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Measuring intake of fruit and vegetables

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1. Introduction

It is widely accepted that fruit and vegetables are important components of a healthy diet, and that their consumption could help prevent a wide range of diseases. Epidemiological data support this protective effect against several types of cancers and cardiovascular diseases *(1-3)*. The increasing scientific evidence that consumption of fruit and vegetables decreases the risk of several chronic diseases has created a firm basis for policy initiatives. Insufficient consumption of fruit and vegetables was among the risk factors recognized as contributing to the worldwide noncommunicable disease burden *(4)*. Experts have recommended a daily intake of least 400 g of fruit and vegetables *(5)*.

WHO aims to promote an increase in fruit and vegetable consumption, so that sufficient quantities become part of the daily diet in all countries. This implies the formulation of recommendations as well as the provision of support to countries in developing and implementing evidence-based strategies. The intake goals should be expressed in numerical terms, so that the potential public health benefits can be evaluated. These goals refer to population averages. However, knowledge of the actual intake distribution will be needed for the strategies to be set up properly and to assess what changes need to be made if the recommendations are to be met *(6)*. It is well known that populations have diverse food availability and preferences, differing dietary patterns and cultural consideration of foods. Local circumstances must be carefully considered in adaptation of dietary guidelines to individual country diets and populations *(7)*. However, there must be some degree of comparability to permit effective monitoring of potential health benefits.

In both these areas ─ quantitative recommendations and monitoring of change ─ it is important to be able to measure intake. However, it is difficult to measure diet accurately. Many dietary guidelines include advice on the consumption of at least five portions a day of fruit and vegetables *(7)*. There is an implicit assumption of a common understanding of the terms “fruit” and “vegetable”, as well as a common appreciation of

the size of a portion. In fact, both the definitions of fruit and vegetables and portion size vary considerably between countries.

This paper analyses the main issues related to measurement of fruit and vegetable intake: how measurement may be affected by differences in definition of groups of fruit and vegetables; the influence of measurement methods and the problem of measurement error, both in the broad context of nutritional epidemiology and specifically in the measurement of fruit and vegetable intake; factors explaining variability in the estimation of fruit and vegetable intake (with particular emphasis on portion size); and the implications of the main issues related to comparability and standardization of fruit and vegetable intake for dietary recommendations and research.

2. Definitions

In a very broad sense the term "vegetables" refers to edible plants, commonly collected and/or cultivated for their nutritional value for humans. Most often, the botanical definition of vegetable is the "edible part of a plant". According to this definition, fruits are a subset of vegetables, as the term "fruit" refers to the mature ovary of a plant which encloses the seeds. This definition includes both fleshy fruits and dry fruits such as cereal grains, pulses and nuts, with specific characteristics of the ripened ovary wall. Despite the precision of botanical definitions, culinary definitions are commonly preferred. Based on cultural uses of foods, they correspond better to what is understood by research participants *(1)*. Apart from these classifications, definitions of fruit and vegetables should always relate to their nutritional qualities and the health benefits attributed to them. Described from a nutritional point of view, fruit and vegetables are low energy-dense foods relatively rich in vitamins, minerals and other bioactive compounds as well as being good sources of fibre *(2)*.

Clearly, there are some groups of plant-based foods that are usually not considered as vegetables in most classifications *(1)*. Minor groupings include some herbs or spices, as well as plant products used to make coffee, tea or chocolate. All of these are classified under specific food groups other than vegetables. In the same way, foods derived from fruit and vegetables, such as jams and jellies, that may not retain the nutritive value of the original food, are usually placed into "sweets" or "sugars" groups in most classifications. Among major groups of plant-based foods, cereals constitute a

category that is clearly identified as differing from fruit and vegetables. Cereals contain on average 70% starch in weight. They are also a valuable source of protein and fibre (non-starchy polysaccharides), mainly in the form of wholegrain cereals. They are the starchy staples in most diets, and contribute to a substantial part of energy intake in many parts of the world *(2)*.

The inclusion of potatoes and tubers, and legumes or pulses as vegetables is more controversial *(2)*. As a group, potatoes and tubers include also sweet potatoes, yams, taro, and cassava or manioc. These plant foods contain variable amounts of starch, from 12% to 50%. The potato is currently the most important starchy food in most developed countries. Pulses are derived from the fruits and seeds of a number of leguminous plants, including those that have matured and dried (often termed “beans” or “legumes”) and immature pulses such as fresh green peas. Dry legumes are the richest plant source of protein; however, they also share with vegetables the fact that they are a good source of fibre and some bioactive compounds such as isoflavones, found particularly in soya beans. While potatoes are often considered as vegetables, many dietary guidelines put this group together with cereals as starchy foods *(7)*. Some dietary guidelines explicitly exclude them from the recommendation to increase intake of vegetables *(2)*. In most cases legumes are included as vegetables, although sometimes dry beans are put with meat and fish in the protein-rich foods *(7)*.

Fruit classification is less debated, although there is no consensus about the inclusion of nuts, which are dried fruits often enclosed in hard shells. Nuts are energy-dense foods, with most of their energy coming from fat, and they are important sources of unsaturated oils and proteins. This may explain why, in some cases, they have been coupled with pulses. However, like fruits, they are high in bioactive compounds, including vitamins and minerals, such as vitamin E *(2)*. The same applies to other botanical fruits with high energy content, such as olives or avocados. Where fruit juices are 100% pure juice, they can provide most of the micronutrients that are present in the original fruit, although fibre is lost and in some cases sugar is added. Many products labelled as “fruit drinks” contain only small amounts of the original fruit juice. In general, most of the properties of the original product are preserved in canned, frozen and dried fruit and vegetables. Many cultures traditionally dry both fruit and vegetables in summer for use in winter, reconstituting them by soaking in water before consumption or cooking; this happens both commercially and domestically.

It may be helpful to use the term "vegetables and foods used as vegetables". This could include the edible part of plants commonly considered as vegetables, and could also easily accommodate other foods such as fresh green pulses and sprouts, fresh sweetcorn (botanically a cereal), botanical fruits used as vegetables such as tomatoes, peppers, cucumbers or eggplants, as well as mushrooms and seaweed (which are not even considered to be plants according to the classification of living organisms). Potatoes and tubers, as well as dry pulses, are not considered to be vegetables. Their exclusion is not a recommendation to avoid eating them, but a recommendation that they should not be included in measurements of recommended intakes of fruit and vegetables. "Fruits" should include fresh or preserved fruits except those classified as vegetables. Despite the high energy content of some fruit and nuts, they are, in most cases, included in the fruit group. With a few exceptions, consumption of these fruits is very low.

3. Measuring intake: assessment of food consumption

Food consumption data may be obtained at the aggregate population or individual level. This section briefly describes the main methods for assessing dietary intake, and their relative merits and drawbacks. A detailed discussion of the different dietary assessment methods is given elsewhere *(8)*. Food supply data at the national level such as *food balance sheets* provide estimates of food availability at the national level. These may be used to derive average per capita availability of food and nutrients. The food balance sheets may, however, overstate the amount actually eaten since they do not account for losses due to waste and processing. *Household surveys* focus on consumption but do not provide information on food distribution among individual members. Aggregate methods are useful for making overall comparisons among geographic areas and for monitoring overall trends over time.

