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Food composition database harmonization for between-country comparisons of nutrient data in the TEDDY Study

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Abstract

The Environmental Determinants of Diabetes in the Young Study (TEDDY) aims at examining the associations between islet autoimmunity and various environmental exposures, (e.g. diet) in Finland, Germany, Sweden and the United States (US). In order to produce comparable results from dietary assessments, the national food composition databases (FCDB) must contain mutually

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comparable food composition data. Systematic comparison (definition, unit of measurement, and method of analysis) of energy, protein, fats, carbohydrates, cholesterol, fiber, 13 vitamins, and 8 minerals was carried out among the FCDB of the four countries. Total fat, cholesterol, vitamin A: retinol equivalents and beta-carotene, thiamin, riboflavin, pyridoxine, vitamin B_{12}, calcium, phosphorus, potassium, magnesium, iron, and zinc are comparable across all four databases. Carbohydrates, fiber, sugars, fatty acids, vitamin D, vitamin E: alpha-tocopherol, vitamin K, vitamin C, pantothenic acid, niacin, manganese, and copper are comparable or can be converted comparable at least across three of the databases. Vitamin E: alpha-tocopherol equivalents, will be comparable across all databases after Finland and Germany subtract tocotrienols from their values. Nitrogen values were added to the Swedish and US databases. After recalculation of protein from nitrogen (Sweden and US), and subtraction of fiber from the total carbohydrate (Finland) followed by recalculations of energy, these values will be comparable across the countries. Starch and folate are not comparable.

Keywords

Diet; Nutrient; Food composition database harmonization; Food analysis; Diet study; Food data management; The Environmental Determinants of Diabetes in the Young; TEDDY study

1 Introduction

The Environmental Determinants of Diabetes in the Young (TEDDY) study is a prospective, multi-center, multi-national study in which approximately 7,800 children with increased genetic susceptibility to type 1 diabetes are followed across six study centers worldwide (1 each in Finland, Germany, Sweden; and three in the United States). The participants are monitored for islet autoantibodies until the age of 15 years. The study aims to examine the associations between islet autoimmunity and various environmental exposures such as diet (TEDDY Study Group, 2008).

Food composition databases (FCDB) provide detailed information on the nutritional composition of foods (Schakel et al., 1997), and they are usually country-specific. These databases are available in different formats, e.g. paper-based, often known as food composition tables; or electronic versions, often known as nutrient databases or databanks. FCDB provide values for energy and nutrients (e.g. protein, vitamins and minerals) for each of the foods listed. These values are either based on chemical analyses which are carried out in analytic laboratories or are estimated from other appropriate data (EuroFIR, 2009).

The goal of FCDB is to provide reliable information on amounts of various nutrients in foods. However, we must be realistic about the accuracy of the information in the FCDB. Widdowson and McCance wrote in 1943: "There are two schools of thought about food tables. One tends to regard the figures in them as having the accuracy of atomic weight measurements; the other dismisses them as valueless on the grounds that a foodstuff may be so modified by the soil, the season, or its rate of growth that no figure can be a reliable guide to its composition. The truth, of course, lies somewhere between these two points of view" (Widdowson and McCance, 1943).

International studies of the relationship between dietary exposures and the risk of diseases require reliable and comparable data on food consumption. Between-country comparisons of diet must consider how food consumption data are collected and processed, and which food composition data are used for national dietary analyses (Slimani et al., 2007; Reinivuo et al., 2009). A comprehensive examination of the nutrients in a country's food supply is fundamental for the development of a representative national FCDB, however, it is costly to maintain these databases (Burlingame, 2004). To achieve the goal of collecting reliable information, all the methods and tools should be standardized between participating centers. To minimize systematic and random errors the standardization must be applied at each phase of the study including data collection, aggregation and coding of foods, and application of the food composition tables through computerized FCDB (Deharveng et al., 1999, Charrondiere et al., 2002). For all participating countries, each assessed nutrient must be defined in the same way, the units of measurement must be comparable, and the methods used to assess nutrient value must be the same or comparable (Deharveng et al., 1999).

In longitudinal studies, nutrient values in the FCDB must be updated frequently and new foods and recipes need to be added promptly (Deharveng et al., 1999; Schakel et al., 2003; Slimani et al., 2007) so that the results are precise and accurate also over time.

The aim of this paper is to compare TEDDY study nutrients between the four national FCDB: FINELI (Finland), LEBTAB (Germany), NFA Food Composition Database (The TEDDY Malmö version of the NFA Database) and Nutrition Coordinating Center (NCC) Food and Nutrient Database (US), and to describe our harmonization efforts.

2 Materials and methods

Data on food consumption are collected by 24-hour recall and 3-day food record in the TEDDY study. The first dietary assessment is carried out by 24-hour parental recall at the age of 3 months and after that by 3-day food record every 3 months until the child is 12 months old, and then every 6 months. The TEDDY study focuses on selected nutrients that may have an etiological link to type 1 diabetes. The nutrients included into the TEDDY study are energy and energy-yielding nutrients including 17 fatty acids, cholesterol, sugars, starch, fiber, 13 vitamins and 8 minerals (Table 1).

The dietary intake data are analyzed using the FCDB from each participating country: FINELI in Finland, LEBTAB in Germany, NFA Food Composition Database (The TEDDY Malmö version of the NFA Database) in Sweden and NCC Food and Nutrient Database in the US, and their respective in-house dietary intake data processing software. The TEDDY Data Coordinating Center in Tampa (FL, US) gathers and stores the outcome files.

