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Report

Quality control procedures for the USDA Food and Nutrient Database for Dietary Studies nutrient values

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Abstract

Accurate dietary assessment depends on a high-quality food and nutrient database. While much progress has been made in the quality of analytical nutrient data, the area of database quality control remains largely uncovered. Increased automation of database maintenance and update processes necessitates stringent quality control procedures. A detailed quality control (QC) plan has advanced over the years and is in place for the Food and Nutrient Database for Dietary Studies (FNDDS) nutrient values file. Multiple checks are performed for all new and revised data at different steps of the update process to ensure integrity and accuracy in the database. Based on the purpose of the checks, they are grouped into three categories: nutrient integrity checks, database integrity checks, and database validation checks. Details of the QC checks used for the FNDDS nutrient values file and features of the QC system are given. This information can be helpful for managers responsible for maintaining nutrient databases, and discussions on this topic may stimulate development of systems to ensure integrity and accuracy in nutrient databases.
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Keywords: Quality control; Database management; Food and Nutrient Database for Dietary Studies; FNDDS

1. Introduction

Reliable dietary intake estimates depend on a high-quality nutrient database (Burlingame, 2003). In recent years, considerable attention has been paid to improve the quality of data on the nutritional composition of foods. New and better methods for laboratory analyses have been developed, and protocols for the critical evaluation of nutrient data have been established (Holden et al., 2002). Furthermore, the National Food and Nutrient Analysis Program has resulted in reliable, nationally representative data on the nutritional composition of many key foods in the American diet (Haytowitz et al., 2002). However, while much has been done to improve the quality of analytical values, the area of database quality control remains largely uncovered. The last published literature available on this topic dates back to the 1980s (Murphy, 1986, 1989; Buzzard et al., 1986). Since that time database preparation has become more automated, and comprehensive quality control routines built into these automated procedures help ensure the integrity and accuracy of the food and nutrient databases.

The United States Department of Agriculture (USDA) Food and Nutrient Database for Dietary Studies (FNDDS) is a database of foods, their nutrient values, and weights for typical food portions consumed by the US population (USDA, 2006). Its main purpose is to provide code foods and portion sizes to allow for the determination of nutrient intakes for participants in *What We Eat in America*, the dietary interview component of the National Health and Nutrition Examination Survey (NHANES). Other applications of the database include MyPyramid Tracker (USDA, 2005b) and the National Cancer Institute's Diet History Questionnaire (Dixon et al., 2003). This paper describes the quality control (QC) procedures for the nutrient values in the FNDDS.

2. Overview of the USDA'S FNDDS

The FNDDS contains information about foods as they are consumed by the US population. It includes food

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descriptions for over 13,000 foods as well as nutrient values and weights for common portions for each of these foods. It is maintained by the Food Surveys Research Group (FSRG) in the Beltsville Human Nutrition Research Center of the USDA. Versions of the FNDDS are tied to releases of data from *What We Eat in America*, i.e., FNDDS 1.0 was used for survey data collected in 2001–2002, FNDDS 2.0 for 2003–2004, and so on.

The database consists of 10 separate, linked, data files that can be grouped into three distinct components—food descriptions, food portions and weights, and nutrient values. Table 1 lists the files in each component and a brief description of each file's contents. Details of the three components, as well as features and availability of the database are provided by Bodner-Montville et al. (2006). The nutrient component of the FNDDS includes values for food energy and 62 nutrients/food components for each food code, as listed in Table 2. The source of FNDDS nutrient values for a new version is always the latest release of the USDA National Nutrient Database for Standard Reference (SR) maintained by the Nutrient Data Laboratory (NDL) also at the Beltsville Human Nutrition Research Center. FNDDS 2.0 is based on SR, Release 18 (USDA, 2005a). About a third of the foods in the FNDDS are direct links with SR items. For example, raw apple in FNDDS is linked to raw apple in SR. The other items in the FNDDS are multi-component foods for which the nutrients are derived by recipe calculations using data from SR for ingredients. For example, the nutrient values in FNDDS for meat lasagna are calculated using data for 12 different SR items such as pasta, meat, various cheeses, etc. The nutrient component of the FNDDS also includes the files that document how items in FNDDS are linked to SR and how retention and yield factors are applied in recipe calculations. This paper focuses on QC procedures for the FNDDS nutrient values file; a separate set of QC procedures covers food descriptions, food portions and weights, and other files in the nutrient component.