Methods used to collect individual information on dietary intake are mainly based on questionnaires or records. An in-depth review of such methods may be found elsewhere *(9)*. *Food diaries* or food records require the subject to report all foods consumed for a specified period, often one week. Weighted records require, additionally, the weight of all consumed foods. The *24-hour dietary recall* (24HR) consists of reporting all foods consumed within the 24-hour period prior to the

interview. Several types of aids may be used to help people in this recollection, especially in determining the amounts consumed. Typically recalls are conducted as face-to-face interviews, but they may be carried out by telephone or self-administered. A *food-frequency questionnaire* (FFQ) contains structured lists of individual foods or food groups. Subjects are asked to estimate the frequency of consumption of those foods, indicating the number of times the food is consumed over a given period (day, week, month). In some cases the FFQ is semi-quantitative as it specifies a standard serving or portion for each item. It can also be quantitative when, in addition to frequency, the respondent may indicate any amount of food consumed. The FFQ may include a wide range of food items. The questionnaire is often self-administered. The literature regarding the design, utilization and validation of FFQs has recently been reviewed *(10)*. The *diet history* is a meal-based collection of usual food intake that aims to report the dietary intake of a typical week for a particular timeframe. Additional tools may be used, starting with a detailed listing of foods commonly consumed, and using aids to estimate the amount consumed of a reported food. The diet history is rather a complex dietary assessment method and requires extensive training for interviewers. Even more complex are methods involving chemical analysis of diets, such as the dietary duplicate method. Such complex methods are not suitable for application at the population level.

3.1 Dietary assessment methods for fruit and vegetable consumption

As for other food components, several issues must be considered when selecting the method to estimate fruit and vegetable consumption. These issues include the specific purpose of the study, the need for group data versus individual data, the population characteristics, the timeframe of interest, and the available resources. Methods based upon aggregate data are useful for crude comparisons among communities or monitoring trends but lack information at the individual level ─ a major limitation. The diet history is highly dependent on interviewers, while food diaries are highly dependent on the compliance of participants. Both methods involve complex logistics, and are less suitable for large populations.

Measurement of food components in body fluids and tissues may also be used as a marker of consumption. Although plasma carotenoids have reportedly been good biomarkers of fruit and vegetable intake, they are only surrogates of consumption and

do not provide direct measures of actual intake *(11)*. They do have a role, however, in validation studies.

Nowadays, as for many other foods, the most often used instruments to estimate fruit and vegetable consumption are the food frequency questionnaire and the 24-hour dietary recall. Both methods are based on memory, and recall problems may appear in either of them, although the 24HR method should be affected to a lesser extent. FFQs are often used to assess past intake or the usual intake over a longer period, while the 24HR questions refer to a short period very close to the interview. Both methods have good compliance. The 24HR method is appropriate to measure current intake in groups of subjects. It is therefore particularly well suited to assess the group mean of fruit and vegetable intake, assuming the representativeness of the population sample and a well-balanced distribution of 24HR surveys by season and weekdays. The main limitation is that the 24HR method does not provide reliable estimates of the usual intake, reflecting day-to-day variations, unless the same subject answers repeated surveys. The best characteristic of the FFQ in this context is its great flexibility and ease of application *(12)*. The quality of the estimates, however, is highly dependent on specification: whether fruit and vegetables are expressed as groups or single foods in the questionnaire, and the number of items included. Questionnaires allow quantitative estimates if they provide a detailed list of fruit and vegetable consumption in a population and specified quantities for each food item. However, it is commonly accepted that FFQs are better suited to ranking subjects by level of intake than to producing absolute estimates of intake. Where a specific food group, rather than overall diet, is the object of the measurement, a tool called *"focused recall"* may be used. This approach combines the short-term recall used in the 24HR method with some simple categorization of responses used in the FFQ. When compared with a full 24-hour dietary recall, the focused recall underestimated vegetable intake by 4.5%, and overestimated fruit consumption by 12.5% *(13)*. However, the focused recall record can be completed in a few minutes by staff with minimal training.

The purpose of the assessment is one of the main issues to consider in the selection of dietary assessment tools. Estimates of fruit and vegetable intake may be needed, for instance, for nutritional surveillance, nutritional assessment, design interventions, or screening for nutritional programmes. Different purposes call for different values, and consequently for different assessment methods. Most analytical studies look for the relationship between disease risk and level of intake. Rather than providing a measure

of absolute intake of fruit and vegetables, these studies ought to be ranking individuals according to their relative intakes. This requirement, often termed as "ranking validity", is met by the FFQ. These instruments are therefore very popular tools *(14,15)*. For other purposes, precise estimates of average fruit and vegetable intake are needed, or a determination of the proportion of a population eating below or above a given level of recommended intake. In these situations alternative instruments must be considered. Even in analytical epidemiology, simply saying that lower or higher intake is associated with higher or lower risk is not enough and analysts should try to determine the quantitative relationship of fruit and vegetable intake to different health outcomes. This may have important policy implications. The appropriateness of each method must therefore be carefully considered.

4. Measurement error: sources, types and effect

A major challenge to nutritional research is the correct measurement of dietary intake. In the absence of truly objective measures of diet, the goal is to obtain the best measure of diet possible, according to the purpose of the study *(8)*. In practice the net measurement error is the result of the interaction of several sources of error. As most tools to assess dietary intake are recalling methods, the unreliability of memory remains the central inherent problem. Many other factors related to the subjects may affect the accuracy with which dietary intake is measured e.g. education, age, gender, cultural background, health status, knowledge and attitudes. Moreover, many aspects of the method used to assess dietary intake may be a source of error. Among these are the structure of the questionnaire, the timeframe recalled, the order of the questions, or the use of visual aids to quantify foods.

Whatever the source, in quantitative terms the overall measurement error can be defined as the difference between observed (measured) intake and the true intake. This overall error can be split into *systematic* and *random* error. In nutritional epidemiology systematic errors are often referred to as *scaling biases*. These arise when the observed intake, on average, overestimates or underestimates the true intake. In some cases this bias is constant, but often the amount of overestimation or underestimation is proportional to the true intake *(proportional scaling bias)*. The component of error not related to the true intake is considered to be random *(16,17)*.

The effects of biases in dietary intake have been considered mainly in the context of analytical research. Although scaling errors may cause bias in relative risk for quantitative differences in intake and may complicate pooling data from different populations, they do not affect relative risk estimates for categories of subjects ranked according to intake level. On the other hand, the random error leads to underestimation of measures of association, a phenomenon often termed as *attenuation*. Validation studies have tried to correct for attenuation bias using the correlation between observed and true intake sometimes called the *validation coefficient*. As surrogates for true intake *(gold standard* or *reference method*) most studies have been based on the average of repeated daily intake. A number of assumptions and requirements must be met by the reference measurement, and more complex designs need a third measurement of intake, often a biomarker, and specific statistical methods *(16,17)*.

