

Review Article

Fruit and vegetable intake: issues with definition and measurement

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Abstract

Accurate determination of fruit and vegetable consumption is essential for research that seeks to determine current fruit and vegetable intake patterns, what type and amount of fruit and vegetable consumption is optimal for human health and for evaluating interventions developed to increase such consumption. However, there are many issues that make accurate determination of fruit and vegetable consumption quite difficult. There are many methods used to measure fruit and vegetable intake, but all have limitations. Also, what foods individuals consider to be or to not be fruits or vegetables appear to be quite variable, with such variability often associated with the individual's racial/ethnic background. Researchers and governmental agencies vary with respect to what foods they include and do not include when calculating fruit and vegetable intake. These differences make it difficult to conduct, evaluate and compare studies in this area. The current paper reviews some of the major issues with measuring and determining fruit and vegetable intake.

Keywords
Fruit and vegetables
Dietary assessment
Nutrition research

There is increasing evidence that persons who do not consume sufficient quantities of fruits and vegetables on a regular basis are at higher risk for a variety of chronic diseases and health issues^(1,2). Studies consistently report that most Americans do not eat enough fruits and vegetables on a daily basis^(3–5). A number of interventions have been developed and implemented to try and increase fruit and vegetable intake among Americans, but so far these efforts have had little success⁽⁶⁾.

There are a number of methodological issues that are raised in any study where fruit and vegetable intake is a variable and these issues can affect results within a given study and comparison of results between studies. Two of the primary methodological challenges in this area are: (i) how to accurately measure intake of fruit and vegetables; and (ii) what to include or not include when assessing fruit and vegetable intake. A closely related issue is what criterion or goal to use if categorizing subjects by fruit and vegetable intake, the goal generally being a chosen number of servings (or more recently cup equivalents) of

fruits and vegetables considered the minimum number that people should be regularly eating. The present paper first briefly reviews why fruit and vegetable intake has become an important issue and how goals regarding intake have been continually refined over time. Then it focuses on two of the primary methodological challenges in this area: (i) how to define fruit and vegetable intake, or more specifically what to include or not include as counting towards fruit and vegetable intake; and (ii) how to accurately measure intake of fruit and vegetables.

Health and fruit and vegetable intake

Chronic diseases are increasing in prevalence worldwide. Nearly a third of deaths worldwide are from CVD⁽⁷⁾ and it is estimated that by 2025, nearly 30% of the adult population in the world will have hypertension⁽⁸⁾. The worldwide prevalences of overweight and obesity⁽⁹⁾ and of diabetes⁽¹⁰⁾ are increasing at epidemic rates, with diabetes prevalence expected to more than double to 366 million persons worldwide by 2030⁽¹¹⁾. In the USA, approximately 90 million persons suffer from at least one chronic disease with seven of every ten deaths attributable to chronic diseases. It is estimated that the annual medical costs associated with chronic diseases exceed \$US 1 trillion⁽¹²⁾.

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While many dietary components contribute to good nutrition and health, much focus has been placed on inadequate consumption of fruits and vegetables⁽¹³⁾. Studies are increasingly showing that low levels of fruit and vegetable intake are associated with the development of major chronic diseases including CVD^(1,2,14,15), cancer⁽¹⁶⁻¹⁸⁾, stroke⁽¹⁹⁾, diabetes^(20,21) and hypertension^(22,23). Thus, development and implementation of effective interventions to increase intake of fruits and vegetables are of utmost importance. However, it is first necessary to identify exactly what should be targeted in such interventions and this in turn requires accurate and consistent methods for determining individuals' fruit and vegetable intake.

Varying goals for fruit and vegetable intake

In light of the association between fruit and vegetable intake and health and disease, researchers have sought to evaluate current intakes of fruit and vegetables among various populations including often determining what proportion of a study population meets a set goal intake of fruit and vegetables. Theoretically the goal is or should be a level of intake that promotes health and prevents disease. For many years, the oft-cited goal was that individuals should consume at least 5 or more servings of fruits and vegetables combined on a daily basis, a goal set out in 1990 in both Healthy People 2000⁽²⁴⁾ and the US Department of Agriculture's and US Department of Health and Human Services' Dietary Guidelines for Americans⁽²⁵⁾. The latter also specified that at least 2 servings come from fruit and at least 3 servings come from vegetables, a seemingly small qualification. However, when the same data were analysed using guidelines similar to those recommended in the Dietary Guidelines for Americans⁽²⁵⁾ only 12% of adults met intake objectives compared with 32% when the goal was the more general '5 or more'⁽²⁴⁾.