The Finnish FINELI FCDB is maintained by the National Institute for Health and Welfare, which was formed by the merger in January 2009 of the former National Public Health Institute and the National Research and Development Center for Welfare and Health. The database contains about 4,300 foods and 290 nutrient factors. The vast majority of the nutrient values are based on direct analytical measurements or they have been derived from analytical measurements of a similar product (Koivistoinen, 1980; Ovaskainen et al., 1996). Nutrient values of interest are included for most of the foods, ranging from folate data for 95% of foods, to energy, energy-yielding nutrients and vitamins A and C data for 100% of foods. Vitamin losses are calculated according to Bergström (1994), and yield factors are calculated according to Bergström (1994) and Vekkilä (1983). Nutrients from food fortification are included in the database values, as are nutrient intakes from dietary supplements. The databases for dietary supplements (Reinivuo et al., 2008) and commercial baby foods are annually updated for the TEDDY study, and the main FCDB is updated at least once a year. The German LEBTAB FCDB was developed for the longitudinal DONALD study and is located in and maintained by the Research Institute of Child Nutrition (FKE) in Germany. The values in the LEBTAB come mainly from German Food Composition and Nutrient Tables (SFK) (Souci et al., 2008), which include both national analytical values and values from other FCDB that used the same method of analysis. Currently, the database includes about 12,900 foods and other dietary components, including additives, supplements, and medicine, and 45 nutrients. A four-digit alphanumeric code identifies each item in the database in a hierarchical order: food group, sub-food group, individual item (Sichert-Hellert et al., 2007). LEBTAB also includes dietary supplements and fortified foods, and it is the most up-to-date FCDB in terms of the number of commercial baby foods in Germany (Sichert-Hellert et al., 2007). Yield and retention factors were retrieved from the German BLS FCDB (Dehne et al., 1999) and added to LEBTAB calculation system in 2009 in accordance with the recommendations proposed by EuroFIR (EuroFIR, 2005). The LEBTAB is continuously updated: food items are added daily and their nutrient values are immediately available for calculations. The LEBTAB has essentially no missing nutrient values, with the exception of fatty acid and tocotrienol values which are available for a limited number of foods. Updates to the German Food Composition and Nutrient Tables (Souci et al., 2008) are also reflected in the LEBTAB.

The Swedish NFA FCDB is maintained by Livsmedelverket (National Food Administration). Since most of the nutrients are analyzed in Sweden, the database reflects the nutrient values of local foods. Some values are from industry sources and some are from food composition tables of other countries (http://www.slv.se/omlivsmedelsdatabasen). To meet the needs of the TEDDY Study, the Malmö TEDDY Diet center expanded their version of the NFA database to include commercial baby foods and dietary supplements. The TEDDY Malmö version of the NFA FCDB includes about 7,100 foods and dishes, and 51 nutrients. All the updates in the national NFA FCDB, made three to four times a year, are also reflected in the TEDDY Malmö version of the database. All the food listings include the mandatory 51 nutrient values that are also included in the national NFA FCDB. Information on fortification has been recently added. The yield factors are calculated according to Bergström (1994) and Vekkilä (1983) – similar to the FINELI. The NFA is currently updating the retention factors according to the method of Bognar (2002) and is following the respective recommendations by EuroFIR (EuroFIR, 2005). These data will be included in the TEDDY Malmö version of the NFA FCDB. Currently, the yield and retention factors for the TEDDY data in Malmö are applied at the recipe level, and nutrient-specific retention factors are applied regardless of the cooking method used (except for vitamin C, for which the retention factor depends upon whether the dish is cooked).

The US NCC food and nutrient database is maintained by the Nutrition Coordinating Center, University of Minnesota. Most of the nutrient values are obtained from the USDA National Nutrient Database for Standard Reference and are updated annually with the most current USDA release (USDA, 2009). The approximate percentages of the analytical values included in the USDA database are: protein and total fat 77%, sugars 44%, thiamin, riboflavin and niacin 72%, others in vitamin B group 61-64%, vitamins C and D 67-84%, vitamin A, beta-carotene and folate 37-49%, vitamin K and alpha-tocopherol 28-30%, fatty acids 41-80%, minerals 69-74% (Gebhardt, 2010). The NDSR Version 2009 NCC Food and Nutrient Database includes >18,000 foods, >7,000 brand-name products, and values for 160 nutrients, nutrient ratios and other food components (NDSR Manual, Chapter 1, 2009). The database is updated annually, and it has virtually no missing nutrient values (NDSR Manual, Appendix 21, 2009). The USDA yield and retention factors are derived from: 1) the USDA Agriculture Handbook No. 102, Food Yields Summarized by Different Stages of Preparation, and 2) the USDA Table of Nutrient Retention Factors, Release 6. The method of application is comparable to that recommended by EuroFIR (USDA, 2005, 2007, EuroFIR, 2005). Dietary supplements and food fortifications are considered in the calculations of nutrient intake.

Systematic comparison (definition, unit of measurement, method of analysis) of nutrients was carried out between the four country-specific FCDB. The process started in 2005 and involved several conference calls and three in-person meetings where the FCDB representatives from each country discussed the definition of the nutrients, units of measurement, and methods of analysis in each country. Various FCDB experts outside the TEDDY study were also contacted, as needed. The country-specific nutrient analyses were not available for every food. In these cases the nutrient values were adopted from other sources, e.g. food composition tables, but always keeping in mind that the method of analysis used for obtaining the nutrient value must be comparable.

3 Results

3.1 Energy

Energy can be expressed in kilocalories (kcal) or in kilojoules (kJ) (Table 2). While Finland, Germany and Sweden use the general Atwater factors: fat 37 kJ/g (9 kcal/g), protein and carbohydrates 17 kJ/g (4 kcal/g), and alcohol 29 kJ/g (7 kcal/g), the US uses food-specific Atwater coefficients, (Merrill and Watt, 1973). In addition, Finland takes polyols into consideration in the energy calculations.

To compare energy values between databases, values in the U.S. dataset will be recalculated based on the general Atwater factors, and Finland will omit the polyols from their energy calculation

3.2 Total protein and nitrogen

Finland and Germany calculate protein values from nitrogen content using a general conversion factor of 6.25 (6.25×nitrogen in grams = protein in grams). While Sweden and the US have been using food group-specific conversion factors, they will add nitrogen into their FCDB as a result of the harmonization efforts. This addition allows protein values from their TEDDY data to be recalculated using the general conversion factor of 6.25 for comparability with Finland and Germany. Nitrogen values were analyzed using the Kjehldal method (AOAC, 1980) in all four countries.

