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Federal Monitoring of Dietary Supplement Use in the Resident, Civilian, Noninstitutionalized US Population: National Health and Nutrition Examination Survey

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Abstract

This review summarizes the current and previous data on dietary supplement (DS) use collected from participants in the NHANES, describes the NHANES DS database used to compute nutrient intakes from DSs, discusses recent developments and future directions, and describes many examples to show the utility of these data in informing nutrition research and policy. Since 1971, NHANES has been collecting information on the use of DSs from participants. These data are critical to national nutrition surveillance and have been used to characterize usage patterns, examine trends over time, assess the percentage of the population meeting or exceeding nutrient recommendations, and help to elucidate the sources contributing nutrients to the diet of the US population. More than half of adults and approximately one-third of children in the United States currently use ≥1 DS in the course of 30 d. DSs contribute to the dietary intake of nutrients and bioactive compounds in the United States and therefore need to be assessed when monitoring nutritional status of the population and when studying diet-health associations. With the recent development and availability of the Dietary Supplement Label Database, a comprehensive DS database that will eventually contain labels for all products marketed in the United States, NHANES DS data will be more easily linked to product information to estimate nutrient intake from DSs. NHANES provides a rich source of nationally representative data on the usage of dietary supplements in the United States. Over time, NHANES has both expanded and improved collection methods. The continued understanding of sources of error in collection methods will continue to be explored and is critical to improved accuracy. *J Nutr* 2018;148:1436S–1444S.

Keywords: NHANES, monitoring, dietary supplements, supplement labels, epidemiology, nutritional surveillance, nutrition databases

Introduction, Background, and History

Nutrition monitoring is important for providing data critical to policymaking and for tracking progress of initiatives, and is used for research purposes. The National Nutrition Monitoring and Related Research Act of 1990 (Public Law 101-445) provided a framework that strengthened national data collection on the US population's dietary and health-related status (1). To accurately assess the dietary intake of a population or large-population groups, nutrients from dietary supplements (DSs) must be included, not only because of the pervasive use of these products but also because they can contribute substantially toward intake of nutrients and other bioactive compounds. The NHANES is a nationally representative survey designed to assess the health and nutritional status of the US population. NHANES collects data on participants via questionnaires and examinations, including participants' usage of DSs. Although the process is arduous, it is critical, because NHANES data are used to inform policy and evaluate whether the population is meeting or at risk of exceeding authoritative nutrient recommendations. In addition, NHANES DS data are used to characterize usage patterns, examine trends over time, address potential safety issues, and provide insights into the association between nutrients and other bioactive compounds and health outcomes.

NHANES has been consistently collecting data on the usage of DSs in the US population since 1971, and data have indicated an increasing trend in usage over time. In NHANES I (1971–1974), 32.9% of adults aged 25–74 y, and in NHANES II (1976–1980), 34.9% of adults aged 18–74 y reported the use of ≥1 DS (regularly or irregularly) (2, 3). Data from NHANES III

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(1988–1994) indicated that 40% of adults aged ≥20 y reported using ≥1 DS in the past 30 d, which further increased to 52% in NHANES 1999–2000 (4, 5). The percentage of adult users remained stable over the next decade; in NHANES 2011–2012, 52% of adults took ≥1 DS in the past 30 d (6), with about 45% of adult supplement users taking >1 product (7). Interestingly, the usage pattern differs among infants, toddlers, and children. Briefel and Johnson (8) found that DS use in general declined significantly among infants and children aged 1–5 y from NHANES I (1971–1974) to NHANES 1999–2000 but remained relatively constant for children and adolescents aged 6–19 y.

Many DSs, such as multivitamin-mineral products (MVMs), contribute ≥100% of the recommended daily intake for ≥1 nutrients. The high doses combined with the high prevalence of use make collecting and accurately capturing nutrient-related information provided by DSs relevant to national nutrition-monitoring efforts. Failure to accurately obtain such data could lead to underestimating total nutrient intake for the total population and subgroups (9, 10). It is also critical to maintain accurate and current DS databases. Collecting information on what supplements are used, and their frequency of use, is only half of the challenge: current and accurate supplement databases that include ingredients and their amounts are the foundation upon which valid intake estimates are based (11). Therefore, this review summarizes DS collection in NHANES since its inception, provides a detailed description of the method currently used to collect DS information in NHANES since 1999 or continuous NHANES, and describes the NHANES DS database that is used to estimate nutrient intakes from DSs. Finally, several examples of studies that have used NHANES data are provided to show the utility of these invaluable data in nutrition research and informing policy.