3. FNDDS nutrient values file QC system

A subset of items from the SR serves as the FNDDS nutrient input file. Nutrient values are obtained directly from the preliminary files slated for the next public release of SR. All data from the SR that are slated for FNNDS undergo QC checks as part of good database management practice. The checks are computerized and have been designed to uncover questionable values and to identify incomplete or inconsistent nutrient values. All questionable values or conditions identified during these checks are reviewed by nutritionists at NDL or FSRG and necessary changes are made. QC checks are conducted after four strategic steps, listed below, during the production of the FNDDS nutrient values file:

1. Receive nutrient values for new and updated SR items slated for use in the FNDDS.
2. Import values from step 1 into the FNDDS nutrient input file.
3. Generate a version of FNDDS nutrient values for analyzing NHANES dietary data.
4. Prepare FNDDS for public release.

Steps 1–3 above may be conducted several times before the FNDDS values are finalized. During the process, questionable values or conditions are identified, evaluated, and corrected. In addition, during this time, other decisions related to new or revised data may be incorporated into the SR, which prompts the need to re-run QC checks. For example, with FNDDS 2.0, steps 1–3 were run six times before the FNDDS values were finalized. Appropriate QC checks are repeated each time preliminary SR values are changed. Finally, selected checks are conducted after step 4,

Table 1
The components and files of the USDA Food and Nutrient Database for Dietary Studies (FNDDS)

FNDDS components and files	Data contained
Food descriptions	
1. Main food descriptions	Primary description associated with each food code
2. Additional food descriptions	Descriptions for additional foods associated with each main food description, sharing the same nutrient profiles and same food portion weights
Food portions and weights	
3. Food weights	Weights (in g) for various portions of each food
4. Food portion descriptions	Descriptions for portions of foods and beverages
5. Subcode descriptions	Descriptions for subcodes, which represent foods that are nutritionally similar to a main food, but have different weights for the same portion description
6. Food code–subcode links	Records that show the association between main food descriptions and subcodes
Nutrients	
7. FNDDS nutrient values	Complete nutrient profile (energy and 62 nutrients[a]) for each food code
8. Nutrient descriptions	Descriptions and units of measure associated with the nutrients in the FNDDS
9. Moisture and fat adjustments	Factors used during calculation of the nutrient values for some foods in the database
10. FNDDS–SR links	Information used during calculation of nutrient values in this database; documents the links between the FNDDS and the USDA National Nutrient Database for Standard Reference (SR)

[a]Number of nutrients included in FNDDS 2.0 (2006).

Table 2
List of nutrients/food components and units in the FNDDS[a]

Food energy (kcal)
Protein (g)
Carbohydrate (g)
Fat, total (g)
Alcohol (g)
Sugars, total (g)
Dietary fiber, total (g)
Water (g)
Saturated fatty acids, total (g)
Monounsaturated fatty acids, total (g)
Polyunsaturated fatty acids, total (g)
Cholesterol (mg)
Individual fatty acids
4:0 (g)
6:0 (g)
8:0 (g)
10:0 (g)
12:0 (g)
14:0 (g)
16:0 (g)
18:0 (g)
16:1 (g)
18:1 (g)
20:1 (g)
22:1 (g)
18:2 (g)
18:3 (g)
18:4 (g)
20:4 (g)
20:5 n-3 (g)
22:5 n-3 (g)
22:6 n-3 (g)
Vitamin A as retinol activity equivalents (mcg)
Retinol (mcg)
Carotenoids
Carotene, alpha (mcg)
Carotene, beta (mcg)
Cryptoxanthin, beta (mcg)
Lycopene (mcg)
Lutein + zeaxanthin (mcg)
Vitamin E as alpha-tocopherol (mg)
Vitamin E, added (mg)
Vitamin K as phylloquinone (mcg)
Vitamin C (mg)
Thiamin (mg)
Riboflavin (mg)
Niacin (mg)
Vitamin B-6 (mg)
Folate, total (mcg)
Folate as dietary folate equivalents (mcg)
Folic acid (mcg)
Food folate (mcg)
Vitamin B-12 (mcg)
Vitamin B-12, added (mcg)
Calcium (mg)
Iron (mg)
Magnesium (mg)
Phosphorus (mg)
Potassium (mg)
Sodium (mg)
Zinc (mg)
Copper (mg)
Selenium (mcg)
Caffeine (mg)
Theobromine (mg)

[a]Nutrients included in FNDDS 2.0 (2006).

when the FNDDS is formatted for release on the web, which occurs biennially. The different types of QC checks are discussed below.