3.3 Total fat, fatty acids and cholesterol

Fats are analyzed using the extraction method in Finland, Sweden and the US, but some total fat analyses in meat are done using spectrometry in Finland. Germany uses mainly gas chromatography. Fatty acids and cholesterol are analyzed using gas-liquid chromatography in all the TEDDY countries. Total fat and cholesterol values are comparable between the countries but only Finland, Sweden, and the US include in their FCDB all nine saturated fatty acids, two monounsaturated fatty acids, and six polyunsaturated fatty acids that are listed under TEDDY nutrients (Table 1). Currently, Germany lists linoleic acid values for all foods, but only includes other fatty acid values for selected foods: fish, selected fats/oils, milk, milk products, nuts and oilseeds.

3.4 Total carbohydrates, fiber, sugars and starch

The Finnish FCDB FINELI provides both “available carbohydrate” and “carbohydrate by difference” (Table 2). In Sweden, carbohydrates are calculated by difference but the Swedish FCDB does not include fiber as carbohydrates. In the US and Finland, total carbohydrates are similarly calculated as “carbohydrates by difference”. Available carbohydrates in the NCC database are calculated as total carbohydrates minus dietary fiber, which corresponds with the carbohydrate values in Sweden. Finland will subtract fiber from the total carbohydrates (carbohydrates by difference) to make the values comparable to those in Sweden and to the available carbohydrates in the US. German carbohydrate values are calculated as a sum of mono-, oligo-, and polysaccharides for the majority of foods. “Carbohydrates by difference” is used for energy calculation in many countries, and we recommend that it be used in the TEDDY Study.

The AOAC currently recommends the enzymatic gravimetric method to analyze dietary fiber content (AOAC, 1980). Finland, Sweden and the US use it as the main analytical method for fiber. Germany uses also specific enzymatic methods for fiber, especially for fiber in cereals. However, a large proportion of Germany's fiber data are reported as the fiber value per 100g, which is calculated as the difference between 100 and the sum of the percentages of water, protein, fat, minerals, and available carbohydrates.

The values for sugars include the sum of mono- and disaccharides in Finland and in the US, but only include added sugars in Germany. The Swedish database includes both mono- and disaccharides; these values will be summed up as a separate procedure to produce a comparable variable.

Starch values are not available in the German and Swedish FC databases. Finland has starch values only for selected foods. In the US, the starch value includes dextrin and glycogen, but 58% of the values in the NCC FC database are estimates.

3.5 Beta-carotene and vitamin A

Beta-carotene, a pigment found in many yellow and red-orange fruits and vegetables, is an antioxidant and a precursor of vitamin A (Smolin and Grosvenor, 2003). All FCDB values for beta-carotene and vitamin A are derived from high-pressure liquid chromatography (HPLC) analyses. The values are thus comparable across the countries in the TEDDY study.

FCDB from Finland, Sweden and the US report both retinol equivalents and retinol activity equivalents, while Germany reports only retinol equivalents. In all four countries, retinol equivalents are calculated by adding retinol and 0.167× beta-carotene equivalents. Retinol activity equivalents are calculated in the same way in Finland, Sweden, and the US (Table 2). Only retinol equivalents are comparable between all countries because the LEBTAB lacks the retinol activity equivalents.

3.6 Vitamin D

Vitamin D refers to a group of fat-soluble secosteroids that are found primarily in two physiologically active forms in foods: ergocalciferol (D2) synthesized by plants, and cholecalciferol (D3) synthesized by animals, including human skin when exposed to UVB rays from sunlight (Smolin and Grosvenor, 2003; NIH Office of Dietary Supplements, 2010a). A metabolite of the cholecalciferol, 25-hydroxycholecalciferol, can also be found in some foods. Fortified foods may contain either vitamin D3 or D2. The main sources of dietary vitamin D are fish, egg yolks, butter and fortified foods like milk, margarine, and various cereals (Bender, 2002). However, diet is considered a secondary source of vitamin D if sufficient solar UVB radiation is available (Lamberg-Allardt, 2006). Meat contains vitamin D only in small amounts, but it may be an important source since what is present is mostly the final active metabolite, calcitriol, which, on a molar basis, is many times more potent than cholecalciferol (Bender, 2002). All the countries except Sweden also consider 25-hydroxycholecalciferol in the vitamin D values. In Germany, 25-hydroxycholecalciferol is reported only for human and cow's milk. Finland and the US take all the dietary 25-hydroxycholecalciferol into account in calculation of the total vitamin D value. However, the conversion coefficients differ between the three countries: 1 in Germany, 1.5 in Finland and 5 in the US (Table 2). These conversion factors are still a matter of dispute (Ovesen et al., 2003), and thus no single conversion factor is recommended. Since there is no consensus regarding which conversion factors to use, the variation in conversion factor values must be considered and comparisons between countries should be made cautiously. Since, single 25-hydroxycholecalciferol values are not available for the German and the US databases, it is not possible to subtract them from the total vitamin D for harmonization purposes. If meat or egg yolk is not a major part of the overall diet, the choice of conversion factor may have an insignificant effect on total vitamin D intake (Ovesen et al., 2003). The main method of vitamin D analysis is HPLC in each TEDDY country.

3.7 Vitamin E

The main sources of vitamin E include various nuts, plant oils, leafy green vegetables, a variety of fish (Bender, 2002) and many fortified foods like breakfast cereals (Murphy et al., 1990). The Institute of Medicine (2000) recommends using alpha-tocopherol, the only biologically active form of the vitamin, as a measure of vitamin E intake. This value is available for Finland, Sweden and the US (Schakel & Pettit, 2004), and it includes both natural and synthetic alpha-tocopherol (Table 2). However, Germany does not have values for alpha-tocopherol alone in its database. All four countries list vitamin E values as alpha-tocopherol equivalents, and use the same formula to transform various tocopherols to reflect their alpha-tocopherol activity: alpha-tocopherol + (0.4 × beta-tocopherol) + (0.1 × gamma-tocopherol) + (0.01 × delta-tocopherol). Some countries include tocotrienols in the formula while others do not. In Finland and Germany, alpha-, beta- and gamma-tocotrienols are summed together with the tocopherols, whereas Sweden and the US do not count them. The main sources of tocotrienols are grains and tropical oils (Traber, 2006). Since grains are a major part of the Western diet there will be a variation in the calculated intakes of alpha-tocopherol equivalents between the four countries if tocotrienols are included in only two country databases. Finland and Germany will subtract tocotrienols from the total alpha-tocopherol equivalents, thus making this form of vitamin E values comparable across the four FCDB.