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Abbreviations used: CVD, cardiovascular disease; DS, dietary supplement; DSLD, Dietary Supplement Label Database; MEC, mobile examination center; MVM, multivitamin-mineral; NHANES-DSD, NHANES dietary supplement database; NHIS, National Health Interview Survey; ODS, Office of Dietary Supplements.

The NHANES Program

NHANES is conducted by the National Center for Health Statistics of the CDC, US Department of Health and Human Services. NHANES is designed to assess the health and nutritional status of the resident, civilian, US noninstitutionalized population through a cross-sectional multistage sampling design. Since 1999, NHANES has been continuously collecting data on a sample of about 5000 persons/y from 15 counties throughout the United States. Before 1999, NHANES was a periodic survey, collecting information over a specified number of years with break years in which no data were collected. NHANES collects data from participants through questionnaires, standardized examinations, and collection of biospecimens. These data are collected via an interview in participants' homes, at a mobile examination center (MEC), and post-MEC follow-ups. NHANES assesses the nutritional status of participants via 24-h dietary recalls, targeted FFQs (e.g., fish consumption, alcohol use), a questionnaire to assess DS usage, diet and behavior questionnaires, anthropometric measurements, and measurement of nutritional status–related biomarkers (12).

Past and Present NHANES DS Data Collection Methodologies

Although many national surveys have included questions on DSs over time, NHANES is currently the only national survey in the United States that regularly collects detailed information on DS use and maintains a DS label database to estimate nutrient values for products reported. In addition, linking this information to dietary intake allows the computation of total nutrient intake from diet and DSs in NHANES. The USDA Continuing Survey of Food Intakes by Individuals and the Nationwide Food Consumption Survey have in the past collected information on DSs. The National Health Interview Survey (NHIS) is a household-based survey that collects data on a variety of health topics via household interviews. The NHIS has collected and continues to collect valuable information on DS use, albeit not annually, on a large sample of the US population. Unlike NHANES, NHIS does not collect detailed data on DSs from the product label or detailed data on dietary intakes of foods and beverages, nor does it include a physical examination or biospecimen collection. Details with regard to the collection of DS use from various national surveys have been described previously (8, 13).

Dwyer et al. (14) and Radimer (13, 15) have described the NHANES DS collection from surveys before the early 2000s, and others have described dietary data collection in general in NHANES (8, 12, 16). This review therefore provides a brief description of past NHANES and focuses on current methods for DS data collection.

Both NHANES I and NHANES II collected data on DS use, but they did not collect brand names and there was no DS database available at that time with the nutrient content of the products. During NHANES I, participants were asked a question on the use of vitamins and minerals. The response categories were "no," "taken regularly," or "taken irregularly" (**Table 1**). A follow-up question was asked to determine the types of products taken and to classify them into 8 categories plus a "miscellaneous" and "prescription unknown" category. These questions were asked at the MEC during the dietary interview, which consisted of a 24-h dietary recall and FFQ.

TABLE 1 Dietary supplement collection in NHANES since 1971[1]