4.1 Assessment of measurement error

Most factors affecting accuracy of dietary intake assessment apply to a similar extent to most diet components. For fruit and vegetables, subjects may be influenced in their reporting by social desirability. They may overreport consumption simply because high intake of such foods is promoted as a healthy habit. Overreporting or underreporting by scaling biases or random errors has been assessed in validation studies. Fruit and vegetable intake, estimated by means of the food-frequency questionnaire or a diet history, was compared with the average intake of twelve 24-hour dietary recall records over a period of one year in a sample of volunteers in a multicentric cohort study in several European countries. The correlation coefficients for fruit and vegetables ranged from 0.30 to 0.79 *(18)*. They were consistently higher for fruits. There was no clear pattern by sex: women showed higher coefficients in Germany and lower coefficients in Spain and the Netherlands; in Italy and Sweden the correlation was better for men regarding fruit intake, and worse for vegetable intake. These results are consistent with validation studies from other cohort or intervention studies *(19−21)*. In order to assess overreporting or underreporting, the mean intakes of fruit and vegetables were compared in the same study in three countries, the Netherlands *(22)*, Spain *(23)*, and Italy *(24)*, where results were given separately for men and women. With very few exceptions the FFQs or diet histories showed a higher consumption than the mean of the twelve 24HR records. This overreporting ranged from 4% to 44% of intake measured

by the reference method. It tended to be higher for vegetables and women tended to overreport consistently more than men.

In comparison with analytical research, relatively little has been reported on the validity of fruit and vegetable intake in public health studies, dietary surveys and nutrition intervention programmes. A report examined bias and precision in three large studies in the United States of America, where dietary assessment was carried out by means of FFQs, with four-day food records or 24HR records as the reference method *(25)*. Underreporting or overreporting of FFQs as compared with dietary recall (the reference method) depend on the type and structure of the questionnaire. The summation method, based on adding up the total servings of all fruit and vegetable items in a comprehensive questionnaire with 30 or more items, yielded very similar estimates both for the FFQ and the food record, but overestimated the consumption of fruit by more than 40%. On the other hand, estimates based on a short FFQ with seven summary questions underreported fruit intake by 16% and vegetable intake by 19%. An interesting study compared a culture-sensitive quantitative FFQ with seven-day weighted food records among 74 volunteers (80% females) in the adult African population of the North West province, South Africa *(26)*. The correlations between intakes from FFQs and dietary records were 0.38 for fruit and 0.41 for vegetables. Vegetable intake was overestimated by 6.7% in the FFQ, while fruit consumption was 36% lower than the estimate of the seven-day record.

Most dietary assessment procedures have been used to characterize average consumption at the group level, rather than to characterize the dietary consumption of individuals, as would be the case in intervention programmes targeting people who met predefined dietary criteria. If scaling bias is ignored, the proportion of misclassification is partly a function of random error. In statistical terms: one, minus the square of the correlation between observed and true intake, equals the proportion of total variance of the observed intake explained by error. A recent paper assessed the expected levels of misclassification using this statistical background, assuming bivariate normal distributions of both the true and observed intake *(27)*. Assuming that the aim is to identify people eating fewer than 400 g per day of fruit and vegetables in a population where this cut-off point is the median of the observed intake, for commonly reported values of the correlation between true and observed intake ranging from 0.3 to 0.7, the predictive values approximately vary from 60% to 75%. This means that between 25% and 40% of subjects, who qualified for specific intervention because they ate fewer than

400 g daily, actually consume the recommended amount or more. In the same way, between 25% and 40% of subjects who are thought to achieve the 400 g per day of fruit and vegetables actually consume less than this amount. Misclassification only becomes negligible for correlations above 0.9, but these values are very uncommon in dietary studies. Following the general rules for diagnostic tests, the predictive values vary with prevalence. Thus, in populations where more than half of the subjects eat fewer than 400 g per day of fruit and vegetables, the positive predictive values improve and the negatives get worse. The opposite occurs in populations where the prevalence decreases of low consumers of fruit and vegetables.

5. Measuring fruit and vegetable intake: determinants and related factors

Valid measures of fruit and vegetable intake are needed for both nutritional research linking health outcomes with consumption as well as for public health research and programmes. Ideally, these estimates must provide valid data at the individual level giving absolute values of actual intake.

5.1 Composite foods, mixed dishes and recipes

The majority of studies report intakes of fruit and vegetables consumed as discrete portions only, and do not disaggregate the data on composite foods. Most dietary guidelines refer to fruit and vegetables as single foods. It is not clear whether nutritional studies include composite foods when estimating fruit and vegetable intake, and how they deal with this issue. In this context mixed foods are considered as being any kind of food, mixed dishes or recipes that include fruit or vegetables with other components. The relevance of including these items may largely depend upon dietary patterns and the way in which fruit and vegetables are commonly consumed in different populations.

A recent report analyses the importance of composite foods in the estimation of fruit and vegetable intake among Irish adults *(28)*. The authors used data from the North/South Ireland Food Composition Survey, collected in a random sample of subjects aged 18−64 years by means of a seven-day food diary. Excluding potatoes, the overall contribution of composite foods to total vegetable intake was 26% (25% for men and 27% for women). For fruit the contribution of composite foods was 12% (14% for men and 10% for women). Mean intakes of vegetables from composite foods among

professional, managerial and technical workers were higher than among semi-skilled and unskilled workers. A clear trend was shown of increasing consumption of vegetables as components of composite foods with educational level. Consumption of fruit from composite foods was significantly lower among subjects below 35 years of age, but there were no differences regarding education level or categories of social class.

The contribution of composite foods to total vegetable intake was similar in a calibration study within a multicentric cohort study. Details about the design of the study and patterns of vegetable and fruit consumption have been published elsewhere *(29,30)*. In this study dietary data were collected by means of a 24HR record for subjects aged 35−74 years from 10 European countries. Overall, 30% of total vegetable intake, excluding potatoes and legumes, was accounted for by foods reported as being ingredients of recipes or components of mixed dishes. This proportion varied markedly by country, ranging from 12% in the United Kingdom to 54% in Greece. A very different picture arose for fruit intake, as only a small amount of less than 1% of total consumption was reported as being components of recipes or mixed dishes.

Overall, underestimation induced by exclusion of composite foods seems to affect vegetables more than fruit intake in food diaries and 24HR records, and is probably higher than the expected underestimation in FFQs. It is most likely that composite foods, where the major components are fruit or vegetables, are considered when people report their frequency of consumption in FFQs. In any case, inclusion of explicit references to mixed vegetable dishes in FFQs seems to increase the instrument's validity *(31)*.

5.2 The relative importance of frequency of consumption and portion sizes

Frequency of consumption means the number of times that a food or food group is consumed over a given period of time. In many FFQs this is the only information gathered and it seems to be sufficient to rank subjects according to their intake. However, in order to get a quantitative estimate of fruit and vegetable intake, frequency must be coupled with some measurement of the amount of each food, either assigned as a standard portion or provided by the subjects as part of the information gathered in the questionnaire.

As already noted, the structure of the questionnaire is related to validity and precision of fruit and vegetable intake based on the frequency of consumption. In particular, the degree of detail with which fruit and vegetables are specified seems to be very important *(25)*. In the same way, a review of different models of brief survey instruments, most of them FFQs, concluded that instruments with a moderate number of fruit and vegetable items have a greater validity in comparison to those with a short list of foods *(31)*. Furthermore, better quality of measurement of fruit and vegetable intake was also attributed to instruments that included questions on portion sizes and on consumption of mixed vegetable dishes.