3.8 Vitamin K

The two natural compounds of vitamin K with biological activity are phylloquinone, found in green leafy vegetables, and menaquinones, which include related compounds mainly synthesized by intestinal bacteria (Bender, 2002). All the countries use HPLC to measure phylloquinone levels. Finland includes menaquinone, although its content in foods is very small and should thus be comparable with the amounts in the other databases (Koivu-Tikkanen, 2001). In Sweden, vitamin K values are available only for selected foods.

3.9 Vitamin C

Fruits and vegetables are good sources of vitamin C (Bender, 2002). Vitamin C levels are reported as the sum of ascorbic and dehydroascorbic acid in all countries except Sweden, where only the ascorbic acid value is reported. Canadian studies revealed that dehydroascorbic acid levels in foods account for a fairly small portion of the total ascorbic acid (Behrens and Madere, 1994). The vitamin C values are broadly comparable between the FCDB despite the difference in analytical methods used (HPLC, colorimetry and fluorimetry) (Deharveng et al., 1999).

3.10 Thiamin, riboflavin, pyridoxine, panthotenic acid and vitamin B_{12}

Thiamin and the other vitamins in the B complex are water-soluble vitamins (Smolin and Grosvenor, 2003). Good dietary sources of thiamin are whole grain cereals, pork and organ meats (Smolin and Grossvenor, 2003). Dairy products, meat, whole grain and enriched cereals are good sources of riboflavin (Smolin and Grossvenor, 2003). Various methods have been used to measure thiamin and riboflavin levels in food. Finland and Sweden use HPLC, while Germany and the US use three methods: HPLC, fluorometry and microbiological methods. All three methods yield similar values (Deharveng et al., 1999).

Meat, legumes, seeds, leafy vegetables and whole grains are rich in pyridoxine (Smolin and Grossvenor, 2003). Finland uses HPLC to analyze pyridoxine whereas the other countries use both HPLC and microbiological methods. Nevertheless, both of the methods produce comparable results (Deharveng et al., 1999).

The main sources for pantothenic acid are eggs, organ meats, legumes and whole grains (Smolin and Grosvenor, 2003). Values for this vitamin are not available in the Swedish FC database. Finland, Germany and the US report panthothenic acid values that are obtained by microbiological assays. The main dietary sources of vitamin B_{12} are meat and dairy products (Smolin and Grosvenor, 2003). Since all the countries report vitamin B_{12} values that are assessed by microbiological methods, the values are comparable.

3.11 Niacin

Meat, liver, fish, cereal and legumes are good sources of niacin, also known as nicotinic acid. Niacin can also be synthesized from tryptophan, which is found in foods such as meat, dairy and eggs. Sixty mg of tryptophan are required to synthesize 1 mg of niacin (Bender, 2002). Finland uses a colorimetric method to analyze niacin, while the other countries use microbiological assays. Some values in the German FC database have been analyzed using HPLC. The values for all the countries are comparable. However, there are differences in how the conversion of niacin from tryptophan is considered (Table 2).The tryptophan value is not available in the German database, but it has been estimated in LEBTAB that the average amount of tryptophan in diet is 1% of the total amount of protein.

3.12 Folate

Folate is a water-soluble vitamin that is found in food whereas folic acid is the synthetic form of folate that is added to dietary supplements and fortified foods (NIH Office of Dietary Supplements, 2010b). Dietary folate equivalents (DFE) refer to units that consider differences in the absorption: 1.0 μg DFE=1.0 μg food folate=0.6 μg folic acid added to foods=0.5 μg folic acid as a dietary supplement without food (Suitor and Bailey, 2000). Fortified breakfast cereals, liver, legumes, yeast, and various fruit are good sources of folate (Smolin and Grossvenor, 2003). All the countries use microbiological assays to estimate folate values in foods; Finland and Germany also use HPLC. The most recent comparison reveals that there is about 23-40% difference between these methods (Kariluoto et al., 2002). In the NCC many values are obtained from manufacturers. Often, the manufacturers do not clearly state how the free and conjugated folate are considered in calculations of total folate, and database descriptions do not always indicate whether the microbiological assay involved folate conjugase treatment alone or whether the food was analyzed using the tri-enzyme treatment method. The results from these methods, depending on the food, can be very different (DeSouza and Eitenmiller, 1990; Shrestha et al., 2000).

3.13 Calcium, phosphorus, potassium, magnesium, manganese, iron, zinc, and copper

Dairy products and small fish consumed with bones are good sources of calcium (Smolin and Grosvenor, 2003). Phosphorus is more widely distributed in diet than calcium: dairy products, meat, cereals, eggs, nuts and fish are good sources of phosphorus. Potassium is mainly found in fruits, vegetables and grains. The best sources of dietary magnesium are green leafy vegetables, whole grain products, nuts and seeds, and the best sources of manganese are whole grains and nuts (Smolin and Grosvenor, 2003). Leafy greens such as spinach, kale and beans are rich in iron but the nonheme iron in plants is less well absorbed than the heme iron in animal sources like meat, fish, and poultry (Smolin and Grosvenor, 2003). Good sources of zinc are red meat, liver, eggs, dairy products, and vegetables, and good sources of copper are organ meats, seafood, nuts, and seeds (Smolin and Grosvenor, 2003).

Atomic absorption spectrometry (AAS) (Koivistoinen, 1980) is the preferred analysis method for minerals in the four TEDDY countries, although it is not the most recent analytical approach. Calcium, magnesium, and iron levels are consistently measured by AAS, and Germany and the US have selected AAS as the main method for analyzing phosphorus. Finland and Sweden use spectrometry-based analysis methods for phosphorus analysis. Finland uses AAS to measure potassium and manganese, and the US. Germany and Sweden use spectrometry to measure potassium. Germany uses several methods to analyze manganese and zinc, including various spectrometry-based analyses and AAS. Finland, Sweden and the US use AAS to measure zinc, and all four countries use AAS to measure the iron content in foods. AAS is used to analyze copper levels in Finland, Germany and the US. The Swedish NFA database does not include manganese and copper values. All the mineral values are comparable between the countries.