				Continuous NHANES	
	NHANES I (1971–1974)	NHANES II (1976–1980)	NHANES III (1988–1994)	(1999–2006)	(2007–2018)
Age group	1–74 y	6 mo–74 y	≥2 mo	All ages	All ages
Mode	Dietary interview in the MEC	Dietary interview in the MEC	Household interview	Household interview	Household interview and dietary interviews (2) in the MEC and via phone
Question	Are you taking vitamins or minerals? (no, taken regularly, or taken irregularly.)	Are you taking vitamins or minerals? (no, taken regularly, or taken irregularly.)	Have you taken any vitamins or minerals in the past month? Please include those that are prescribed by a doctor or dentist and those that are not prescribed. Do not include topical vitamins.	Have you used or taken any vitamins, minerals, herbals,[2] or other dietary supplements in the past 30 d?[3] Include prescription and nonprescription supplements.	Household interview: Have you used or taken any vitamins, minerals, herbals, or other dietary supplements in the past 30 d? Include prescription and nonprescription supplements. Dietary interviews: All day yesterday, (day), between midnight and midnight did (you/SP) take any vitamins, minerals, herbals, or other dietary supplements?[4]
Hand card shown with examples?	No	No	No	Yes	Yes
Product containers shown to interviewer?	No	No	Yes	Yes	Yes
Information recorded from product container	N/A	N/A	Product name and manufacturer information	Product name, form, and manufacturer information	Product name, form, and manufacturer information
Referent period	No time frame	No time frame	Past month	Past 30 d[3]	Past 30 d Past 24 h (two 24-h dietary recalls)
Additional data collected			Frequency of use in the past month, amount usually taken when used, and how long product taken	Frequency of use in the past 30 d, amount usually taken when used, and how long product taken	Frequency of use in the past 30 d, amount usually taken when used, how long product taken, and the reason(s) for taking each product reported
Nonprescription antacids containing calcium and/or magnesium collected?	No	No	Yes[5]	Yes	Yes
Database used to provide nutrient values for the dietary supplement data collected	Not available	Not available	Database created based on label information in 1996; database contracted out (not developed or maintained in-house)	NHANES dietary supplement database developed and maintained at NCHS	NHANES dietary supplement database developed and maintained at NCHS
Data provided for researchers	8 categories, plus 1 miscellaneous category and 1 prescription unknown category	28 categories, plus 1 miscellaneous category and 1 prescription unknown category	All products reported and ingredients and questions on supplement usage patterns	All products reported and questions on supplement usage patterns NHANES dietary supplement database	All products reported and questions on supplement usage patterns NHANES dietary supplement database

(*Continued*)

DSs were collected with the use of similar methodology during NHANES II. The main difference was that the number of categories was expanded to 28, with additional categories for "miscellaneous" and "prescription unknown." Both the NHANES I and NHANES II provided general information on DS use, specifically for vitamins and minerals. Amounts of nutrients in these products were not queried, and therefore nutrient intake from DSs cannot be estimated in NHANES I and II.

NHANES III (1988–1994) was the first NHANES in which nutrient information from DSs and amounts consumed were collected. Participants were asked during the home interview if they had taken a DS in the past month (Table 1). Although the question specifically asked only about vitamins and minerals,

TABLE 1 *Continued*

				Continuous NHANES	
	NHANES I (1971–1974)	NHANES II (1976–1980)	NHANES III (1988–1994)	(1999–2006)	(2007–2018)
Categories	Unknown, prescriptions, miscellaneous: *1)* multiple vitamins; *2*) multiple vitamins and minerals; 3) iron only; *4*) multiple vitamins with iron; *5*) vitamins E, A and D; *6*) vitamin C; *7*) calcium; *8*) vitamin B	Unknown, prescriptions, miscellaneous: *1*) multiple vitamins; *2*) multiple vitamins with additional supplements; *3*) multiple vitamins and minerals; *4*) multiple vitamins and minerals with additional supplements; *5*) iron; *6*) multiple vitamins with iron; *7*) iron with additional supplements; *8*) Geritol; *9*) vitamin E; *10*) vitamin E with additional supplements; *11*) vitamin A; *12*) vitamin A with additional supplements; *13*) vitamin D; *14*) vitamin D with additional supplements; *15*) vitamin C; *16*) vitamin C with additional supplements; *17*) calcium; *18*) calcium with additional supplements; *19*) magnesium; *20*) magnesium with additional supplements; *21*) zinc; *22*) zinc with additional supplements; *23*) B vitamins/B-complex; *24*) B vitamins/B-complex with additional supplements; *25*) potassium; *26*) potassium with additional supplements; *27*) fluoride; *28*) fluoride with additional supplements	N/A	N/A	N/A