Increasing knowledge regarding health and nutrition has led to frequent refinements in what is considered goal intake. Healthy People 2010 objectives were more specific than Healthy People 2000 objectives with the goal being at least 2 daily servings of fruits and at least 3 daily servings of vegetables and the additional requirement for vegetables that at least one-third or more of servings be dark green or orange vegetables⁽¹³⁾. The US Department of Health and Human Services and the US Department of Agriculture also set out more specific goals in their Dietary Guidelines for Americans 2005⁽²⁶⁾. Those guidelines recommended that fruit and vegetable intake increase with increasing energy needs and stated that many persons would need to eat nine or more servings daily to meet recommendations. In a study where the criteria for meeting fruit and vegetable intake were similarly specific, and with the adequate level of intake being tied to gender, age and level of activity, it was estimated that fewer than 5% of American adults met the recommended levels of fruit

and vegetable intake⁽⁴⁾. Healthy People 2020, launched in December 2010, reflecting the increasing agreement of the importance of both consuming a variety of fruits and vegetables and consuming amounts of fruits and vegetables correlated with overall energy needs, has set goals where consumption of fruits and vegetables is stated in cup equivalents per 1000 kcal (4184 kJ) rather than in servings and where an additional specific goal is stated for consumption of a specific category consisting of dark green and orange vegetables and legumes in addition to the general categories of fruits and of vegetables⁽²⁷⁾. The Dietary Guidelines for Americans 2010 not only recommends increased consumption of vegetables, especially dark green and orange and red vegetables and legumes, but also provides specific recommended daily intakes for five categories of vegetables in relation to daily energy intake. These recommendations are based on the association between increased intake and reduced risk for many chronic diseases as previously discussed and on the fact that fruits and vegetables are nutrient-dense foods and eating them may also help in maintaining healthy body weight⁽²⁸⁾.

Issues with defining and measuring intake

There are some basic issues in how fruit and vegetable intake is assessed that potentially threaten the validity, reliability and comparability of results. The first issue is regarding the definition of what counts as a fruit or a vegetable. Should researchers include fried potatoes in their definition of what constitutes fruit and vegetable intake or should they even include any type of potatoes? Should condiments, such as ketchup or a slice of onion on a sandwich, count towards fruit and vegetable intake? Are there consistent differences between categories of individuals in what they think is or is not a vegetable? From a research standpoint these issues make it difficult to compare results between studies, etc. and also make it difficult to determine what recommendations should actually be for fruit and vegetable intake. The second issue is how to accurately measure fruit and vegetable intake.

Issue 1: What counts towards fruit and vegetable intake?

The first issue relates to what is defined as being included in fruit and vegetable intake when intake is assessed, specifically what items that are consumed by people will be categorized as contributing to fruit and vegetable intake. In order to estimate fruit and vegetable intake a definition must specify what plant foods count towards such intake and what quantity corresponds to a serving if servings are being calculated⁽²⁹⁾. The former seems pretty straightforward as it would seem clear what foods are in the category 'fruits and vegetables'. However, that term covers a highly heterogeneous group of foods, especially across cultures and geographic locales⁽³⁰⁾. Also, researchers often will include

foods that are not technically fruits and vegetables or exclude certain foods from their definitions even though those foods are technically a fruit or a vegetable, the latter through either inadvertent omission or purposeful omission.

Legumes (dried beans and peas), which are not by definition fruits or vegetables, are often included in definitions of what is included in calculating fruit and vegetable intake, but not always in the same manner. Before MyPyramid, generally all servings of legumes were calculated in vegetable consumption, but with MyPyramid, legumes were first counted towards the meat and beans group and any servings of legumes remaining once that category's requirements were met were then allocated to the vegetable category⁽⁵⁾. As previously mentioned, Healthy People 2020 specifically includes legumes along with dark green and orange vegetables as a target category for increased intake⁽²⁷⁾. However, recent major studies in Europe have not included legumes (or potatoes) when calculating vegetable consumption⁽³¹⁾. Legumes also potentially present a definition problem when assessment methodologies involve FFQ or screeners that do not specifically indicate in some way to respondents that legumes are to be considered in the fruit and vegetable category, as respondents might not consider them to be vegetables and thus would not count them unless prompted to do so.

An example of inadvertent omission is the definition that was initially used to calculate fruit and vegetable intake for Healthy People 2000. The Healthy People 2000 baseline data on fruit and vegetable intake were revised in part because in the original baseline data analyses, fruits and vegetables that individuals had consumed that were part of a mixed food (e.g. a stew containing meat and vegetables) were not counted in calculating fruit and vegetable intake because mixed foods had not been included in the original definition of fruits and vegetables⁽²⁴⁾. Many food items that people prepare and consume contain a combination of vegetables, grains and meat or seafood, and thus not counting the fruits and vegetables contained in such foods could lead to significant underestimation of fruit and vegetable consumption.