4 Discussion and conclusions

Nitrogen, total fat, fatty acids (saturated, monounsaturated, and polyunsaturated), cholesterol, beta-carotene, retinol equivalents, vitamin K, vitamin C, thiamin, riboflavin, pyridoxine, pantothenic acid, vitamin B_{12}, calcium, phosphorus, potassium, magnesium, manganese, iron, zinc, and copper values are comparable between the FCDB in the TEDDY countries. However, Germany does not include all the fatty acids values in LEBTAB and Sweden does not include pantothenic acid, manganese and copper in the NFA database. In addition, the NFA database has vitamin K values only for selected foods. Despite these similarities, important differences were detected and actions for harmonization were taken.

Finland will subtract fiber and polyols from the total carbohydrate value, thus making carbohydrate values comparable with the calculated values from Sweden and the US. After recalculation of protein from nitrogen and consequent recalculation of carbohydrates by difference (Sweden and the US), and after further recalculation of energy (Sweden, the US, and Finland) using new protein and carbohydrate values, energy and energy yielding nutrients will be comparable between the FCDB. FAO (1998) recommends taking into consideration the small energy yield from fiber in the calculation of total energy intake. However, we could not include it in the energy calculations because the fiber is not clearly and comparably defined in all four countries. . German carbohydrate values are mainly estimated from analyses of separate carbohydrate fractions, and are calculated as a sum of mono-, oligo-, and polysaccharides for the majority of foods – a method which is likely to be comparable with other analytical methods if the comparable fractions of carbohydrates are considered in the calculations (Deharveng et al., 1999). Germany only includes added sugar in their FCDB, therefore their values for sugar cannot be compared with those in the other TEDDY countries. Sweden will sum up mono- and disaccharides to have sugar values comparable with those in Finland and the US.

The majority of the vitamin D values in Germany and the US are from various food composition tables where the method is not specified. However, many of the vitamin D values in the NCC database were adopted from the Finnish analyses (Mattila, 1995), so the vitamin D should be reasonably comparable between these two FCDB. However, the method used to convert 25-hydroxycholecalciferols differs between Finland and the US, and in Germany 25-hydroxycholecalciferols are considered only in human and cow milk; Sweden has not considered it at all. Vitamin D values, therefore, must be compared with caution.

Finland and Germany include tocotrienols in their total alpha-tocopherol equivalents. Meat, fish, eggs, dairy, fruits, and most vegetables and nuts contain no tocotrienols, (Chun et al., 2006; Syväoja et al., 1985; McLaughlin & Weihrauch, 1979). Therefore, the exclusion of tocotrienols does not affect the total alpha-tocopherol equivalent values in most of the foods. However, the largest sources of the tocotrienols are cereal grains and tropical oils. Due to the importance of grains in diets, we recommend subtracting the alpha-, beta-, and gamma -tocotrienols in calculations of the total amount of alpha-tocopherol equivalents. Finland and Germany will subtract alpha-, beta-, and gamma -tocotrienols from the alpha-tocopherol equivalents to make this form of vitamin E comparable with the amounts reported in the Swedish and the US FCDB. Regarding the total alpha-tocopherol, Sweden will use the same conversion factor (0.5) as Finland in converting synthetic alpha-tocopherol comparable to natural alpha-tocopherol. After this procedure, the alpha-tocopherol values will be broadly comparable with the values in the US FCDB, which uses the conversion factor 0.45. Sweden does not take dehydroascorbic acid (DHAA) into account in calculations of vitamin C, but omission of these values will most likely not cause significant differences between the total vitamin C values in the FCDB (Behrens and Madere, 1994). Since Germany estimates the tryptophan value from total dietary protein, its calculations of niacin equivalents may not be comparable with other countries.

Folate values for processed and packaged foods in all databases are dependent on manufacturer-derived information on food labels, where the method is often not specified. Kariluoto et al. (2002) compared microbiological and HPLC methods, and reported that the *L. casei* microtitre plate method results in higher food folate levels than HPLC Due to differences in analytical methods and variation in the source of information from manufacturers, the folate values are not comparable between the FCDB.

Germany will convert the measurement units of vitamin E (alpha-tocopherol equivalents), pyridoxine, and manganese from micrograms into milligrams to make them comparable with the measurement units used in the other countries.

Our review reveals that values for energy and 21 nutrients are comparable – or can be converted to be comparable – between all four databases. The fatty acids that are summed up into three subgroups (saturated, monounsaturated and polyunsaturated), and five nutrients (sugars, fiber, pantothenic acid, manganese, copper) are comparable between three countries only. Vitamin D and niacin values between the FCDB should be compared with caution due to differences in conversion methods. Values for starch are only available for Finland and the US, FINELI has starch values only for selected food items, and 58% of the NCC starch values have been estimated. Folate analysis methods have not been consistent over years in the TEDDY countries. Thus, starch and folate values should not be compared across the countries.

Several comparisons of nutrient values in the FCDB of selected countries have been published. Deharveng et al. (1999) compared food composition tables in nine European countries in the European Prospective Study on Cancer and Nutrition (EPIC). The authors emphasized the importance of defining foods in the same way in each table if the nutrient values of foods were directly compared. For example, the typical “rye bread” in Finland is considerably different than the ”rye bread” in the US. However, in the TEDDY diet study it is important that the nutrient content for a country-specific food reflects the appropriate values in the national FCDB, because we do not compare nutrient values of the composite dishes or foods but nutrient intakes from the whole diet. Each country lists their foods in food records using their country-specific names and nutrient contents. Deharveng et al. (1999) faced similar problems, in that they could not consistently find explicit documentation related to how nutrient values were retrieved, e.g. manufacturer information. They also emphasized the importance of re-calculating protein and energy values to make them mutually comparable. The method of calculating protein from nitrogen often varies from country to country, or between food groups.