A recent report has assessed the influence of adding information on portion sizes to FFQs *(32)*. A short questionnaire with six items based on the behavioural risk factors surveillance system (BFRSS) was used to estimate fruit and vegetable intake based only on frequency of consumption. The second set of questions used was identical, except for its inclusion of explanatory definitions of serving size based on the United States Food and Drug Administration (USFDA) definitions. The questionnaire was administered to a sample of adults from Washington State (United States of America), using a random-digit-dialled telephone survey. The information was combined to produce two summary scores. These were then used to evaluate whether the individual met the recommendation of eating at least five portions of fruit and vegetables a day. The specific wording of questions had a large effect on the overall fruit and vegetable consumption: only 26% reported that they ate at least five servings per day based on a BFRSS-type measure. This prevalence increased to 50% when the question included a definition of serving size. This effect was similar across categories of age, sex, income and education. A similar result was found among adult blacks from a rural area in North Carolina, United States of America *(33)*. In a telephone questionnaire some participants answered with the aid of two-dimensional portion models that had been mailed to them before the telephone interview. Where subjects had information on portion sizes, estimates of fruit and vegetable intake increased by 18%. According to these results, omission of portion size information may substantially affect the underestimation of fruit and vegetable consumption. Nevertheless, it must be kept in mind that these results come from two brief FFQs, and that it has also been shown that questionnaires with a short list of items tend to underestimate consumption both compared to reference methods and to detailed questionnaires *(25,31)*.

In a different approach to this issue, a study was made of data from the EPIC-Norfolk study, taking the seven-day food diaries of 269 subjects with a mean age of 69 years *(34)*. Intake frequencies (servings per day) were calculated as the number of occurrences divided by the number of diary days for each subject. Average serving sizes in grams were calculated as the total weight of fruit and vegetables consumed, divided by the total number of servings reported by each subject. Foods eaten in very small amounts that could not be considered a portion, such as those used for condiments, were not considered. By comparing high and low levels of consumption (those eating at least, or less than, 400 g per day, respectively) it was found that frequency of intake had much more impact on classification than serving size. High-level consumers ate about twice the amount of fruit and vegetable reported by low-level consumers (531 g versus 260 g per day). However, there was a difference of only 13% in the mean serving sizes (93 g versus 82 g), while the difference in frequency of consumption was 78% higher (5.7 versus 3.2 servings per day). These results suggest that strategies to increase average fruit and vegetable intake towards the recommended daily consumption of 400 g should focus on encouraging people to eat fruit and vegetables more often.

In another report, different counting methods were compared, looking at how estimation of fruit and vegetable consumption depends on the food databases used to analyse intake *(35)*. The authors used 24HR records collected from 617 randomly selected fourth-grade students (aged 8–9 years) in Minnesota (United States of America). Three schemes were applied to calculate servings of fruit and vegetables: the "5 A Day" counting scheme was based on grouping fruits and vegetables as they are presented in food guidelines such as the *Food Guide Pyramid*; a second scheme used the classification drawn up by the University of Minnesota Cancer Prevention Research Unit (CPRU), which was also based on broad categories of fruit and vegetables; and the third scheme used a very detailed list and serving sizes that had been provided by the USFDA. The average number of servings estimated according to the detailed scheme of the USFDA was 4.1; the mean number of servings was slightly lower (3.9 servings) for the "5 A Day" scheme, and higher for the CPRU scheme (5.1 servings). On the assumption that the USFDA scheme is the most accurate, as it is the one with the greatest degree of detail, different schemes may produce either underreporting or overreporting. However, this effect is not homogenous. For vegetables the CPRU scheme yielded the same estimate as the USFDA and the "5 A Day" counting scheme produced substantial underreporting. Both the "5 A Day" and CPRU overestimated fruit

intake in comparison with the USFDA estimate. A remarkable feature of these two studies *(34,35)* is that they deal with frequency of consumption and portion sizes derived from dietary data where subjects have not estimated them directly, instead they described what they ate in a free way without any constraint to a predefined framework of frequencies and standard amounts coupled to these frequencies.

5.3 The size of portions: epidemiological studies

While relative intakes of a group of subjects may be assessed based solely on frequency of consumption, valid and reliable estimates of individual intakes always need some kind of quantification of the portion eaten at each consumption occasion. Recalling and reporting sizes of food consumed is a difficult cognitive task. People must refer to weights, volumes and dimensions, with a considerable variety of units and shapes. Many factors are involved in the cognitive process of recalling portion sizes, and consequently a diversity of strategies may be considered in dietary recall procedures *(36)*. Overall, it seems that portion sizes of foods that are commonly bought or consumed in defined units, as is the case for many fruits, are usually more easily reported than irregularly shaped foods. Two-dimensional or three-dimensional models and pictures may help, as well as common household measures. The latter, however, tend to produce overestimation. Whatever the means and aids used, it is widely accepted that accuracy of reporting is highly dependent on training of both the interviewer and respondents. An additional difficulty is the potential variation over time of actual portion sizes. It has been shown that average portion sizes of commonly consumed foods in the United States increased both inside and outside the home for most categories of foods between 1977 and 1996 *(37)*. This may be important when different timeframes are considered in different surveys.

In order to give an idea of the amount of fruit and vegetables people actually eat at each consumption occasion it may be useful to analyse data from studies where respondents are not asked to estimate a portion size, or to refer to a predefined amount to be coupled with frequency of consumption. In these studies predefined serving sizes, standard portions, household measures and visual aids may be offered to respondents as one among several ways to better quantify food. The final amount reported always refers to the amount of a particular food as it was consumed by the subject on a specific occasion. These amounts are referred to as “actual portions” or “serving sizes”, as

opposed to “standard” or “estimated” portion sizes. Serving sizes for different fruit and vegetables from the EPIC-Norfolk study (United Kingdom), estimated from seven-day food diaries *(34)* are shown in Table 1, calculated as the total weight of fruit and vegetables consumed, divided by the total number of servings consumed by each subject. The geometric mean weight of a serving of fruit and vegetables combined was 86.2 g, but average servings tend to be larger for fruits than for vegetables. The largest servings were observed for commonly eaten fruits such as oranges and apples; soft fruits such as strawberries and raspberries were also eaten in relatively large servings. Average serving sizes of frequently consumed vegetables such as carrots, peas and broccoli were less than 80 g. This weight, used as the reference for portions in current recommendations for fruit and vegetable consumption in the United Kingdom, seems appropriate on average, but there is a wide variation. For instance, within the median intake of 61 g for carrots, 20% ate 39 g or less and 80% ate 72 g or more per portion; similarly, for strawberries the median intake was 103 g with 20% eating 60 g or less and 80% eating 150 g or more. However, no such high degree of variation was found for consumption of apples, pears, grapefruit or bananas.