Researchers often specifically omit from their definitions certain foods that are technically part of the fruit and vegetable category. Even when methodologies for measuring intake are used where all can be accurately counted in the results, such as 24h recalls, the variable definitions for coding may disallow certain food items that contain fruits and vegetables or that are fruits or vegetables. Exclusion is often based on the idea that some sources of fruits and vegetables (such as French fries) have such a high energy content in relation to nutritive value that they should not be counted when calculating fruit and vegetable intake⁽³²⁾. How much the behavioural approach affects results depends on what food items are not counted. Cullen *et al.*⁽³²⁾ compared these two coding approaches using the same data sets and found that the intakes with the behavioural approach were 5% to 15% lower.

What foods that are technically fruits and vegetables are excluded from a definition and the rationale for such exclusions can be quite variable between studies. A few studies have excluded salads such as coleslaw because they are considered to be served in too small a serving size and the nature of the assessment tool cannot account for such small portions, or because of their high fat content they are deemed too nutritionally poor in relation to energy to count⁽³³⁾. Condiments such as ketchup, and even sandwich toppings, such as lettuce and tomatoes, are also often excluded in the definition of fruit and vegetable intake when servings are directly assessed. In this case the rationale usually given is that the amounts are too small to constitute a serving or even half a serving and that the assessment method is based on number of servings rather than actual weights of everything consumed that is then converted into servings as is the case with 24h recall methods⁽³³⁾. Depending on specifically what is being excluded, this appears to be more an issue related to assessment methodology rather than pure definition as certainly lettuce and tomatoes are counted in all studies if they are consumed in larger portions such as in a salad. The logic in excluding condiments is that they may be frequently eaten yet their portion size is so small that to exclude them would have little effect on estimated intake whereas including them could lead to large overestimates of intake.

Excluding fried potatoes, especially French fries, can have a substantial impact on results as one recent study showed that French fries account for a significant percentage of total vegetables consumed, accounting for 14% of fruit and vegetable intake for adult women, nearly 18% for adult men, and nearly 30% for adolescents⁽³⁾. Sometimes even non-fried potatoes are not counted towards vegetable intake. The Japanese system for classifying foods puts potatoes in the grain category along with rice and other grains and not in the vegetable category⁽³⁴⁾. In the UK's '5-a-day' programme all servings of potatoes are excluded when calculating fruit and vegetable intake⁽³³⁾. Recent studies in Europe also have excluded potatoes when calculating vegetable intake⁽³¹⁾. Since the end goal of increasing fruit and vegetable intake is to improve human health it might be logical to exclude certain foods that are technically fruits and vegetables if their consumption is actually counterproductive to that goal. Conversely, the reason the broad category of fruits and vegetables has been the target for assessment and intervention rather than specific fruits and vegetables or specific nutrients found in fruits and vegetables is that science has yet to clearly identify which components found in fruits and vegetables are crucial to human health⁽³⁰⁾. In the context of variety of intake of fruits and vegetables being the goal and therefore the focus of assessment and intervention, excluding fried potatoes, or even all potatoes, may make theoretical sense if the focus is total or overall vegetable intake as opposed to categories of vegetable intake.

A possibly important issue with respect to including potatoes in fruit and vegetable intake is its potential effect on differences in fruit and vegetable intake by ethnicity or cultural background. While potatoes are a traditional staple for many Caucasian groups, they are not a staple for many Asian/Pacific Islander groups. Conversely, rice is a staple for the latter and not the former. A number of studies in the USA report that rice consumption is much higher for Asian Americans than for Caucasian Americans^(34–36). The implication is that in populations where rice consumption is high, such as most Asian and Pacific Islander groups, differences in estimated fruit and vegetable intakes may occur by ethnicity in comparison to Caucasians because potatoes are counted towards fruit and vegetable intake and rice, of course, is not. Again, this would be more of a concern where the assessment evaluates overall or total vegetable intake as opposed to categories of vegetables.

Issue 2: How do you accurately measure fruit and vegetable intake?

There are a number of methods used for obtaining fruit and vegetable intake data from individuals, including 24 h dietary recalls, food diaries, measurement of biomarkers, FFQ and short screeners. The 24 h dietary recall method is often considered the most accurate method for obtaining fruit and vegetable intake data^(37,38). However, in the past there have been a number of issues with its use. First and foremost was the fact that both the data collection process and the data analysis process were highly resource-intensive⁽³⁸⁾. Another issue was and is that dietary intake for a given individual tends to vary greatly from day to day so that a single 24 h dietary recall is usually not representative of an individual's typical intake and therefore multiple recalls are required for studies where an individual's typical intake is important⁽³⁸⁾. Computer-based, self-administered 24 h dietary recall methodologies have been developed in recent years that may address many of the traditional limitations of this method⁽³⁹⁾. However, more research is needed on these new methods.

