into the 10-food group indicator (Appendix 6), where one point is allocated whenever a food item contained in the 10-food groups has been underlined in the 16-food group list. Even if each food group has one or more underlined food item only one point is allocated, thus contributing equally to the final score. The value of zero is given if none of the food items in the food group were consumed. The sum of the consumed food groups represents the total DDS.

Only food items that were consumed in a quantity greater than 15 grams (roughly a tablespoon) should be considered and included in the 10-food group indicators. The minimum quantity rule of 15 grams was defined by secondary analysis where a comparison was made between two indicators: the first, imposing a 1 gram rule and the second, imposing a 15 grams rule (Arimond *et al.*, 2010). A minimum consumption of 15 grams of a food group per day is required in order for a food group to be accounted for in the score and, therefore, helping to provide a better indication of MPA.

2.4.2 INFANT AND YOUNG CHILD DIETARY DIVERSITY SCORE (IYCDDS)

IYCDDS is defined as the "Proportion of children 6–23 months of age who receive foods from four or more food groups" (WHO/UNICEF, 2010). This means that children who received four or more food groups out of seven during the previous day were more likely to have an adequate diet than children who consumed food items from less than four food groups. The indicator is based on the count of 7-food groups. It was developed for children of 6–23 months old through secondary analysis of ten data sets from a multi-country study that included countries in Africa, Asia and Latin America. The 7-food groups were selected by examining the sensitivity and specificity of the indicators performance with a different number of food groups. The indicator was further investigated using a 1 gram and 10 gram minimum consumption cut-off, and concluded that a 1 gram cut-off per day provided a better result. Therefore, since the cut-off is so low the consumption of any amount of food from each food group is sufficient enough to be accounted for in the construction of the score, except if an item is only used as a condiment (WHO/UNICEF, 2010). The food group classification includes:

1. Grains, roots and tubers
2. Legumes and nuts
3. Dairy products (milk, yogurt, cheese)
4. Flesh foods (meat, fish, poultry and liver/organ meats)
5. Eggs
6. Vitamin-A rich fruits and vegetables
7. Other fruits and vegetables

The cut-off of at least four of the above 7-food groups indicates a minimum dietary diversity in infants and young children. The cut-off was selected because it was shown to be associated with better quality diets for both breastfed and non-breastfed children (WHO *et al.*, 2008). Briefly (in a similar approach as that explained in section 2.4.1), the selection of the cut-off was based on data analysis from the multi-country study, where the association between IYCDDS and mean micronutrient density adequacy (MMDA) of the diet for nine and ten nutrients was tested (WHO *et al.*, 2008; WHO/UNICEF, 2010). The indicators were positively and significantly associated with MMDA at all ages in all countries and for both breastfed and non-breastfed children. Although sensitivity and specificity analyses failed to identify a cut-off point that performed best across all contexts, the cut-off point of four was selected based on extensive stakeholder consultations and discussions (Leroy *et al.*, 2015). The consultation agreed that the consumption of foods from at least four food groups on the previous day would mean that in most populations the child had a high likelihood of consuming at least one animal-source food and at least one fruit or vegetable that day, in addition to a staple food (grain, root or tuber) (WHO/UNICEF, 2010).

To construct the IYCDDS score, data on child food consumption are collected through an interview with the parents or caregivers. The interviewer asks about the different types of foods the child ate the day before the interview, using a 24-hour recall approach. The food items recalled by the respondent are then underlined and given a value of 1 in one of the 7-food groups for the construction of the IYCDDS score (WHO/UNICEF, 2010). Results may be reported separately for breastfed and non-breastfed children. However, diversity scores for breastfed and non-breastfed children should not be directly compared, because breast milk is not counted for in any of the above food groups, since the indicator is meant to reflect the quality of the complementary diet. It is recommended that the indicator be further disaggregated and reported for the following age groups: 6–11 months, 12–17 months and 18–23 months (WHO, 2008). Detailed steps for IYCDDS data collection are presented in the guide published by WHO (WHO, 2010).

2.4.3 APPLICATIONS AND USES OF INDIVIDUAL LEVEL DIETARY DIVERSITY SCORE

DDS at the individual level has been used to evaluate the probability of having a varied diet, and has also been associated with the probability of micronutrient adequacy in the diet (Arimond *et* *al.*, 2010; Ruel, 2003a). In this regard, Kennedy and colleagues found that DDS was associated with the adequacy of 11 micronutrients – vitamin A, vitamin C, vitamin B6, vitamin B12, thiamine, riboflavin, niacin, folate, calcium, zinc and iron – in the diets of women of reproductive age in an urban area of Mali (Kennedy *et al.*, 2010). DDS was also shown to be a useful indicator of micronutrient adequacy in children (24–71 months old) in the Philippines (Kennedy *et al.*, 2007).