[1] Some of the contents of the data from this table were also provided in Ahluwalia et al. (12) and Radimer (13). MEC, mobile examination center; N/A, not available; NCHS, National Center for Health Statistics; SP, survey participant.
[2] The word "herbals" was specifically included in the question midcycle NHANES 2005–2006. It is important to note that examples of herbal products were included on the hand card since 1999.
[3] For NHANES 1999–2000 the referent period was the "past month".
[4] The question slightly differs for participants that reported supplements during their household interview. Because this interview utilized dependent interviewing, information from the household or first 24-h dietary recall if it was the second recall, is used for the dietary interviews. The question reads as follows: "The next questions are about your use of dietary supplements, vitamins, minerals and herbals all day yesterday, (day), between midnight and midnight. This includes prescription and over the counter dietary supplements. During the interview in your home (and our exam center) you reported taking (supplement name). Did you take this supplement yesterday (day) (between midnight and midnight)?"
[5] Only asked for adults (aged ≥18 y).

participants did volunteer other types of information about the use of other DSs (i.e., herbals). Participants were also asked how long they had taken each product, how frequently, and how much they usually took. Importantly, participants were also asked to show interviewers the product containers for all DSs taken in the past month. The name and manufacturer of the product were recorded by interviewers. The data on product names and manufacturers were collected to later obtain product labels for information on ingredients and amounts. Unfortunately, due to a lack of resources to edit and process the incoming data, a product label database was not initially constructed. Years after the survey was completed, an external contractor obtained the labels and provided nutrient values for products reported by NHANES participants. However, the label information obtained was from products on the market in 1996, and therefore may not reflect formulations of products on the market during the data collection period (1988–1994). Nonetheless, these data allowed the estimation of total nutrient intakes from foods, beverages, and DSs for a nationally representative sample of the US population.

Beginning in 1999, DS usage information was collected from participants during the home interview as in NHANES III. Participants were asked about their use of vitamins and minerals, as well as herbals and other types of DSs in the past

30 d (hereafter referred to as the 30-d frequency questionnaire). The interviewer referred participants to a hand card that provided examples (Table 1). Participants were asked to show the DS bottles/containers to the interviewer, who recorded the name, form, and strengths for selected single-nutrient products and manufacturer information electronically into the tablet personal computers. If the container was not seen, the interviewer asked the participants to recall the name of the product taken. Although the percentage of containers actually seen by interviewers differed somewhat between survey cycles, containers generally were seen for >80% of products reported. The interviewer asked follow-up questions for each product reported, such as how long, how often, and how much of the product was usually taken. Beginning in 2007, NHANES began asking about the motivations for using each product reported, and these procedures have continued since.

In 2007, in addition to the 30-d frequency questionnaire administered in the home, NHANES began asking participants about DS use in each of the two 24-h dietary recalls, directly after the collection of information on foods and beverages, to allow the calculation of total nutrient intake using the same referent period (14). The first 24-h dietary recall is collected at the MEC and the second 24-h dietary recall is collected via phone about 3–10 d later. This provides researchers with the ability to estimate total nutrient intakes and distributions of usual intakes from foods, beverages, and DSs reported by participants using similar methodology. In addition, collecting DS use in the past 24 h as part of the dietary recall in the MEC can help explain variability in laboratory biomarkers collected during the examination, particularly those that reflect fairly short-term intake or conditions. For example, if a participant reported a very low intake of folate from foods, but serum folate was high, this could be due to folate supplement intake, and having information about DS use during this same time period is critical to help explain findings. NHANES uses a "dependent" style of interviewing for both 24-h dietary recalls in that the DS product names collected during the home interview are used in the recall interviews. This decreases participant burden and can help reduce measurement error. Participants are asked during the 24-h dietary recall if they had taken each of the products reported during the home interview in the 24-h period before the interview (midnight to midnight), and how much they took. Any other products taken in that 24-h period and not reported in the home are also queried. Participants are then asked how much was taken and for how long that product or a similar product had been used. Nonprescription antacids are also collected with the use of a similar methodology to capture intake of calcium and magnesium.

The NHANES DS Data base

As with dietary assessment in general, one challenge to research on DSs and their links to health outcomes is the difficulty in accurately assessing total intake. Collecting detailed information about each DS used by a participant is very important; however, without a well-maintained composition database, it would not be possible to estimate nutrient intake from these products. The most significant DS-related update from NHANES III to the continuous NHANES is the development and maintenance of the NHANES DS database (NHANES-DSD).