A similar exercise was performed for the cohorts of the calibration study in the EPIC project in 10 European countries *(29,30)*. Since these data were gathered by means of 24HR records there is no role for frequency in the estimation of portion sizes. Mean portion sizes were calculated by averaging the quantities reported on each occasion at which a subject referred to consumption of a food classified within the groups of fruit or vegetables; separate averages were estimated for potatoes and legumes. The main parameters of the corresponding distribution are shown in Table 2. These estimates took into account only foods that were reported as single foods, excluding those reported as ingredients of a recipe. All the distributions tended to be right-skewed. In agreement with the estimates made in the previous EPIC study, the mean portion size for vegetables was below 80 g (68.1 g) while it was clearly above for fruits (127.3 g). The average portion of legumes was high, at 138.1 g (it should be recalled that, in this document’s classification, the vegetable group did not include legumes). Potatoes and other tubers had an even higher mean portion size, of 155.6 g. Both fruit and vegetable groups showed a high variation, especially vegetables, which showed a standard deviation almost equal to the mean, and an inter-quartile range exceeding the mean value by about 15%. In Table 3, mean portion sizes are compared by country and several demographic and diet-related variables. For vegetables, mean

portion sizes were within the range 70−90 g in France, Italy, the Netherlands, Greece and Germany, with smaller portions found in Spain, the United Kingdom, and Scandinavian countries, the lowest value being 43.8 g in Sweden. The average portions of fruits were markedly higher in all countries, ranging from 98.1 g in the United Kingdom to 155.8 g in Spain. Average portions of both fruit and vegetables were larger for men than for women and tended to increase with age for vegetables only, without showing any pattern of change in portion sizes by education level. Obese subjects tended to eat larger portions of vegetables and fruits, adjusted for age and sex. Finally, people eating larger amounts of vegetables consumed greater portions as well, while the average portion size of fruit seemed not to be related to the total amount of fruit consumed.

5.4 The size of portions in dietary guidelines and public recommendations

Many countries have adopted the recommendation to eat at least 400 g a day of fruit and vegetables, and many experts and organizations include this recommendation in their guidelines *(2,5,38)*. Campaigns now advise people to eat five portions of fruit and vegetables daily, adopting the well-known simple message of "5 A Day", initiated in the United States and extended to several countries *(39)*. Many national dietary guidelines, however, only provide qualitative advice, such as "increase your fruit and vegetable consumption", "eat a variety of fruit and vegetables every day" or "eat plenty of fruit and vegetables". This is the case, for instance, for Chile, China, Finland, France, Ireland, Norway, Portugal and Sweden *(40-47)*. Dietary guidelines from some countries, such as Denmark, Germany or Indonesia *(48-50)*, give recommendations in quantitative terms as portions or servings without a definition of what is meant by such a portion or serving.

Several countries provide definitions of portions or servings in guidelines along with public recommendations. These definitions are summarized in Table 4 *(51−69)*. the listing is not intended to be exhaustive, but to give a broad picture of how portion sizes are expressed around the world. Several countries take the consumption of 400 g, or five portions of fruit and vegetables, every day, as their minimum starting point for recommendations. Most provide disaggregated recommendations for fruit and vegetables, while a few make overall recommendations. Examples of vegetable portions or servings are, in general, defined by reference to household measures for a serving of

vegetables, while for fruit the definition tends to refer to single items of fruit, according to their size. In most cases a distinction is made between raw and cooked vegetables. Although household measurements and natural units for fruits are extensively used, only certain guidelines provide weight and volume references for the common measures given *(51–55)*. The British guidelines *(53)* explicitly state that the definitions given have been adapted to fit portion sizes equivalent to 80 g. In some national guidelines *(56–58)* there is only an indication of weight reference for portion size, while in others *(59–69)* servings or portions are defined based on volume. All the guidelines provide examples of a "reference portion" using foods commonly consumed in each particular country, but, in some cases such as United Kingdom *(53)* and New Zealand *(54)*, a detailed list is given of fruit and vegetables with their specific mean weights. The most often used household measure is a cup, equivalent to a volume of 250ml; most guides equate this volume to the weight of one portion of raw leafy vegetables, while a half-cup is a weight-equivalent of one portion of cooked or raw chopped vegetables. One whole medium-sized fruit is in general considered as one portion; examples of such fruits are apples, oranges, pears, bananas, peaches, mangoes, or two smaller-sized fruits, such as plums, kiwis or apricots. For large fruits such as melons, watermelons, papayas and pineapples, one slice is referred to as one portion, but no formal definition of such a slice is provided. There is more heterogeneity when defining one portion of very small fruits (berries, cherries), although a half cup is often mentioned.

6. Standardization and comparability of intake

Many fruit and vegetable promotion programmes attempt to achieve increased consumption by advising people to eat at least a certain number of portions or servings a day (usually five). The portion size therefore needs to be clearly defined. However, it is evident that such a universal definition of portion size does not exist. This is understandable given the large variability of dietary patterns, which are strongly related to cultural aspects such as food preferences, as well as to food availability. Consumers need health information that is clear, unambiguous and easily understandable, taking into account the different ways foods are usually eaten and quantified in each country.

Ideally, any common definition of portion sizes should be: user-friendly to the public; consistent with accepted guidelines; representative of portions or servings

commonly used; and comparable. But is the real need for comparable estimates of fruit and vegetable intake, or is it for standardization of portion sizes? Clearly, once it is agreed that increasing fruit and vegetable intake is to be promoted by asking people to increase their frequency of consumption, a common standard for a portion size to be coupled to this frequency must be established in order to get a universally valid message. However, this is, to some extent, an oversimplification of the overall issue. As noted earlier, a final estimate of fruit and vegetable intake involves several determinants, and portion size is just one of them.

6.1 Standardization of fruit and vegetable measurements

If standardization is considered as the referral of quantitative data from different sources to a common scale, this kind of standardization already exists: simply express the recommendation in standard units of weight, such as g, so that the advice is to eat a minimum of 400 g per day of fruit and vegetables. The problem then becomes one of translation of weight to common languages, each one of them reflecting a different cultural background. Four principal elements play a role in this exercise of translation: which specific foods must be considered as fruit and vegetables, to what extent composite foods or recipes should be considered in accounting for overall consumption of fruit and vegetables, the frequency of consumption, and the portion size to be coupled with that frequency.

Even though it is not straightforward, a definition of fruit and vegetables and requirements to include or exclude composite foods could be agreed, or at least some criteria could be set up. To establish the quantitative minimum weight recommended, the relationship between two factors needs to be considered. However, although several combinations of frequencies and servings or portions could be valid, the message of "eat at least five a day" has become so widely diffused that in practice this must be considered as a fixed rather than a variable factor. It appears that building a common system of expressing portion sizes would be the easiest way of getting a standardized measurement of vegetable intake across countries, with an approximate weight of 80 g.

Despite the great variation in national contexts, there do seem to be some common factors underlying most definitions. For vegetable portions, a volume of 250 ml of raw leafy vegetables or half of this volume (125 ml) of cooked or chopped vegetables accounts for approximately 80 g. This volume is, in many cases, described as being

equivalent to a “cup” or “bowlful”. For fruit, the edible part of one whole medium-sized fruits or two smaller-sized fruits account for at least 80 g. For very large or very small fruits, as well as juices, some adjustment must be made to fit the approximate scale.