Deharveng et al. (1999) suggested that the nutrients of interest in their study could be separated into three groups in order to harmonize the data. The first group included nutrients that were comparable even if definition or analytical methods differed slightly, e.g. nitrogen, fats, cholesterol, vitamin D, tocopherols. The second set group included nutrients that were not readily comparable but that could be converted and thus made comparable, e.g. protein, carbohydrates, energy, vitamin A. The third group included those that were not comparable and that could not be converted to be comparable: folate and fiber (Deharveng et al., 1999). The findings in the EPIC Study were similar to ours: it is usually feasible to convert macronutrient values to make them comparable. However, nutrients for which analytical assessments have changed over the years, or for which documentation is unclear, may not be successfully harmonized. Documentation of good quality is an essential part of building useful FCDBs (Burlingame, 2004).

Hakala et al. (2003) compared nutrient intake data from similar populations, Finland and Sweden, using two different FCDB and concluded that the mean values of nutrients corresponded remarkably well to each other for the majority of the examined nutrients. They also noted that many of the differences are real, and are due to factors such as different fortification of foods, or differences in the amount of fertilizer used in countries. They also pointed out that analyses of nutrient content of the same food may differ greatly based on the geographic location where the food is sampled. For example, the vitamin D level in perch ranges from 0.28 to 25.3 μg/100 g (Mattila, 1995).

Schakel et al. (2003) compared FCDB used in the INTERMAP study that was conducted in China, Japan, the United Kingdom, and the United States. They emphasized that it is important to update the database frequently: new foods and new preparation methods should be included because the food supply changes frequently.

We recommend that each country will calculate its nutrient values using the original method, and to record any changes that are made after harmonization. In this way, the overall effect of harmonization efforts on nutrient values can be estimated.

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Table 1

The nutrients in the TEDDY diet study.

Energy (in kilojoules or kilocalories)
Total protein
Nitrogen
Total fat
Fatty acids:
Saturated Fatty Acids
4:0 butanoic
6:0 hexanoic
8:0 octanoic
10:0 decanoic
12:0 lauric
14:0 myristic
16:0 palmitic
18:0 stearic
20:0 arachidic
Monounsaturated Fatty Acids
16:1 palmitoleic
18:1 oleic
Polyunsaturated Fatty Acids
18:2 linoleic
18:3 linolenic
20:4 arachidonic
20:5 eicosapentaenoic
22:5 docosapentaenoic
22:6 docosahexaenoic
Cholesterol
Total carbohydrates
- Sugars
- Starch
Fiber
Beta-carotene
Vitamin A (retinol equivalent, retinol activity equivalent)
Vitamin D
Vitamin E (total alpha-tocopherols, alpha-tocopherol equivalents)
Vitamin K
Vitamin C
Thiamin
Riboflavin
Niacin (niacin equivalents)
Folate (total folate)

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Pyridoxine
Panthothenic acid
Vitamin B12
Calcium
Phosphorus
Potassium
Magnesium
Manganese
Iron
Zinc
Copper

Table 2

Comparison of definitions of energy and nutrients, comparison of unit of measurements and analysis methods between the four food composition databases (FCDB) in TEDDY.

	FINLAND (FINELI)[1]	**GERMANY**[1] **(LEBTAB)**	**SWEDEN (NFA)**[1]	**US (NCC)**[1]	**Approaches adopted for harmonization**
Energy, kJ or kcal	Calculated in kilojoules (kJ): 37×fat+17×protein+17 ×carbohydrates +29×alcohol +13×organic acids +10×polyols (g) Carbohydrates used in energy calculation: Available carbohydrate	Calculated in kilocalories (kcal): 9×fat+4×protein + 4×carbohydrates + 7×alcohol (g) Carbohydrates used in energy calculation: depends on which type of carbohydrates are available	Calculated in kJ: 37×fat+17×protein+ 17×carbohydrates+29× alcohol (g) Carbohydrates used in energy calculation: per 100g as the difference between100 and the sum of the percentages of water, protein, fat, fiber, ash, and alcohol	The basic principle has been to calculate the energy values (kcal) using food *specific* Atwater factors for each food group, and when proprietary, values calculated in the same way as in Germany	The mutually comparable energy will be calculated using general Atwater factors: 37×fat+17×protein+ 17×carbohydrates+29×alcohol (g), when using kJ kcal= kJ/4.18
Total protein, g	Calculated from nitrogen using conversion factor 6.25	Calculated from nitrogen using conversion factor 6.25	Calculated from nitrogen using a food group specific conversion factor	Calculated from nitrogen using a food group specific conversion factor (Merrill and Watt, 1973).	Total protein will be calculated from nitrogen using universal conversion factor 6.25.
Nitrogen, g	Kjeldahl	-not available in LEBTAB but in Souci et al. (2008), which is the base for the LEBTAB (Kjehldal) -can be calculated as: nitrogen = protein/6.25(g)	Kjehldal -nitrogen available in the NFA database since 2007	Not available before the TEDDY Study	Nitrogen (Kjehldal) added to the NCC in 2008 as a result of the harmonization efforts. Nitrogen will be added also to the Malmö version of the NFA.
Total fat, g	Gravimetric method	Mostly gas chromatography	Hydrolysis and extraction; gravimetric methods	Gravimetric methods	Total fat values provided by recent analyses should be comparable, as agreements on extraction and hydrolysis procedures have been reached in Europe in recent years (Deharveng, 1999).
	FINLAND (FINELI)	**GERMANY (LEBTAB)**	**SWEDEN (NFA)**	**US (NCC)**	Approaches adopted for harmonization
Fatty acids, g	Gas-liquid chromatography (GLC) *Saturated Fatty Acids* 4:0, 6:0, 8:0, 10:0, 12:0, 14:0, 16:0, 18:0, 20:0 *Monounsaturated Fatty Acids* 16:1, 18:1 *Polyunsaturated Fatty*	Gas-liquid chromatography (GLC) *Saturated Fatty Acids** 12:0, 14:0, 16:0, 18:0 *Monounsaturated Fatty Acids** 18:1 *Polyunsaturated Fatty Acids* 18:2, 18:3*, 20:4*,	Gas -liquid chromatography (GLC) *Saturated Fatty Acids* 4:0, 6:0, 8:0, 10:0, 12:0, 14:0, 16:0, 18:0, 20:0 (the four first FAs summed up to one variable) *Monounsaturated Fatty Acids*	Gas-liquid chromatography (GLC) *Saturated Fatty Acids* 4:0, 6:0, 8:0, 10:0, 12:0, 14:0, 16:0, 18:0, 20:0 *Monounsaturated Fatty Acids* 16:1, 18:1 *Polyunsaturated Fatty*	German fatty acid values do not cover all the foods and therefore only Finnish, Swedish and US fatty acid values are mutually comparable.