The NHANES-DSD contains label information from prescribed and over-the-counter DS products that have been reported by NHANES participants since the NHANES 1999–2000 through the NHANES 2013–2014 survey cycles. This database gets appended with each new NHANES cycle. This includes many types of products such as, but not limited to, vitamins, minerals, botanicals, amino acids, fish oils, and fiber supplements. The database currently contains ~12,600 records, which include new products and reformulations of products. In addition, NHANES maintains default and generic formulations of products in the NHANES-DSD to assign to participants when not enough information was collected during interviews to identify the product taken or when only strengths of nutrients are known and not brands. The database also contains label information on nonprescription antacids containing calcium, magnesium, or both. One advantage of the NHANES-DSD is that data are maintained for products that may no longer be on the market or have been reformulated, so that outside researchers that use the NHANES-DSD to provide nutrient values from DSs for their own studies can use appropriate data for relevant years.

Figure 1 describes the process used to collect, maintain, and link product-level data to participants in order to estimate nutrients consumed from DSs (17). The NHANES-DSD requires a considerable investment of time and labor to evaluate incoming data, obtain labels from manufacturers, update the information, track constantly changing formulations, and maintain the overall database. Because all NHANES DS data are released on the NHANES website for use by researchers and policymakers, the data need to be standardized for easier use by researchers. This is because the nutrient data provided on product labels are sometimes listed as compounds that need to be converted into elemental amounts, are in different units (e.g., International Units and micrograms), or may be in different units than in the What We Eat in America–NHANES dietary data (e.g., vitamin D in supplements is reported in International Units and in micrograms for the dietary data).

NHANES DS data are released in 2-y cycles and include both the data collected from participants on supplement usage and the data from the NHANES-DSD. New, reformulated, generic, and default products are appended to the NHANES-DSD for each 2-y NHANES and can be merged with the participant data using a unique DS ID. To use these data, users are encouraged to read the NHANES DS documentation and analytical guidelines and to review the online dietary tutorial on the NHANES website. More details on NHANES data release can be found elsewhere (12).

Recent Developments

In 1999, at the time NHANES-DSD was constructed, there were no freely available, comprehensive DS-composition databases available. However, this is no longer the case. The Dietary Supplement Label Database (DSLD), a joint project of the NIH Office of Dietary Supplements (ODS) and the National Library of Medicine, is a DS database made available to the public in June 2013, which is continuously updated and to date contains >75,000 labels and label information for products marketed in the United States. NHANES has begun to use the DSLD as a resource for product labels. However, because participants sometimes report DSs that are not yet included in the DSLD, some work to obtain these product labels is still necessary. In addition, correct formulations need to be verified by manufacturers to ensure that the product reported at the time of the survey matches the correct product formulation on the market at that time. The NHANES staff collaborate with the ODS to ensure that products reported in NHANES are