6.2 Comparability of measurements: validity and calibration

Most of the issues raised so far relate to the standardization measures useful to formulation of recommendations and dietary guidelines. This section deals with the more research-oriented requirement for the comparability of data. When pooling data, comparison is allowed to the extent that the data use the same measurement scale. This is often referred to as “standardization” or sometimes “adjustment” (mainly in epidemiological literature). Establishing the standard is the key issue in that case. However, in research, validity is the central issue for measurement quality. To improve validity is also to improve comparability: the more accurate the measured intake, the closer it approaches true intake. True intake may be considered an “ideal” standard.

In practice, a reference method is used as a surrogate for unmeasured “true” intake, in order to improve both the validity of dietary intake estimates as well as the comparability of data from different sources. This procedure is often referred to as “calibration”. Usually, unbiased point estimates and uncorrelated errors with the measurement instrument are requirements for a reference method. Theoretical backgrounds as well as practical development and application for multicentric cohort studies have been reviewed elsewhere *(70,71)*.

The calibration approach uses the reference method as a standard measurement. However, it is important to keep in mind that “standardization” in this instance refers to the measurement method as a whole. This may or may not include standardization of every component involved, including portion sizes, but not restricted to this factor. This approach was developed in the context of multicentric prospective studies, but should also be considered in other fields of nutritional research, such as measurement of fruit and vegetable intake when comparability across populations is a major requirement.

7. The challenge of measuring global fruit and vegetable consumption

Clearly the assessment of fruit and vegetable intake worldwide needs valid and comparable measurements. As has already been pointed out, one major limitation is the lack of a common definition for the collective term "fruit and vegetables". Furthermore, the food content of potentially important components depends on numerous factors such as their preparation method, the variety of products and their growing and storage conditions. These factors are increasing in importance as many foods are transported to ensure year-round availability, mainly in industrialized countries *(72)*.

Another limitation on getting valid measurements of fruit and vegetable intake relates to the lack of survey data from many regions. When these data are available, there are other issues to consider such as the intrinsic difficulties of survey methodology. To achieve comparable estimates, appropriate adjustment factors must be applied according to the age and sex structure of the population.

One way of dealing with this lack of survey data is to use the available estimates of national mean intakes of fruit and vegetables. However, when comparability is a major issue, possible discrepancies between ecological and individual data must be taken into account. A recent report looked at fruit and vegetable consumption in 15 countries, comparing population survey data with national availability data provided by the FAO food balance sheets *(73)*. Overall, fruit and vegetable intake had been overestimated in all countries except Finland, with consumption overestimates ranging from 5% to 90% in European countries, and in Australia, China and Japan. The greatest discrepancies were seen in Israel and the United States, where estimates taken from food balance sheets were more than double the estimates taken from survey data.

Given so many limitations, there seem to be two options: either to use the available data, applying assumptions and extrapolations when needed and interpreting them with caution; or to exclude regions and countries which do not have good data on fruit and vegetable intake at the individual level, which would mean in practice a continued focus on developed countries. An obvious alternative would be to encourage countries to assess their dietary intake — and specifically their populations' fruit and vegetable consumption — using comparable methods, agreed through broad consensus, and trying to balance the needs for greatest accuracy, simplicity and low cost *(72)*. Section 7.1 outlines one suggestion for achieving simple and comparable measures of global fruit

and vegetable intake, as well as specific considerations related to both measurement and public health issues concerning fruit and vegetable consumption in developing countries.

7.1 Measuring fruit and vegetable intake: a surveillance approach

This approach is based on the fact that comparable surveillance systems need standardized data collection over time and across countries, and must be flexible enough to be applied in a variety of settings. The STEPwise approach *(74)* is the tool WHO recommends for risk-factor surveillance and is intended to contribute to improving global information and monitoring trends on key health-related measures. The assessment is questionnaire-based. So, for example, fruit and vegetable intake is gauged through asking four basic questions. First, the subject is asked how many days in a typical week he or she eats fruit, and how many servings of fruit he or she eats on one of those days; then the same two questions are asked for vegetables. Cards are available during the data collection, showing some examples of local fruit and vegetables, as well as representing the size of a serving. It has been pointed out that FFQs with a moderate number of fruit and vegetable items have greater validity than those with a short list of foods *(31.* However, the STEPwise questionnaire refers to two generic terms rather than to a list of specific foods. In this case the issue of fruit and vegetable definition is particularly important, i.e. the subject must clearly know which foods or food groups he or she should have in mind when reporting fruit and vegetable consumption. Where composite foods are considered, if good representation is provided of the actual serving sizes typically consumed in each particular country, it can be expected that the estimates of fruit and vegetable consumption produced are reasonably valid.

7.2 Measurement of fruit and vegetable intake in developing countries

Lack of availability of extended survey data at the individual level seems to be one of the main drawbacks to gathering comparable estimates of global fruit and vegetable consumption. However, there are also some issues, specific to developing countries, that are relevant to the issue of measurement of fruit and vegetable intake *(75)*. Most less developed countries are largely tropical. This fact determines which staple food crops are grown, as well as which foods are available to complement the agricultural produce.

It is also likely that some plant-based foods will be gathered through foraging in the wild. In many rural areas people may be, at least partially, self-dependent for foods and in some populations high rates of illiteracy may be found. These aspects have both advantages and disadvantages for dietary assessment: such populations are often difficult to access and require direct interview, however, informants often have first-hand knowledge and recall of exact ingredients and recipes.

Developing countries are experiencing marked demographic changes, characterized by population shift from rural to urban areas. The effect of these changes on dietary intakes has been studied in projects such as the Transition, Health and Urbanisation study (THUSA) in South Africa, developing and testing specific instruments (such as a quantitative FFQ) which are sensitive to the language and culture of the target population's food habits *(76)*. A final issue to consider is affordability. For example, many rural people in Africa eat their vegetables as one dish containing leafy green plants growing wild, as well as other vegetables, depending on what is available. This one dish or relish is eaten in large portions with the staple (usually grain), often more than once a day. Although there is little variety, the portion sizes may ensure adequate fruit and vegetable intake *(77)*. This fact emphasizes the need for instruments and guidelines to be adapted to the country context. In this setting, a recommendation to eat a wide variety of vegetables would not be culturally sensitive or affordable.

8. Summary - implications for research, public health, and dietary guidelines

Both public health measures related to dietary habits, and nutritional research and intervention programmes, need valid estimates, at the individual level, of absolute values of actual fruit and vegetable intake. Of the diverse range of dietary assessment tools available, the most commonly used are the food-frequency questionnaires and the 24-hour dietary recall. Each method has unique features with advantages and drawbacks depending on the purpose of the study. All of them are affected by both systematic and random errors. The 24HR record appears to achieve an acceptable mean estimate at population level but needs repeated recalls to provide estimates of intake at individual level. The FFQ seems to be valid as a means of ranking subjects by level of fruit and vegetable intake but it may be affected by scaling biases and random error when estimating absolute fruit and vegetable intake. In general, compared to reference

methods, FFQs tend to overestimate mainly vegetable intake, although their results are highly dependent on how questions are structured and worded. Correlations with reference methods are often within the range 0.3 to 0.7 *(14)* leaving room for non-negligible random error. Social desirability bias must be considered among the qualitative factors which affect fruit and vegetable intake but which are not related to the method of assessment. This bias is a reflection of people's tendency to report a higher consumption of foods thought to be healthy.