Food diaries, in which the individual keeps a record of everything he/she eats over a given period of time, represent another method for assessing fruit and vegetable intake. Like 24 h dietary recall, food diaries have the potential to accurately capture true intake for a given period of time and thus might be a good method for evaluating the association between diet and chronic disease⁽⁴⁰⁾. However, this method can be quite resource-intensive and it may be less adept than FFQ, for example, in assessing usual intake as opposed to intake for a specific day or time period which may not be representative of usual intake^(29,41). Another major concern with food diaries is that accuracy in reporting intake may vary greatly between respondents depending on factors such as education, socio-economic status and other respondent characteristics, or that certain respondent characteristics may be associated with either inaccurate

reporting in diaries or with changing eating patterns during recording periods such that reported fruit and vegetable intake is higher than actual usual intake^(41–43).

Measurement of certain biomarkers such as plasma carotenoids is also used to indirectly assess fruit and vegetable intake in individuals although such measurements tend to be quite specific to certain types or categories of fruits and vegetables and are not necessarily good for evaluating overall fruit and vegetable intake⁽⁴⁴⁾. Fruit and vegetable intake patterns may also lead to differential results in biomarker levels⁽⁴⁵⁾. Such markers are also affected by numerous physiological factors beyond dietary intake⁽⁴⁶⁾. Biomarkers might play a more valuable role in validating other assessment methods⁽⁴⁰⁾ and in reflecting physiological nutritional status⁽⁴⁶⁾ rather than in assessing overall fruit and vegetable intake.

Another methodological approach for gathering data on fruit and vegetable intake is the FFQ. An FFQ typically consists of a pre-coded form containing a large list (sixty to 120) of specific food items that assesses frequency with which each item is consumed and often the usual portion size when consumed. Any given food item may consist of a single food or a group of highly similar foods⁽⁴⁷⁾. This approach does not require multiple administrations to assess an individual's usual intake⁽⁴⁸⁾. Short screeners, which are really a type of FFQ, are also used for assessing fruit and vegetable intake. These are typically FFQ with fewer than twenty questions that ask about frequency of intake of various categories of fruits and vegetables over a given period of time⁽⁴⁹⁾. From a research standpoint, a short screener that is highly accurate in both ranking fruit and vegetable intake and assessing actual intake is highly desirable since short screeners can be easily administered to large populations at a relatively low cost⁽⁵⁰⁾. However, there is concern that both FFQ and short screeners, while being somewhat accurate in ranking individuals by intake, are not very accurate in assessing actual intake⁽⁵¹⁾, with short screeners tending to underestimate actual intake and longer FFQ tending to overestimate actual intake^(29,50).

A related issue with regard to accurately assessing actual intake of fruits and vegetables is that assessment tools that require respondents to self-determine to some degree what foods they eat are fruits or vegetables might be understood differently by different individuals. One study evaluated respondents' understanding of assessment tools specifically in relation to what the tools meant to include and not include in defining what constitutes fruit and vegetable intake⁽⁵²⁾. Results indicated that many respondents misunderstood what to include or not include when determining their answers. For example, when queried about a question asking about '100% fruit juice' intake, many respondents did not understand the question and mistakenly included fruit-flavoured drinks when reporting intake. In a similar type of study respondents underwent cognitive testing regarding understanding of questions using the Behavioral Risk Factor Surveillance System

(BRFSS) module and a newly created screener as the source of the questions⁽⁵³⁾. A number of questions were found to be frequently misinterpreted and there were often ethnic/cultural differences in how a question was interpreted. For example, many whites when asked what they considered to be a 'bean' only included green beans, while many Hispanics and African Americans only included legumes. In a more recent study of American adults from various racial/ethnic backgrounds, there were significant differences between racial/ethnic groups on how to classify a number of foods (fruit, vegetable or other) including beans, potatoes and rice. In that same study, nearly a fifth of respondents considered rice to be a vegetable⁽⁵⁴⁾.

Summary

The present overview of issues with both how to measure fruit and vegetable intake and how to define what to count as constituting fruit and vegetable intake suggests that more research is needed on both issues. Currently there is a great deal of variation in how studies define and measure intake, making it difficult to interpret individual studies and to compare results among studies. In addition to the absolute differences in intake the varying definitions and methods produce, there is also a question regarding their relative value in evaluating intake, particularly among disparate groups such as minority groups. Both issues need to be addressed if we expect to accurately assess fruit and vegetable intake in any given population, if we are to determine what factors are associated with such intake and if we wish to identify targets for interventions to increase such intake.

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