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Short communication

The U.S. National Health and Nutrition Examination Survey and human exposure to environmental chemicals

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ABSTRACT

Researchers are increasingly interested in using human biomonitoring – the measurement of chemicals, their metabolites or specific reaction products in biological specimens/body fluids – for investigating exposure to environmental chemicals. General population human biomonitoring programs are useful for investigating human exposure to environmental chemicals and an important tool for integrating environment and health. One of these programs, the National Health and Nutrition Examination Survey (NHANES), conducted in the United States is designed to collect data on the health and nutritional status of the noninstitutionalized, civilian U.S. population. NHANES includes a physical examination, collecting a detailed medical history, and collecting biological specimens (i.e., blood and urine). These biological specimens can be used to assess exposure to environmental chemicals. NHANES human biomonitoring data can be used to establish reference ranges for selected chemicals, provide exposure data for risk assessment, and monitor exposure trends.

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Introduction

People in modern societies may be exposed to a wide spectrum of environmental chemicals. Although for many chemicals the health significance of these exposures is unknown, studies to investigate the prevalence of exposure are warranted because of the potential harmful health effects of some of the chemicals, as often indicated in animal studies. The availability of sophisticated analytical chemistry techniques has facilitated measuring trace levels of multiple environmental chemicals in human biological matrices, mainly blood and urine, with a high degree of accuracy and precision (i.e., human biomonitoring) (Angerer et al., 2007; National Research Council, 2006; Pirkle et al., 1995). These advances have contributed to the remarkable increase in human biomonitoring research to determine internal exposure (i.e., body burden) in the past few decades (Needham et al., 2007).

Although human biomonitoring data per se do not provide information on health effects, general population human biomonitoring programs are useful for investigating human exposure to environmental chemicals and are important tools for integrating environment and health (Angerer et al., 2006; National Research Council, 2006; Schulz et al., 2007). Since 1999, in the United States, the Centers for Disease Control and Prevention (CDC) annually conduct one of these programs: the National Health and Nutrition Examination Survey (NHANES) (CDC, 2011b).

Collection of data for NHANES

NHANES is designed to collect data on the health and nutritional status of the non-institutionalized civilian U.S. population. Since 1999, each year, approximately 7000 randomly selected residents across the United States have the opportunity to participate in NHANES; participation is confidential and voluntary. NHANES, administered by CDC's National Center for Health Statistics, includes a physical examination and collection of detailed medical history and biological specimens from participants. The participants also complete an extensive questionnaire on demographics and health behaviors (CDC, 2009). Although biological specimens are used mostly for clinical and nutritional testing, some can be used to assess exposure to environmental chemicals, including metals, volatile organic compounds and other organic pollutants such as cotinine, phthalates, polyfluorinated chemicals, and dioxins (CDC, 2011a).

Since NHANES 1999, blood is collected on NHANES participants one year of age and older, and urine specimens are requested of all participants six years of age and older. Therefore, human biomonitoring urinary measures are restricted to participants six years of age and older. Similarly, environmental chemical measurements in blood or blood serum are only available from participants 12 years and older, with the exception of lead, cadmium, and mercury (minimum age of 1 year) and cotinine (minimum age of 3 years)

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(CDC, 2009). Furthermore, the majority of the environmental chemical data for NHANES is based on the analysis of specimens from subsamples of participants. In most cases, this is a one-third sample of persons aged 6 years or 12 years and older. Subset distributions often change with survey cycles (e.g., if age groups have changed) (CDC, 2009).

The origins of the current NHANES go back to The National Health Survey Act of 1956, legislation which provided for establishing a continuing National Health Survey with the goal of obtaining information about the health status of U.S. residents. Three National Health Examination Surveys were conducted between 1959 and 1970. During 1950s–1960s, scientific evidence of malnutrition within certain segments of the U.S. population and increasing scientific data linking diet and health prompted the establishment in 1969 of a continuing National Nutrition Surveillance System to measure the nutritional status of the U.S. population and monitor changes over time. NHANES was then created after combining the National Nutrition Surveillance System and the National Health Examination Survey (CDC, 2009).

NHANES I (1971–1975), NHANES II (1976–1980), Hispanic HANES (1982–1984), and NHANES III (1988–1994) were conducted before 1999, when NHANES became a continuous (i.e., annual) survey. The collection of environmental chemical data began with NHANES II and blood lead levels (BLLs) were first measured among participants three years of age and older. Lead in blood was also measured in the Hispanic HANES conducted in the early 1980s. NHANES III included, in addition to BLLs, measures of cadmium, selenium, and cotinine in blood, as well as blood and urine measures of selected pesticides.