3.1. Nutrient integrity checks

Nutrient integrity checks, listed in Table 3, were developed to confirm consistency between two or more related nutrient values or to verify reasonableness of values for selected nutrients. Three different types of nutrient integrity checks—*Nutrient crosschecks*, *Edit limits*, and *Nutrient change validations*—are conducted. Fourteen *nutrient crosschecks* are conducted on each food item after step 1, and the first six are repeated after step 3 as a precautionary measure. Checks 1–6 compare values for two different, but related, nutrients. For example, total sugar values are compared to total carbohydrate values. Checks 7–14 first perform calculations, and then compare the calculated values to ranges as described in Table 3. When the specified conditions are found, the data are flagged for review. For example, grams of moisture, protein, total carbohydrate, total fat, ash, and alcohol in 100 g of food are first summed, and then compared to a specified range based on the food group, as listed in Table 3.

Edit limits are boundaries set for defining extreme values that are reviewed for accuracy. In the current FNDDS QC plan, edit limit checks as listed in Table 3, are used for all new and updated values for selected nutrients. For example, to check "added" vitamin E in ready-to-eat cereals in FNDDS 2.0, we identified and reviewed all values that exceeded 200% of the adult RDA in an average serving. When theobromine values were first added to the database, all theobromine values greater than zero for foods not containing chocolate were identified and reviewed. In addition, edit limit checks based on literature values are used when new nutrients are first added to the database. Originally, edit limit checks were used for all new and updated SR nutrient values that were to be used for FNDDS. SR items were grouped into 145 food groups, and within each group, values equal to $\pm 50\%$ of the mean value for each nutrient were used as maximum and minimum limits. All outliers were then reviewed. However, with the large number of nutrients now in the database, the large number of SR items being updated annually, and the time needed to review outliers, this task has been replaced with nutrient validation checks described below to target large changes in the values for review.

Nutrient change validations are conducted after step 3 to identify and confirm the accuracy of substantive changes that

Table 3
Nutrient integrity checks

Nutrient crosschecks
1. Total sugar (g) > carbohydrate (g)
2. Retinol (mcg) > vitamin A as retinol activity equivalents (mcg)
3. Folic acid (mcg) > folate as dietary folate equivalents (mcg)
4. Food folate (mcg) > folate as dietary folate equivalents (mcg)
5. Vitamin B12, added (mcg) > vitamin B12 (mcg)
6. Vitamin E, added (mg) > vitamin E as alpha tocopherol (mg)
7. Sum of moisture, protein, carbohydrate, total fat, ash, and alcohol in 100 g of food
   <97 g or >103 g for meat and meat products
   <99 g or >101 g for all other food
8. Energy value compared with energy calculated using the algorithm ($4 \times$ protein + $4 \times$ carbohydrate + $9 \times$ total fat + $7 \times$ alcohol)
   percent difference > ±25%
9. Total fat compared with the sum of total saturated fatty acids, total monounsaturated fatty acids, and total polyunsaturated fatty acids
   percent difference > ±25%
10. Total saturated fatty acids compared with sum of individual saturated fatty acid values (4:0, 6:0, 8:0, 10:0, 12:0, 14:0, 16:0, and18:0)
   percent difference > ±25%
11. Total monounsaturated fatty acid value compared with sum of individual monounsaturated fatty acids values (16:1, 18:1, 20:1, and 22:1)
   percent difference > ±25%
12. Total polyunsaturated fatty acid value compared with sum of individual polyunsaturated fatty acids (18:2, 18:3, 18:4, 20:4, 20:5, 22:5, and 22:6)
   percent difference > ±25%
13. Vitamin A as retinol activity equivalents compared with vitamin A calculated using the algorithm (retinol + 1/12 beta-carotene + 1/24(alpha-carotene + beta-cryptoxanthin))
   percent difference > ±25%
14. Ash compared with the sum of mineral values (calcium, iron, magnesium, phosphorus, potassium, sodium, zinc, copper, and selenium): >25% or <−500%. A broad range is used because some minerals are not quantified in the database

Edit limit checks
1. Define and identify extreme values for nutrients newly added to the database
2. Vitamin E, added > 75 mg (based on twice the adult RDA in an average serving of ready-to-eat cereals)
3. Vitamin B12, added > 12 mcg (based on twice the adult RDA in an average serving of ready-to-eat cereals)
4. Vitamin B12, added or Vitamin E, added > 0 in food groups other than infant formulas, cereals, and meal replacement
5. Caffeine > 0 in food groups other than beverages and chocolate containing foods
6. Theobromine > 0 in foods other than tea and chocolate containing foods