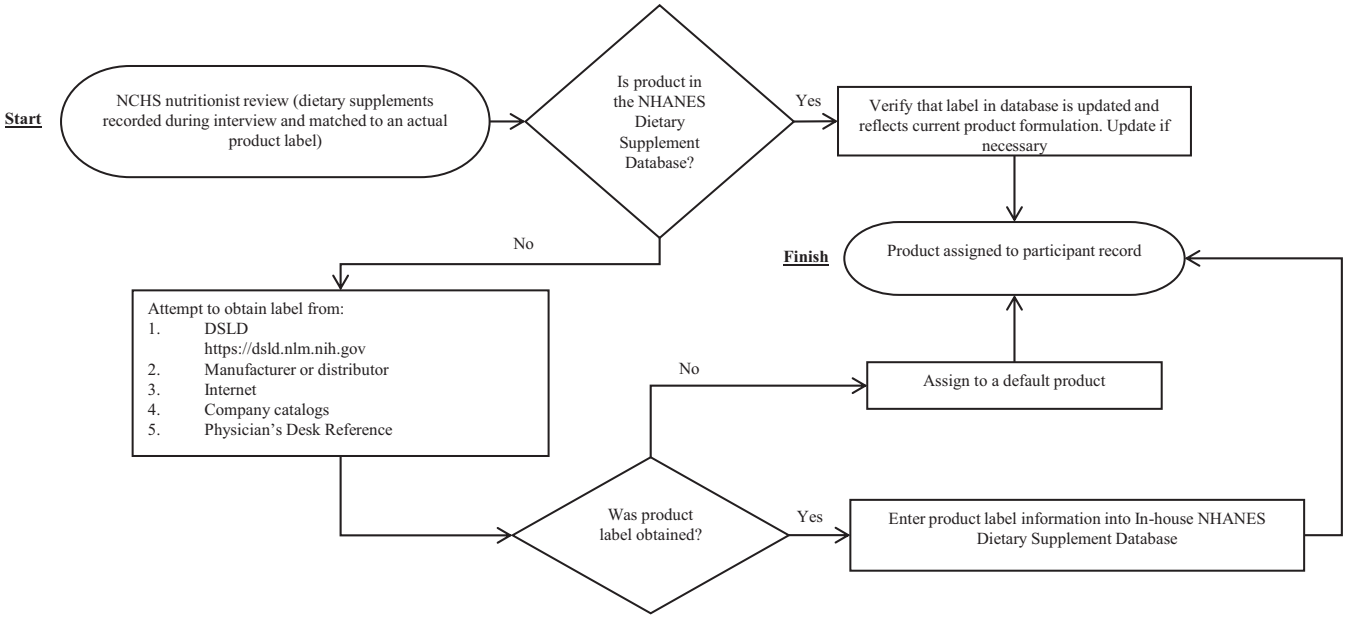

FIGURE 1 NHANES dietary supplement data-processing flow chart. *If label is not in the DSLD, NHANES obtains the product label and provides a copy to the DSLD for inclusion. DSLD, Dietary Supplement Label Database; NCHS, National Center for Health Statistics.

represented in the DSLD by regularly sending product labels so that they can be included in DSLD. In the future, when the DSLD is fully populated, we anticipate that NHANES will be able to use this database to provide nutrient values for DSs taken by NHANES participants.

Although the NHANES-DSD and DSLD have improved access to information on DS composition since 2012, the nutrient data are derived from labels. Label values can differ from analytically derived values, especially for certain nutrients (18). Beginning in 2005, the ODS in conjunction with the Nutrient Data Laboratory of the USDA began a project to analytically test the composition of DSs. These data are available online and can be linked to specific cycles of NHANES to improve estimates of nutrient intake (https://dietarysupplementdatabase.usda.nih.gov/).

Uses of NHANES DS Data

Table 2 describes some of the important uses of the NHANES DS data. The NHANES DS data have been invaluable in characterizing the usage patterns both for the total US population and for subgroups. They have also been used to assess nutrient intake from DSs alone and as part of total nutrient intake. This research is used to inform policy with regard to nutrient recommendations.

Usage patterns by the population and large-population groups. Block et al. (2) were the first to use data from NHANES I to describe vitamin and mineral usage in a nationally representative sample of 11,227 adults aged 25–74 y. Understanding and characterizing use previously had been challenging; information was available mostly on specific age groups or specific geographical areas, and surveys lacked the statistical power to assess use in nonwhite subgroups (2). NHANES I overcame these limitations and provided more accurate estimates on DS use in the US adult population. At the time, it was possible to assess usage by many demographic variables, including white and black race subgroups. Block et al. found that 22.8% of the US adult population had reported regularly taking a DS, with usage higher in whites than in blacks (24.1% compared with 11.7%) (2). The authors also found that during NHANES I (1971–1974), the most popular DSs used were multivitamins, vitamin C, and vitamin E.

NHANES III provided data that allowed more specific characterization of supplement use on a national level and provided an opportunity for assessment of total nutrient intake and, therefore, more accurate evaluation of nutrient exposures in the US population. Ervin et al. (19) provided a detailed look at DS use in the United States during 1988–1994. This report indicated that about 40% of the population aged ≥2 mo reported taking ≥1 DS in the past month. Non-Hispanic whites were more likely to use supplements than non-Hispanic blacks and Mexican Americans (43% compared with 30% and 29%). The authors also found that almost 91% of children aged 2 mo to 11 y who reported taking a DS reported taking 1 product, whereas about 66% of adults aged ≥40 y were taking 1 product, and 44% were taking >1 product. This report provided strong evidence that a significant proportion of the US population of all ages were taking DSs, and that in certain age groups many were taking multiple products. In another report, Ervin and Kennedy-Stephenson (20) estimated total nutrient intake from diet and DSs and found that although most older adults as a group were not meeting recommendations for calcium, supplement users had higher calcium intake, particularly non-Hispanic white women, than did nonusers. This finding was similar to another report in which a higher percentage of older women (but not men) who were supplement users met recommendations for B-vitamins compared with nonusers (21).