Comparability of fruit and vegetable intake measurement is essential to provide universally valid messages aimed at increasing health around the world. Different populations have different food availabilities, food preferences, and cultural backgrounds related to dietary habits. This makes it difficult to establish common guidelines without taking local circumstances into account. However, some degree of standardization should be achieved. In this document four major factors related to the comparability of fruit and vegetable intake across countries have been identified; portion size is probably one of the most important but is not the only one.

8.1 Definition of fruit and vegetables

Apart from botanical and culinary classifications, food groupings must take into account the nutritional properties of foods as well as their health effects. It is proposed to include as vegetables: the edible part of plants commonly considered as vegetables, as well as foods used as vegetables such as fresh green pulses and sprouts, fresh sweetcorn, botanical fruits used as vegetables such as tomatoes, peppers, cucumbers or eggplants, as well as mushrooms and seaweed. Cereals, potatoes and other tubers, as well as dry pulses, are thus not considered as vegetables. Fruits should include: fruits that are fresh, canned, frozen and dried unless they are classified as vegetables regardless of their high energy content, such as avocados, olives, and nuts. Only fruit juices that are 100% pure should be considered as fruit.

8.2 Composite foods

The term "composite foods" refers to manufactured foods and recipes that include fruit or vegetables among their components or ingredients. Including these foods in fruit and vegetable intake assessments may be important, depending on the dietary patterns

of each country. Inclusion of composite foods may however induce errors when estimating fruit and vegetable intake in surveys. Dietary guidelines often do not make any explicit reference to such foods. Inclusion of composite foods seems to affect assessment of vegetable intake more than of fruit consumption. In Europe, composite foods accounted for 20% to 30% of total vegetable intake, but less than 10% of fruit consumption. It seems reasonable to consider composite foods or recipes that are mainly based on fruits or vegetables, if fruit and/or vegetables account for at least 75% of the total weight of the recipe. This may be relevant particularly when reporting frequency of consumption.

8.3 Frequency of consumption

It is important to consider the completeness, structure, and wording of questionnaires seeking to estimate fruit and vegetable intake. In general terms it seems that questionnaires with a moderate number of items have greater validity than those with a short list. That validity is improved when questions on portion size are included. Although FFQs have been in use for a long time, improvements have been made and questionnaires are now good quality and validated *(78,79)*. Although the recommended five portions a day is a minimum for dietary guidelines, further insight is needed on this issue. Some evidence exists that fruit and vegetable promotion strategies should also include a recommendation to increase consumption frequency (*34*) Some guides already provide separate advice for fruit and vegetables, specifying a range of recommended amounts.

8.4 Portion size

Where nutritional surveys are estimating absolute intake the main issue is validity of the data. Portion size is only one of the elements used in obtaining unbiased and precise estimates. In dietary guidelines the reference used is “standard portions”. Since most recommendations mention the need either to eat at least five portions of fruit and vegetables, or 400 g of fruit and vegetables a day, it is often assumed that a standard portion weighs about 80 g. From the studies reviewed it seems that this reference portion is appropriate on average, but that in practice, the actual portions consumed tend to be less than 80 g for vegetables and more than 80 g for fruit. Actual portion size is

widely variable, both across countries and between subjects of the same country. The average consumption value of 80 g per portion is more realistic when a variety of both fruit and vegetables is consumed.

Common rules are needed to express the weight of portions in user-friendly terms. Two main factors appear to be quite consistent across countries: a portion of 80 g can be composed of a volume of 250 ml (one cup) of raw leafy vegetables or half this volume (125ml) of cooked or chopped vegetables. For fruit, an 80 gram portion equates to the edible part of one whole medium-sized fruit or two smaller-sized fruits. It is always advisable to provide detailed lists of fruit and vegetables consumed in each country together with their average weights. These should be accompanied by overall recommendations formulated in very broad terms. Reference volumes of household measures commonly used in each country may be helpful as well. These data should be based on actual measurements carried out in each country, otherwise the apparent homogeneity of some portion-size definitions might only reflect the fact that they come from the same source. Since important variability exists for portion sizes, it is more likely that an average portion will be consumed when people eat a wide range of foods rather than a restricted list. Food guidelines should therefore always make explicit the need for people to eat a variety of fruit and vegetables, not simply because of the nutritional benefits, but because, by doing so, there is an increased likelihood that they will consume at least the recommended daily total of 400 g.

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Table 1 Average serving sizes of vegetables and fruits (grams).

Vegetable	Mean	Median	20th percentile	80th percentile	Fruit	Mean	Median	20th percentile	80th percentile
Canned beans	147	137	79	210	Melon	168	151	102	227
Spinach	107	97	97	136	Orange	163	160	120	210
Sweet corn	101	43	28	105	Pear	158	160	127	170
Vegetable dishes	99	75	24	174	Fruit salad	128	130	81	184
Tomato	86	85	43	120	Grapefruit	126	116	116	140
Cabbage	84	90	58	96	Apple	113	112	112	112
Leek	84	67	45	104	Plum/greengage	112	92	46	159
Cauliflower	81	60	60	114	Raspberry	107	114	36	219
Mixed salad	74	75	45	90	Rhubarb	106	90	55	140
Broccoli	72	54	54	89	Strawberry	103	96	60	150
Dried beans	72	60	55	90	Blackberry	101	76	70	140
Courgette	65	60	33	94	Peach	97	120	52	122
Soup	65	48	36	102	Banana	95	100	80	100
Brussels sprout	63	56	39	87	Grape	83	70	50	114
Carrot	56	61	39	72	Pineapple	81	80	41	112
Pea	56	45	29	81	Orange varieties	74	70	60	96
Swede	55	47	35	67	Kiwi	52	60	30	65
Onion	53	46	17	71	Blackcurrant	39	40	10	57
Parsnip	52	42	33	65	Dried fruit	31	28	16	40
Mushroom	50	40	21	66	Prune	31	24	20	49
Cucumber	34	24	20	40					
Pepper	32	20	10	60					
Lettuce	26	24	15	33					

Adapted from Ashfield-Watt *et al.* 2004 *(34)*, with permission of the publisher.

Table 2 Distribution of portion sizes in the calibration study of the European Prospective Study into Cancer and Nutrition cohorts from 10 European Countries

	Vegetables	**Fruits**	**Legumes**	**Potatoes**
Mean	68.1	127.3	138.7	155.6
Standard deviation	67.4	90.7	106.1	92.1
Median	50.0	114.8	105.0	141.0
20th percentile	19.2	51.6	53.3	71.0
80th percentile	102.0	180.0	210.0	228.0
Inter-quartile range	78.0	106.2	135.0	122.5

Portion sizes are defined as the amount (grams) reported by consumers at each consumption occasion of a food belonging to one of four major groups, identified and quantified as a single food.