Since the tool is simple and inexpensive to use, studies can be repeated several times in 1 year, helping to capture the seasonal effect. Savy and colleagues have used DDS to study the seasonal variations of women's diets in a rural area of Burkina Faso. The authors assessed the DDS of ten standard food groups at the beginning and at the end of the seasonal cereal shortage. They concluded that DDS could help to identify vulnerable individuals from a socio-economic and nutritional point of view when DDS was measured at the end of the shortage season (Savy *et al.*, 2006). Additionally, DDS has been used to evaluate variations of dietary intakes between populations in different settlements or regions in South Africa (Acham *et al.*, 2012). It has also been used to investigate the associations between environmental, physiological and sociodemographic variables and dietary diversity in Bolivia, Botswana and Burkina Faso (Benefice *et al.*, 2006; Clausen *et al.*, 2005; Savy *et al.*, 2006). Furthermore, the dichotomous MDD-W indicator has been used for the first time in Tajikistan to collect baseline nutrition information across four regions of the country. The study was useful to identify the percentage of women that consumed five or more food groups, and were classified as being more likely to have an adequate diet and meet their nutritional requirements. Regions in Tajikistan with less varied diet diversity, along with the food groups that were consumed less by Tajik women, were identified in the study (Lazarte *et al.*, 2015). As a result of such studies, DDS has been shown to be a potentially low-cost, field-friendly tool for rapid assessment of dietary diversity, an important feature of dietary quality and micronutrient adequacy.

2.4.4 VALIDITY OF INDIVIDUAL LEVEL DIETARY DIVERSITY SCORE

Several authors have constructed and validated DDS by secondary data analysis (Arimond *et al.*, 2004; Arimond *et al.*, 2010; Kennedy *et al.*, 2010; Martin-Prével *et al.*, 2015). This involves the comparison of results from DDS with existing results from individual dietary assessments methods (i.e. quantitative 24-hour recall), anthropometric measurements and/or biochemical markers. One major limitation of DDS studies validated through secondary data analysis is that the MPA and the food group indicators were generated from the same data sets; as such, measurement errors may be correlated and this could bias the results of associations (Arimond *et al.*, 2010). With secondary data analysis, DDS has been shown to associate with the MPA for micronutrients calculated from previous data of quantitative 24-hour recalls (Arimond *et al.*, 2010; Kennedy *et al.*, 2010; FAO, 2015b). Additionally, DDS has been compared with the results of energy intake, nutrient adequacy and anthropometric measurements calculated from previously collected dietary data in adults (Arimond *et al.*, 2010; Hoddinott *et al.*, 2002) and children (Arimond *et al.*, 2004; Steyn *et al.*, 2006). In one study, HDDS (a 12-food group indicator) was presented as a proxy indicator of household food access and was associated with energy availability calculated from data sets in ten countries: India, the Philippines, Mozambique, Mexico, Bangladesh, Egypt, Mali, Malawi, Ghana, and Kenya. The authors found that a 1 percent increase in dietary diversity was associated with a 0.7 percent increase in total per capita caloric availability (Hoddinott *et al.*, 2002). Meanwhile WDDS, a 9-food groups indicator (Arimond *et al.*, 2010) was presented as a proxy indicator for micronutrient adequacy in women of reproductive age. WDDS was associated with the MPA for 11 micronutrients – vitamin A, vitamin C, vitamin B6, vitamin B12, thiamine, riboflavin, niacin, folate, calcium, zinc and iron. Where MPA was calculated from data sets of quantitative 24-hour recalls from five low resource settings (Burkina Faso, Mali, Mozambique, Bangladesh and the Philippines), the authors reported that MPA for micronutrients in all sites were correlated with all 9-food groups of DDS. Associations were stronger for WDDS when a 15 gram minimum consumption cut-off was required for a food item to be included in the food groups for the final score (Arimond *et al.*, 2010). A similar approach was used to assess the associations between MDD-W and MPA (Martin-Prével *et al.*, 2015). Additionally, Arimond *et al.* (2004) reported the association between DDS (7-food group indicator) and height-for-age Z-scores (HAZ) in children 6 to 23 months old. They extracted and analysed data from the demographic and health surveys in 11 countries: Benin, Cambodia, Nepal, Ethiopia, Haiti, Colombia, Peru, Malawi, Rwanda, Mali and Zimbabwe (Arimond *et al.*, 2004). The data were adjusted for a number of potentially confounding factors, i.e. age, sex, breastfeeding status, mother's education, household wealth/welfare residence area, etc. The authors reported that in 10 out of the 11 countries, significant associations were found between DDS (7-food group indicator) and HAZ, either as a main effect or as an interaction with other factors, e.g. age, breastfeeding, urban or rural living area (Arimond *et al.*, 2004).