Examine trends in usage patterns over time and motivations for DS use. Data from continuous NHANES have provided an opportunity to examine trends in DSs over time. This is an essential element in nutrition monitoring, because food sources and lifestyles change over time, and these changes may alter intakes and the nutritional status of the population. For example, it is important to monitor vitamin D status over time, because there were changes in food

TABLE 2 Key uses of NHANES data on dietary supplements: Examples of how NHANES dietary supplements data can be used to answer important research questions[1]

Usage patterns by the population and large-population groups	Usage of DSs from a 30-d questionnaire and two 24-h dietary recalls
	Usual nutrient intakes from DSs
	Total nutrient intake from foods, beverages, and DSs on a given day
	Usual total nutrient intake from foods, beverages, and DSs
Examine motivations for DS use and trends in usage patterns over time	Estimate the top motivations for using DSs and types of DSs
	Determine if there are differences in why people are using DSs by sociodemographic factors
Examine association of health/well-being with DS use, and nutrient intake from DSs alone/total nutrient intake from diet and DSs	Assess associations between DS use and biomarkers of exposure to selected nutrients
	Assess the association between DS use and health outcomes
	Determine the association between baseline DS use and mortality or morbidity using passive follow-up (i.e., data from the National Death Index, Medicare Claims and Enrollment)
Inform policy	DRI development/updates
	Evaluating nutrient adequacy of US diet (DGAC)
	Intakes in relation to setting or tracking fortification policies

[1] DGAC, Dietary Guidelines Advisory Committee; DS, dietary supplement.

consumption (especially of vitamin D–fortified foods, with new foods being fortified with the vitamin), increasing use of vitamin D–containing supplements, and changes in recommendations for sun exposure. Since NHANES III, there have been data necessary to assess both vitamin D exposure and vitamin D status in the US population. This includes data on DSs and information on nutrients from labels, estimated vitamin D levels in foods, season of data collection and the geographical location of participants, and measured circulating concentrations of 25-hydroxyvitamin D (22). This approach allows researchers to estimate vitamin D status and exposures of vitamin D in continuous NHANES and to compare with NHANES III to assess changes over time.

Folate nutritional status is another example of how data from NHANES III have been used with continuous NHANES to monitor population intakes and sources of intake of the vitamin pre- and postfortification of flour in the US food supply. One study found that postfortification (after 1998), 2.7% of the US population exceeded the Tolerable Upper Intake Level and that this was specifically confined to groups who were taking folic acid–containing supplements as well as consuming diets with fortified and enriched grain products and ready-to-eat cereals. The Tolerable Upper Intake Level was also more likely to be exceeded when supplement users were consuming >400 μg folic acid from DSs (23). Other NHANES-based studies have estimated total folate intake in women of childbearing age, identifying the fraction of the population at adequate, inadequate, or excessive amounts of intake (24, 25). These examples show the importance of NHANES data and their potential to provide snapshots of the population at given times, monitor intakes over time, and provide information on the sources of intake.

Another important research question focuses on the motivations for why people are using DSs. Previously, this information was limited, particularly on a nationally representative sample. As a reminder, in 2007, NHANES added questions on the motivations for using each DS reported by participants. In a report by Bailey et al. (26), the authors found that the most common motivations reported by US adults taking DSs were as follows: to improve health (45%), to maintain overall health (33%), for bone health (25%), to supplement the diet (22%), and to prevent health problems (20%). The authors also found that 23% of the products were used on the basis of recommendations of a health care provider (26). This report provided novel findings that helped to elucidate why US adults were taking these products and also the demographic, behavioral, and health characteristics of users.