Beginning with NHANES 1999, CDC's National Center for Environmental Health has provided data on the concentrations of certain chemicals, selected based on a nomination process, in urine and blood of NHANES participants, presented by age group, sex, and race/ethnicity, in the National Reports on Human Exposure to Environmental Chemicals (CDC, 2011a). Since 1999, the number of chemicals measured in people's blood or urine for the reports has increased from 27 to 219. The Fourth Report released in 2009 includes findings from NHANES for 1999–2000, 2001–2002, and 2003–2004. The February 2011 Updated Tables present data from the 2005–2006 and 2007–2008 NHANES for 54 of the chemicals previously reported through 2004 in the Fourth Report along with nine recently added chemicals. The 2009 Fourth National Report on Human Exposure to Environmental Chemicals and the February 2011 Updated Tables together provide the most comprehensive human biomonitoring assessment of the U.S. population's exposure to environmental chemicals (CDC, 2011a). They may also help prioritize and foster research on the human health risks that result from exposure, which for many of the chemicals included in the reports are largely unknown.

Data estimates from NHANES are probability-based, and hence are representative of the U.S. population. NHANES data can be used to establish reference ranges for select chemicals, provide exposure information for risk assessment (e.g., set intervention and research priorities, evaluate effectiveness of public health measures), and monitor exposure trends. NHANES data have shown that in the general population, including pregnant women, exposure to some environmental chemicals is prevalent (Woodruff et al., 2011). NHANES data also suggest variability in exposure to many chemicals by sex, age, and race/ethnicity.

Uses of NHANES

Reference ranges can be used to assist epidemiologic investigations, to correlate the levels to other NHANES parameters/measurements (including potential health effects), and to identify (1) populations with the highest exposures, (2) potential sources/routes of exposure, and (3) chemicals with highest prevalence/frequency.

Lead, which was first included in NHANES approximately 40 years ago, provides a clear example of the usefulness of NHANES data to improve public health. Lead can cause several ailments, including anemia, kidney injury, abdominal pain, seizures, encephalopathy, and paralysis. In addition, chronic exposure to lead can affect blood pressure in adults and neurodevelopment in children. In 1991, CDC, based on prospective population studies, established 10 μg/dL as the BLL of concern in children. Recent research has suggested that adverse neurodevelopment may occur at BLLs even below CDC's level of concern (Jusko et al., 2008), and it is well accepted that lead exposure on the developing brain may damage the ability to learn and can adversely impact population intelligence.

Of interest, among 1–5 years old children, the BLL geometric mean (1.9 μg/dL) and BLL percentage above 10 μg/dL (1.6%) in NHANES 1999–2002 were lower than those from NHANES 1991–1994 (geometric mean BLL, 2.7 μg/dL; 4.4% of children had BLLs ≥ 10 μg/dL). These decreases are likely related to the removal of lead in gasoline in the United States, starting in the mid-1970s; the banning of lead solder in U.S. food cans, which was also enacted during that time period; and the implementation of lead abatement programs in housing.

As a result of these interventions, the prevalence of BLLs ≥ 10 μg/dL declined 84% from 8.6% in NHANES 1988–1991 to 1.4% in NHANES 1999–2004 (Jones et al., 2009), an important public health victory. Nonetheless, BLLs > 10 μg/dL continue to be more prevalent among children with known risk factors, including low household income; minority race/ethnicity; urban residence; and residence in housing built before the 1950s. These findings show that public health efforts to reduce the number of children with elevated BLLs in the general population continue to be successful, but elevated BLLs still remain a major public health concern among specific population groups.

Even a comprehensive program such as NHANES has limitations: persons under 1 year of age are not included, and no data are collected on fetal exposures. Therefore, a need exists for assessing exposure during critical periods of development – a period of increased susceptibility to the potential adverse effects of chemical exposures. In addition, NHANES can only be used to obtain national estimates; for confidentiality reasons, NHANES data cannot be used to examine concentrations of environmental chemicals by locality or state. Furthermore, NHANES by design can only provide cross-sectional data, and it cannot provide information on proximity to sources of exposure or on the use of particular products.

Also, in general, human biomonitoring data in NHANES do not allow the identification of exposure source(s) or route(s). Additional research to identify the relative contribution of the numerous sources and routes by which humans are exposed to some of these environmental chemicals is needed so measures to reduce exposure, if necessary, can be implemented. Finally, the detection of an environmental chemical in blood or urine does not imply disease or other health effects. Further epidemiologic studies are needed to advance our understanding of potential human health risks of exposures to select environmental chemicals; these studies could include the examination of subtle changes when assessing the effects of environmental exposures to these compounds paying special attention to potentially vulnerable segments of the population (e.g., children, women of reproductive age).

Disclaimer

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