Source: Agudo et al. *(30)*

Table 3 Average portion sizes in the calibration study of the EPIC project according to country, demographic, and diet-related variables , 10 European countries

		Vegetables	**Fruits**
Sex	Male	70.5	138.7
	Female	66.3	123.1
Age group	<45 years	64.2	125.4
	45-54 years	67.4	129.8
	55-64 years	68.2	129.7
	65+ years	69.7	121.9
Country	France	80.3	130.5
	Italy	81.6	147.9
	Spain	65.8	155.8
	United Kingdom	54.8	98.1
	The Netherlands	71.9	110.6
	Greece	89.6	127.9
	Germany	81.1	130.0
	Sweden	43.8	100.7
	Denmark	54.7	137.0
	Norway	49.2	110.3
Highest school level	None	68.4	125.5
	Primary completed	67.8	130.3
	Technical / professional	68.4	129.1
	Secondary school	67.1	128.2
	University degree	67.0	125.2
	Not specified	69.6	120.8
Body mass index	Normal	66.7	125.7
	Lean	67.4	123.1
	Overweight	67.7	129.1
	Obese	71.2	134.8
Total vegetable or fruit intake	1st quartile	39.2	132.4
	2nd quartile	59.3	125.6
	3th quartile	72.1	125.1
	4th quartile	99.8	129.7

Mean portion sizes calculated as the amount (grams) reported by consumers at each consumption occasion of a food belonging to the groups of vegetables or fruit, identified and quantified as a single food; adjusted by season, day of the week, age and sex. Source: Agudo A et al. (*30*)

Table 4 Guidelines on fruit and vegetable consumption per day and definition of portion size.

(A) guidelines and portion definition with weight and volume references

Reference	Country	Guideline and portion definition
(51)	Greece	3 servings of fruit, 6 servings of vegetables One serving: A cup of raw leafy vegetables or half cup of other vegetables, cooked or chopped (i.e. ~ 100g of most vegetables); one apple (80g), one banana (60g), one orange (100g), 200g of melon or watermelon, 30g of grapes.
(52)	The Netherlands	At least 2 portions of both vegetables and fruit Approximate portions of 100 grams. Examples: 1 bowl of crudités contains 50 grams of vegetables. A piece of fruit (apple) 100 grams; one bowl of fruit, 100 grams.
(53)	United Kingdom	At least 5 portions of fruit and vegetables overall (adults) Portions equivalents to 80 grams. 3 tablespoonfuls of cooked vegetables (carrots, peas); 2 tablespoons of pulses; 1 cereal bowlful of mixed salad; one average slice very large fruit (melon); half large fruit (grapefruit); 1 medium fruit (apple); 2 small fruits (plum); 1 tablespoon of very small fruits (blueberries); 1 average handful of dried fruit (raisin); 1 small glass of 100% fruit juice. Volume references: tablespoon=15ml, handful/bowl=300 ml, small glass=150ml. Detailed list of foods provided.
(54)	New Zealand	At least 5: at least 3 servings of vegetables per day, at least 2 servings of fruit One serving: 1 medium potato, (135g), half cup of cooked vegetables (50-80g), half cup of salad or mixed vegetables (60g), 1 tomato (80g); 1 apple, pear, banana or orange (80g), 2 small apricots or plums, half cup of fresh fruit salad, half cup of stewed fruit (fresh, frozen or canned - 135 g), 1 cup fruit juice, 250ml or a serving of dried fruit (only one counts).
(55)	United States of America	3-5 servings of vegetables, 2-4 servings of fruit One serving: 1 cup of raw leafy vegetables; half cup of other vegetables, raw or cooked; 1 medium apple, banana, orange, pear; half cup of chopped, canned, or canned fruit; quarter cup of dried fruit; threequarter cup of 100% fruit or vegetable juice. Weight references: 1 cup of raw leafy vegetables = 2 ounces or 56 grams; half cup of cooked or chopped raw vegetables = 3 ounces or 84 grams.

(B) guidelines and portion definition with weight references

Reference	Country	Guideline and portion definition
(56)	Switzerland	3-4 portions vegetables, 2-3 portions fruit One portion: 100g fresh vegetables, 150g- 200g cooked vegetables, 50g of green salad or 100g mixed salad; 1 apple, 1 banana or 3 plums.
(57)	Australia	4-8 servings of vegetables, 2-4 servings of fruit One serving of vegetables equals 75g; One serving of fruit equals 150g.
(58)	Japan	5 or more servings of vegetables, 2-4 servings of fruit One serving of vegetables = approximately 70g; one serving of fruit = 100g-200g (gross weight).

(C) guidelines and portion definition with volume references

Reference	Country	Guideline and portion definition
(59)	Spain	3-5 portions of vegetables, 2-4 portions of fruit One portion: 1 average dish of salad; 1 average dish of cooked vegetables; 1 eggplant, tomato (big), 2 cucumbers, 2 carrots; 1 medium-sized fruit (apple, orange, pear), 1 slice of melon or watermelon; 2-3 small fruits (plums, apricots) one cup of very small fruits (raisin, berries).
(60)	Canada	5-10 servings of vegetables and fruits (overall) One serving: 1 medium-sized fruit or vegetable (banana, apple, carrot), 1 slice of melon; half cup of fresh, frozen or canned vegetables (broccoli); 1 cup of salad; half cup of juice. Volume reference: 1 cup = 250ml.
(61)	Mexico	5-10 servings of vegetables and fruits (overall) One portion: 1 medium-sized fruit (apple, pear); 1 cup of vegetables or fruits; 1 cup of 100% juice; quarter cup or 5 pieces of dried fruits.

Reference	Country	Guideline and portion definition
(62)	Argentina	5-10 servings of vegetables and fruit (overall) One portion: 1 medium-sized fruit (apple, pear); 1 cup of leafy vegetables; half cup of cooked or canned vegetables or legumes; quarter cup of dried fruits; threequarter cup of 100% juice.
(63)	Brazil	4-5 portions of vegetables, 2-4 portions of fruit One portion: 1 cup of leafy raw vegetables; half cup of other vegetable, raw, cooked or chopped; 1 medium-sized fruit or slice of large fruit,half cup of raw or chopped fruit.
(64)	Malaysia	At least 5 portions of vegetables and fruit (overall) One serving: half cup of cooked dark green leafy vegetables with edible stems; half cup cooked fruit or root vegetables; half medium-sized guava; 1 small to medium whole orange, pear or apple; 1 medium-sized banana; 1 slice papaya, pineapple, watermelon.
(65)	Philippines	3 servings of vegetables, 2-3 servings of fruit One serving: 1 cup raw or half cup cooked leafy vegetables, half cup raw or cooked of other vegetables; 1 medium-sized fruit, 1 slice of large fruit.
(66-68)	South Africa	3-5 portions of vegetables, 2-4 portions of fruit One portion: 1 cup free vegetables (asparagus, broccoli, cabbage, eggplant, green beans, lettuce, radishes, tomatoes); half cup of other vegetables (peas, beetroot, carrots, pumpkin, onions, butternuts); 1 medium-sized apple, peach, orange, grapefruit, pear; 1 small banana or mango; 4 apricots or prunes; 20-24 medium grapes or strawberries; 4 tablespoons raisins; half cup sliced fruit.
(69)	Mauritius	At least 5 portions of vegetables and fruit (overall) One portion: 1 cup of raw or half cup of cooked vegetables; 1 mango, banana, apple, pear, orange, mandarin; 1 slice of papaya, pineapple, watermelon; 2 small plums, peaches, nectarines, kiwis; half cup grapes.

Sources: see reference list.