Examine associations of health and well-being with DS use and nutrient intake from DS alone and total nutrient intake from the diet and DSs. In 2007, NHANES began collecting data on DS use as part of the two 24-h dietary recalls. This was in addition to the supplement data collected during the 30-d questionnaire administered in participants' homes. This recall data make it possible to estimate total nutrient intake and usual intakes with the use of similar methodologies for foods/beverages and DSs, and can thus assess how different dietary assessment methods can affect population estimates of prevalence and intake. For example, Nicastro et al. (27) found that both collection from the 30-d questionnaire and two 24-h dietary recalls was useful, but the combination of both methods captured a larger percentage of DS users, and that calibration can be used to obtain the most accurate information from each instrument. The ability to estimate total nutrient intake is very important in order to assess associations between nutrients and health outcomes. NHANES allows for assessment of intake from DSs, foods and beverages, and prescription medications. This is especially important for nutrients such as vitamin D and omega-3 FAs, in which supplements contribute a substantial amount to intake (6, 28). NHANES data also have been used to estimate exposures of many bioactive constituents, such as caffeine from foods and supplements, and their associations with health (29, 30).

NHANES also allows for the assessment of the independent effects of vitamin and mineral supplements on disease risk. The linkage program at the National Center for Health Statistics works to provide key information such as administrative data from the National Death Index and Medicare Claims and Enrollment data, linked with NHANES participants, allowing an opportunity to study health outcomes. Bailey et al. (31) used data on supplements from NHANES III linked with follow-up data from the National Death Index to assess if MVM and multivitamin use was associated with cardiovascular disease (CVD) mortality. Although no association was noted between MVM use and CVD mortality overall, a decreased risk of CVD mortality was observed among women who reported using MVM products for >3 y compared with nonusers. NHANES data has also been linked with the Centers of Medicare and Medicaid Services Medicare Claims and Enrollment data to and can be used to identify targeted health conditions.

Medicare Claims and Enrollment data provide information on the prevalence and incidence of many conditions, including chronic degenerative diseases that affect a large percentage of older adults. It is crucial to study the effects of diet and supplements on chronic disease and other health conditions to add to scientific findings to determine how intake may decrease or increase disease burdens (32).

Future Directions

The comprehensive data collected in NHANES offer an opportunity to explore the interplay of genes, nutrition, and environment with health outcomes. NHANES has a biorepository with stored NHANES participants' blood, urine and DNA, which includes biospecimens from NHANES III (1988–1994) and subsequent NHANES cycles beginning in 1999–2000. More information on the NHANES biospecimen program, including what specimen types are available and the process for using the data is detailed elsewhere (33). Researchers have begun to use the multifactorial complex data collected in NHANES to examine gene-environment exposures. For example, in a recent publication, Mazidi et al. (34) found that longer telomeres were associated with vitamins and minerals from foods with the use of NHANES data.

NHANES has, over time, improved DS collection and adapted to the growing needs of researchers. Although recording information from the label is more accurate than participant recalls of the product names, interviewer errors in entry or omissions cannot be ruled out. Photographing the DS container during the interview in the participant's home would provide information on the exact formulation taken and would reduce the assumptions that currently need to be made when complete and accurate information is not entered by the interviewer. However, an easy, quick, affordable, and operationally feasible device has not been identified for use in NHANES. Barcode scanning would be another option to capture more accurately the DSs used by participants. However, a database would need to be available containing uniquely assigned barcodes for each product. These avenues are being explored in the context of future surveys in NHANES.

Little is known about the measurement error structure and validity of the NHANES DS collection methods. To understand the magnitude of error and the types of error (e.g., random error, systematic error), it would be necessary for validation studies to be conducted. Examples of potential sources of measurement error include the follows: *1*) errors in participants' recall when reporting all DSs taken, the amount typically taken, and the number of days in the past 30 d that the product was taken; *2*) errors in transcribing information from the product label during collection by interviewers; *3*) matching the product reported to the wrong formulation of the product actually taken by the participant; *4*) errors when entering product label information into the database; and *5*) label ingredient amounts differing from what was actually in what was consumed. Future work may include studies to assess NHANES DS collection methods and other methods used to collect DS use from participants in surveys and studies.

Conclusions

In conclusion, NHANES has been collecting information on DSs since 1971. Over time, NHANES has both expanded and improved collection methods, providing a rich source of nationally representative data to both researchers and policymakers. These data are vital for national nutrition monitoring and can also be used to characterize usage patterns of DS use in the US population, estimate nutrient intake from supplements, and characterize total nutrient intake from diet and DSs, as well as examine diverse diet-health relations.

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