Nutrient change validations[a]
1. Nutrient changes of 10% or more in 100 most frequently reported foods
2. Nutrient changes of 10% or more in foods that contributed 1% or more to energy intake
3. Nutrient changes of 10% or more in foods that contributed 1% or more to the total weight of all foods consumed
4. Nutrient changes of 10% or more in foods that contributed 1% or more to the total intake of at least 1 nutrient
5. Nutrient changes of 10% or more for the top 100 foods that contributed to total energy intake or to the total weight of all foods consumed by Hispanics
6. Impact assessments for selected changes in frequently consumed items
7. A change in energy, moisture, protein, total carbohydrate, total fat, ash, or iron for any food, if the change is 50% or more. This check is excluded when values in the older FNDDS version are less than 1 unit measure of a nutrient or energy.
8. A change of 100% or more for any nutrient not listed in 7 above. This check is excluded when the value in the older FNDDS version is less than 1 unit of a nutrient
9. All changes from zero values in the older FNDDS version
10. All changes that result in zero values in the new FNDDS version

[a]Intakes are based on the latest NHANES dietary intake data.

took place in nutrient values since the previous version of FNDDS was released. Table 3 lists the conditions that cause a change to be identified for validation. The first five conditions relate to a small subset of foods within the FNDDS that are selected based on consumption data from the latest NHANES. When QC was run for preparation of FNDDS 2.0, which was used for processing NHANES 2003–2004, consumption data from NHANES 2001–2002 were used to develop this subset. Selection was based on frequency of consumption and contribution to total nutrient intakes as designated for these entries in Table 3. In addition to frequently consumed foods by the general population, the subset includes highly consumed foods by Hispanics (condition #5), the largest minority population in the US (US Census Bureau, 2006), because their dietary patterns may differ from those of the mainstream US (Bermudez et al., 2005; Dixon et al., 2000). Only 294 foods (about 4% of the foods in FNDDS) comprised the subset, but in terms of the final NHANES 2003–2004 dietary data, this subset accounted for 49% of all foods reported, 57% of the total energy intake, and 52% of the total fat intake for all individuals. This subset includes foods such as milk, soda, coffee, peanut butter, and burritos. These selected foods then underwent an intensive review process, where all changes were identified as resulting from revisions either to SR nutrient values or to SR-FNDDS linkages, including recipes.

The items in question were then either corrected or confirmed as accurate by nutritionists in the Nutrient Data Laboratory or Food Surveys Research Group, respectively. This intensive quality review led to 382 substantive changes in FNDDS nutrient values. Statistical analyses were done later to estimate the effect of the intensive review process, using 24-h dietary recall data from NHANES 2003–2004 ($n = 8893$). For 40 of the 62 nutrient/food components in FNDDS, mean intake estimates using the pre- and post-quality review values were significantly different at $p = 0.001$ (Ahuja et al., 2007). In addition to the nutrient change validations for these foods, when a change occurs to a very high consumption item, such as a change in the fat content of fast food French fries, an impact assessment may be conducted during QC to estimate the effect of the change on national intakes. The other conditions listed as nutrient change validations in Table 3 (checks 7–10) identify large changes in nutrient values. These changes also undergo an intensive review. All foods reported fewer than five times in the previous NHANES are excluded from all nutrient change validations.

3.2. Database integrity checks

Database integrity checks, listed in Table 4, have been developed to verify referential integrity between files and to identify errors that may have been introduced during data import or processing. Selected *file crosschecks* and *input file checks* are conducted after each processing step. For example, all nutrients must be present for each food item and the nutrient codes used must be valid. An extensive set of database integrity checks are completed for all the FNDDS files listed in Table 1. Table 4 lists only the file checks and crosschecks relevant to the FNDDS nutrient values file.