	FINLAND (FINELI)[1]	GERMANY[1] (LEBTAB)	SWEDEN (NFA)[1]	US (NCC)[1]	Approaches adopted for harmonization
	Acids 18:2, 18:3, 20:4, 20:5, 22:5, 22:6	20:5*, 22:5*, 22:6* *= available only for fish, selected oils/fats, milk, milk products, nuts and oilseeds	16:1, 18:1 *Polyunsaturated Fatty Acids* 18:2, 18:3, 20:4, 20:5, 22:5, 22:6	*Acids* 18:2, 18:3, 20:4, 20:5, 22:5, 22:6	
Cholesterol, mg	GLC	GLC Small insignificant amounts of cholesterol from plant products are considered	GLC	GLC It is assumed that cholesterol is present only in foods of animal origin.	Cholesterol values are comparable between the countries.
	FINLAND (FINELI)	**GERMANY (LEBTAB)**	**SWEDEN (NFA)**	**US (NCC)**	Approaches adopted for harmonization
Carbohydrates, (CHO), g	Available carbohydrates are calculated as a sum: mono- + disaccharides + starch + dextrin + glycogen Carbohydrates "by difference" are calculated per 100 g as the difference between 100 and the sum of the percentages of water, protein, fat, ash and alcohol	Carbohydrates are calculated as a sum: mono-+ oligo- +polysaccharides for some, and for some foods the CHO is calculated by difference as in Finland	Carbohydrates are calculated: per 100 g as the difference between 100 and the sum of the percentages of water, protein, fat, fiber, ash and alcohol	Available carbohydrate includes sugar and starches and is calculated as the difference between total carbohydrate and dietary fiber for most foods. If high organic acid content, then the sum of sugars and starch is used. Total carbohydrate is calculated per 100 g as the difference between 100 and the sum of the percentages of water, protein, fat, ash and alcohol	Carbohydrates by difference in Sweden, available carbohydrates in the US, carbohydrates by difference minus fiber in Finland would be mutually comparable. Due to varying methods of assessing carbohydrate values in Germany, German carbohydrate values have to be compared cautiously with the values from other countries.
Sugars, g	Sum of mono- and disaccharides	Only added sugar available in the database	Need to sum monosaccharides and disaccharides	Sum of mono- and disaccharides	Sugar values are comparable between Finland and the US, and also Sweden after summing up mono- and disaccharides. Germany provides only added sugar.
Starch, g	Polarimetry and calculation: Available CHO – sugars Values available for basic foods	Not available	Not available for most of the foods.	AOAC[2] - includes dextrin and glycogen - 58% of the values estimated	Starch available only for Finland and the US, due to missing values in Finland and variation in analysis methods the values are not comparable.
Fiber, g	AOAC, total fiber, insoluble and soluble available separately	Enzymatic methods and calculation by difference: total fiber=100- water - protein -fats - minerals - available carbohydrates (when	AOAC, total fiber, insoluble/soluble fiber not available separately.	AOAC, total fiber insoluble and soluble available separately	Finland, Sweden and the US use methods that are mutually comparable.

	FINLAND (FINELI)[1]	GERMANY[1] (LEBTAB)	SWEDEN (NFA)[1]	US (NCC)[1]	Approaches adopted for harmonization
		values given per 100 g of food)			
	FINLAND (FINELI)	**GERMANY (LEBTAB)**	**SWEDEN (NFA)**	**US (NCC)**	Approaches adopted for harmonization
Beta-carotene, ug (microgram)	High-Pressure Liquid Chromatography (HPLC)	High-Pressure Liquid Chromatography (HPLC)	High-Pressure Liquid Chromatography (HPLC)	High-Pressure Liquid Chromatography (HPLC)	The values are mutually comparable.
Vitamin A, Retinol Equivalents, ug OR Retinol Activity Equivalents, ug	HPLC **Retinol activity equivalents**= retinol + beta-carotene/12+ (alpha-carotene + beta-cryptozanthin)/24 (µg) **Retinol equivalents**= retinol+0.167× beta-carotene equivalents (µg)	HPLC **Retinol equivalents**= preformed retinol + beta-carotene/6 + sum of vitamin A active carotenoids (=alpha-carotene + beta-carotene + gamma-carotene + cryptoxanthin + mutatochrome)/12 (µg) **Retinol activity equivalents** not available.	HPLC The new version of NFA has retinol activity equivalents included. **Retinol activity equivalents** = retinol + beta-carotene/12+ (alpha-carotene + beta-cryptozanthin)/24 (µg) **Retinol equivalents** available, which are calculated retinol+ beta-carotene/6 + other carotenoids/12 (µg)	HPLC **Retinol equivalents** = retinol + beta-carotene equivalents /6 (essentially the same as retinol equivalents in the other countries) (µg) **Retinol activity equivalents**= retinol + beta-carotene equivalents/12 (µg)	Retinol equivalents comparable between the countries. Retinol activity equivalents would be comparable between Finland, Sweden and the US. NFA still calls retinol activity equivalents 'retinol equivalents' according to the Nordic Nutrient Recommendations.
Vitamin D, µg	HPLC Vitamin D includes both ergocalciferol and cholecalciferols as well as 25-hydroxycholecalciferol (conversion factor is 1.5)	HPLC If 25- hydroxychole-calciferol measured then it will also be taken into consideration (in human and in cow milk), cannot be subtracted later.	Alkaline hydrolysis, extraction, HPLC Both ergocalciferol and cholecalciferol given together. 25-hydroxycholecalciferol is not included.	Most of the values taken from various food composition tables and therefore the method of analysis may not be consistent. 25- hydroxychole-calciferol is considered in the total vitamin D value (conversion factor 5).	There are differences how the 25- hydroxycholecalciferols are included into the total vitamin D. 25-hydroxycholecalciferol is not available separately for all the FCDB to make changes in calculation of total vitamin D possible.
Vitamin E, Total alpha-tocopherols, mg OR Alpha-tocopherol Equivalents, mg	HPLC Alpha-tocopherols (AT) where the synthetic ATs converted to comparable with the natural using conversion factor 0.50 Alpha-tocopherol equivalent	Mostly HPLC Alpha-tocopherol equivalent (in micrograms)	HPLC Alpha-tocopherols (AT) where the synthetic ATs converted to comparable with the natural using conversion factor 0.67 Alpha-tocopherol equivalent	HPLC or GLC Alpha-tocopherols (AT) where the synthetic ATs converted to comparable with the natural using conversion factor 0.45 Alpha-tocopherol equivalent	Sweden will use 0.50 instead of 0.67 in converting synthetic ATs into format that can be summed up with the natural ATs, and will thus be comparable with AT values in Finland and the US. Finland and Germany will subtract tocotrienols from the total alpha-tocopherol equivalent value to make the values comparable with the FCDB in the other countries.
	FINLAND (FINELI)	**GERMANY (LEBTAB)**	**SWEDEN (NFA)**	**US (NCC)**	Approaches adopted for harmonization
Vitamin K, µg	HPLC- Phylloquinone	HPLC - Phylloquinone	Not available	HPLC - Phylloquinone	Vitamin K values are