Torheim and colleagues validated a DDS (10-food group indicator) by comparing the scores with nutrient adequacy assessed via a 2-day weighed food record collected by two studies in western Mali. They found acceptable correlations ($r=0.25$, $P<0.05$) between DDS and nutrient adequacy estimated by the weighed food records in one of the studies (Torheim *et al.*, 2003). Furthermore, if DDS aims at assessing the risk of inadequate micronutrient intake, a validation study comparing the results with biochemical indicators is recommended if resources are available. Only a few studies have assessed DDS against biomarkers. One study by Fujita *et al.* (2012), evaluated how well a 10-food group DDS predicts vitamin A status, measured as serum retinol concentration, in adult women from northern Kenya. Their findings showed that DDS was positively related to retinol concentration ($P= 0.045$) and that dietary diversity had a significantly positive effect on serum retinol concentration. Results suggested that women having more diversified diets had improved intake of vitamin A and serum retinol as compared with women who had less diversified diets with equivalent vitamin A content (Fujita *et al.*, 2012).

2.4.5 STRENGTHS AND LIMITATIONS OF INDIVIDUAL LEVEL DIETARY DIVERSITY SCORES

Based on several published reviews and reports (FAO/FANTA/IRD, 2014; Herforth, 2015; Rose *et al.*, 2008; Ruel, 2003b), Table 11 shows the strengths and limitations of DDS.

Table 11 - *Strengths and limitations of individual level dietary diversity score*

STRENGTHS	LIMITATIONS
• A useful indicator for assessing dietary diversity (a key element of dietary quality)	• Collects only qualitative dietary data
• Can potentially be used as a global indicator to classify individuals at risk of micronutrient inadequacy	• Cannot represent habitual intake of an individual person

STRENGTHS	LIMITATIONS
• Has a cut-off point to identify adequate diets for IYCDDS and MDD-W	• Does not assess the full picture of dietary quality of subjects
• Quick, simple and inexpensive data collection and analysis	• Not designed to collect information on within-person variation
• Non-intrusive, low participant burden	• Relies on respondent's memory when data collection is based on 24-hour recall
• Showed high response rate among target populations	• Cannot assess dose-response effects via follow up intervention studies
• Suitable for populations eating from common bowls (does not require detailed quantitative information of the consumed food)	• Nutrition supplements are not taken into account
	• Dietary diversity may significantly vary by season. Data interpretation needs to be cautious when comparing dietary diversity data across seasons and regions

The DDS indicator is potentially suitable and feasible in low resource settings with limited resources and capacity to conduct more robust dietary assessment such as diet records or 24-hour recalls. DDS can provide valuable information on dietary diversity, which is an important factor in diet quality and micronutrient adequacy. The duration of a DDS interview is relatively short. The tool is easy to understand and execute, and the data analysis and interpretation are straightforward. However, caution must be taken when adapting the tool to specific populations, taking into consideration context-specific characteristics (i.e. dietary habits, seasonal variations, geographical differences, etc.).

BOX 9. QUICK GUIDE TO USING INDIVIDUAL LEVEL DIETARY DIVERSITY SCORES

Define the project objectives, sample size and budget

Define the unit of analysis/data collection

- √ At individual level (e.g. MDD-W, IYCDDS)

Select the method used to collect information

- √ 24-hour recall (open free recall) or list-based method

Select the mode of data collection (e.g. pen and paper, tablets, etc.)

Define the number of days recalled

- √ Normally one day. DDS does not represent an individual's usual diet even if the information is collected for more than one day.

Conduct adaptation of the DDS questionnaire to population characteristics (REF, training course)

- √ Local adaptation of the DDS questionnaire can be conducted by meeting with local key informants and by focus group discussions.
- √ Understanding the food and meal patterns of the target population.
- √ Foods classified in the DDS questionnaire should represent those commonly consumed by the target population.
- √ The list of foods should be revised and modified (add or delete food items).
- √ The questionnaires should be translated into the local language.

Define how to proceed for mixed or composite dishes

- √ All the ingredients included in composite dishes should be recalled. It is recommended that the enumerators should have an understanding of local recipes to identify and record all ingredients consumed.

Define a minimum quantity rule

- √ A minimum quantity rule should be set and followed for foods to be counted in the construction of the score (e.g. 15 grams).
- √ It is recommended to validate the minimum quantity within the target population.

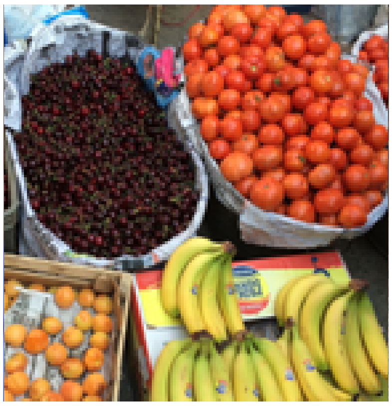
Consider seasonal variation: food availability can be greatly affected by seasonal variations

Define the days for conducting the method

- √ Any day of a habitual food intake is preferred; avoid days when the eating patterns may be significantly different from habitual (e.g. fasting days, feast days)

Consider conducting capacity development for enumerators

- √ Training on dietary data collection;
- √ How to probe the respondent using standardized and non-leading questions;
- √ Knowledge about the foods and food preparation methods of the study population is an asset.



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Nutrition and Food Systems Division
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