3.3. Database validation checks

After QC has been completed for step 3 in the production of the FNDDS nutrient values file and all resulting revisions have been completed, the nutrient values are used to prepare preliminary intake estimates for NHANES. These estimates are then used in the final QC phase, which is conducted in conjunction with our survey data quality assurance program (Anand et al., 2006). The final set of QC checks is used to provide overall validation of both the nutrient values and the survey's 24 h food recalls and are listed in Table 5. Checks are run separately for the whole US population and for following gender/age groups: adult males, adult females, males aged 12–19, females aged 12–19, children aged 6–11 and 1–5, and infants. Within each group, daily intakes above the 99th percentile for a nutrient are identified and reviewed to determine the food source of the nutrient, and changes in nutrient values for these food sources, if any, are investigated and confirmed. An extremely high daily nutrient intake by a survey respondent may be perfectly valid, indicate an error in the intake data, or reflect an anomaly in the nutrient database. For example, when FNDDS 1.0 was in production and preliminary data were run for NHANES 2001–2002, we found extremely high thiamin intakes for participants who reported consuming soy burgers. When we investigated, we found that the SR soy burger was a product highly fortified with thiamin, so the NDL provided data for soy burger that would better reflect all the brands of the product. Mean nutrient intakes and intakes at the 10th and 90th percentiles for the gender/age groups mentioned above are also compared with intakes from previous years, and unusually high or low values are investigated. Mean intakes of new nutrients are compared with intakes from other studies if available in the scientific literature.

Table 4
Database integrity checks

File crosschecks
1. All items in the description file must also be present in the nutrient file.
2. All nutrients must be present for each food item.
3. All SR codes referenced in the FNDDS–SR links file must be present in the FNDDS input nutrient file.
4. Nutrient values in the FNDDS nutrient input file must be identical to values released in SR.
5. FNDDS and SR values must be identical where a 1:1 relationship exists.
Input file checks
1. Codes for new SR items must not pre-exist in the FNDDS nutrient input file.
2. SR code, nutrient code, and source code must be valid.
3. Nutrient values must not be blank or less than zero.
4. Updated values must differ from their original values.
5. More than 1 value per nutrient must not exist for a food item.

Table 5
Database validation checks

1. Intakes of survey respondants above the 99th percentile are reviewed and food sources of extremely high intakes are identified[a]; changes in nutrient values for these food sources, if any, are confirmed
2. Intakes at 10th, 50th, and 90th percentiles are reviewed, and compared to intakes from previous surveys[a]
3. Mean intakes for nutrients newly added to the database are compared to intakes from published literature, if available

[a]Checks are run separately for the whole US population and for selected sex–age groups—adult males, adult females, males age 12–19, females age 12–19, children age 6–11 and 1–5, and infants.

3.4. Additional FNDDS QC procedures

In addition to the QC checks discussed above, FNDDS data processing also includes other procedures that contribute to database quality. Procedures are in place to check all updated information including food names, food portions, and weights (Anderson et al., 2004). These procedures include maintaining all historical data and update files as separate files, which provide a way to track when, why, and how many changes were implemented. Reports for the number and type of changes made for a new version are also generated, which can be used as an additional check of the update process. Additionally, once a new version of FNDDS is final, its data are incorporated into the multi-version FNDDS that is maintained for trend analysis of survey data (Anderson et al., 2001; Ahuja et al., 2006). An additional set of QC routines are conducted at that time to ensure that changes to foods are tracked over time and that data are present for distinct time periods.

3.5. Features

The advantages of the FNDDS QC system are that it is multifaceted, automated, modular, and flexible.

- *Multifaceted*: A variety of checks are used to ensure accuracy and integrity of different aspects of the nutrient values file. The nutrient integrity checks are conducted to confirm the consistency of the nutrient values; the database integrity checks maintain and verify file integrity, and the database validations provide overall validation of the nutrient data using survey intake data.
- *Integrated*: The QC procedures have been integrated into data processing, allowing checking of processes and corrections of errors as soon as possible. New and updated values are confirmed before the next step of the update process is conducted.
- *Automated*: Most of the QC checks for the FNDDS have been automated and are part of the Food Database Management System, an in-house software application designed to manage this database (Anderson et al., 2004). Automation of the QC procedures results in improved processing time and efficiency in updating the FNDDS nutrient values. For example, the typical time required to run QC checks for preliminary new and updated SR nutrient values file and print any possible errors is about 5 min.
- *Modular and flexible*: The FNDDS QC system is designed to be modular in format. For example, separate modules exist for running nutrient integrity checks and database integrity checks. This allows enhancements to be added seamlessly as needed over time. New checks are added to meet new challenges, such as the addition of new nutrients or changes in the marketplace. For example, for the next update a list of frequently reported brand name foods will be added to the subset of foods selected for nutrient change validations.

4. Conclusion

QC is an integral part of data processing procedures. It must include a variety of checks and all input data should undergo the QC process. However, it is necessary to maintain a balance between rigorous QC and the time and resources available. QC checks should be automated to lessen the burden. Further discussions on this topic would be helpful in developing systems to ensure integrity and accuracy in nutrient databases.

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