	FINLAND (FINELI)[1]	GERMANY[1] (LEBTAB)	SWEDEN (NFA)[1]	US (NCC)[1]	Approaches adopted for harmonization
					comparable between Finland, Germany and the US.
Vitamin C, mg	HPLC Ascorbic acid and dehydroascorbic acid.	HPLC Ascorbic acid and dehydroascorbic acid.	HPLC Ascorbic acid only.	Reduced ascorbic acid by dichloroindophenol and total ascorbic acid by fluorimetric method.	The methods are comparable. Swedish vitamin C values will be slightly smaller than in other countries.
Thiamin, mg	HPLC	Fluorimetry	HPLC, fluorimetry	Thiochrome procedure or microbiological methods.	All the methods give comparable results.
Riboflavin, mg	HPLC	HPLC	HPLC, fluorimetry	Fluorimetric or microbiological methods	All the methods give comparable results.
Niacin (equivalents), mg	Colorimetric method Niacin equivalents = niacin + tryptophan/60 (mg)	HPLC and microbiological methods, tryptophan not available. Niacin equivalents, mg, calculated as: niacin, mg +(protein in grams) /6) (mg)	Acid hydrolysis, extraction, microbiological assay, turbidimetric detection. Niacin equivalents = niacin + tryptophan/60 (mg)	Microbiological methods Niacin equivalents = niacin + tryptophan/60 (mg)	The German niacin equivalent values should be compared with caution because there are no tryptophan values available in the LEBTAB, but they are estimated from the total protein.
Folate, µg	HPLC and microbiological assay, separate values available.	HPLC and microbiological assay, values from different methods not available separately.	Microbiological method since 1999, radiolabeled protein method before. Not clear how the values have been derived from free and conjugated folates.	Microbiological method. Not clear how the values have been derived from free and conjugated folates. Large portion of the information received from manufacturer.	Results from the four FCDB may not be internally and mutually comparable.
Pyridoxine, mg	HPLC	Microbiological method or HPLC (in micrograms)	Microbiological method or HPLC	Microbiological method or HPLC	
Pantothenic acid, mg	Microbiologic method	Microbiologic method	Not available	Microbiologic method or radioimmunoassay	The values are comparable between Finland, Germany and the US.
	FINLAND (FINELI)	**GERMANY (LEBTAB)**	**SWEDEN (NFA)**	**US (NCC)**	Approaches adopted for harmonization
Vitamin B12, µg	Microbiological assay	Microbiological assay or mass spectrometry	Microbiological assay	Microbiological assay or chromatographic method	The values are comparable between the four countries.
Calcium, mg	Atomic absorption spectrometry (AAS)	Atomic absorption spectrometry (AAS)	Atomic absorption spectrometry (AAS)	Atomic absorption spectrometry (AAS)	The values are comparable between the four countries.

	FINLAND (FINELI)[1]	GERMANY[1] (LEBTAB)	SWEDEN (NFA)[1]	US (NCC)[1]	Approaches adopted for harmonization
Phosphorus, mg	Photometric vanadomolybdate method	AAS	Emission spectrometry	AAS	The values are comparable between the four countries.
Potassium, mg	AAS	Emission spectrometry	Flame spectrophotometry	AAS	The values are comparable between the four countries.
Magnesium, mg	AAS	AAS	AAS	AAS	The values are comparable between the four countries.
Manganese, mg	AAS	Emission spectrometry, AAS, florescent X-ray spectrometry (in micrograms)	Not available	AAS	The values are comparable between Finland, Germany and the US.
Iron, mg	AAS	AAS	AAS	AAS	The values are comparable between the four countries.
Zinc, mg	AAS	Various methods, mostly emission spectrometry, AAS, florescent X-ray spectrometry	AAS	AAS	The values are comparable between the four countries.
Copper, mg	AAS	Emission spectrometry	Not available	AAS	The values are comparable between Finland, Germany and the US.

FINELI located at National Institute of Health and Welfare in Helsinki, Finland.

LEBTAB located at Research Institute of Child Nutrition, Dortmund, Germany

NFA database located at National Food Administration, Uppsala, Sweden

NCC database located in University of Minnesota, USA.

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[1] The following food composition databases have been compared:

[2] AOAC Association of Official Analytical Chemists; the official method of analysis