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Trends and variability in the levels of urinary thiocyanate, perchlorate, and nitrate by age, gender, race/ethnicity, smoking status, and exposure to environmental tobacco smoke over 2005–2012☆

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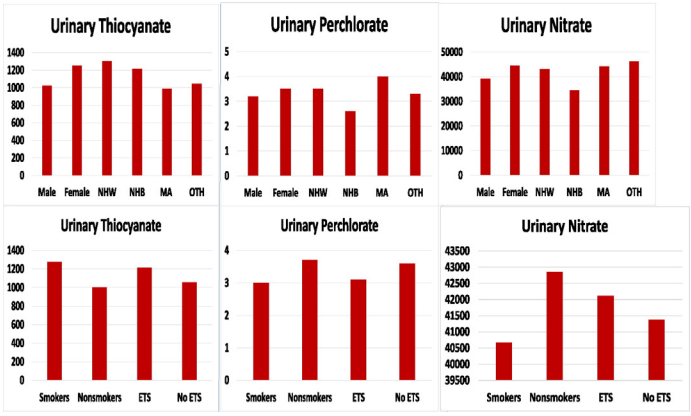
HIGHLIGHTS

- Smokers had higher levels of u-SCN than nonsmokers among ≥20 years old.
- Smokers had lower levels of u-P8 than nonsmokers among ≥20 years old.
- Adjusted levels of u-P8 declined over 2005-2012.
- Among adults, males had lower levels of u-SCN, u-P8, and u-NO3 than females.
- Exposure to ETS was associated with higher levels of u-SCN.

GRAPHICAL ABSTRACT



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ABSTRACT

Data from National Health and Nutrition Examination Survey for 2005–2012 were used to study the trends and variability in the levels of urinary thiocyanate (u-SCN), perchlorate (u-P8), and nitrate (u-NO3) by gender, race/ethnicity, active smoking, and exposure to environmental tobacco smoke (ETS) at home for those aged 12–19 and ≥20 years old. For those aged ≥20 years, adjusted levels of u-SCN, u-P8, and u-NO3 (i) were lower for males than females ($p < 0.01$), and (ii) were higher for non-Hispanic white (NHW) than non-Hispanic black (NHB) ($p < 0.01$). Also, for those aged ≥20 years NHB had higher adjusted levels than Mexican American (MA) for u-SCN ($p < 0.01$) but NHB had lower adjusted levels than MA for u-P8 ($p < 0.01$) and u-NO3 ($p < 0.01$). For those aged 12–19 years, adjusted levels of u-SCN, u-P8, and u-NO3 did not vary by gender ($p > 0.05$), and adjusted levels of u-P8 and u-NO3 for NHB were lower than for NHW ($p < 0.01$) as well as higher for NHB than MA for u-SCN ($p < 0.01$) and lower for NHB than MA ($p < 0.01$) for u-P8 and u-NO3. Among those aged ≥20 years, active smoking was associated with higher adjusted levels of u-SCN ($p < 0.01$) in a dose-response manner and active smoking was associated with lower adjusted levels of u-P8 ($p < 0.01$) in a dose-response manner. Exposure to ETS was associated with higher adjusted levels of u-SCN ($p = 0.02$) and lower adjusted levels of u-P8 ($p < 0.01$) among ≥20 years old. Adjusted levels of u-P8 decreased over 2005–2012 among both 12–19

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($p < 0.01$) and ≥20 years old ($p = 0.04$). There was borderline increase in the adjusted levels of u-NO3 for those aged ≥20 years ($p = 0.05$) over 2005–2012.

1. Introduction

Perchlorate, nitrate, and thiocyanate have been shown to competitively inhibit uptake of iodine by the thyroid (Horton et al., 2015) resulting in perturbed thyroid homeostasis. Association between exposure to urinary perchlorate (u-P8), nitrate (u-NO3), and thiocyanate (u-SCN) and thyroid function has been investigated by several authors (Horton et al., 2015, Ko et al., 2014, Charatcharoenwitthaya et al., 2014, Suh et al., 2014, Steinmaus et al., 2007, 2010, 2013, 2015) among various groups and populations.

Association of prenatal exposure to perchlorate, thiocyanate, and nitrate with neonatal size and gestational age has been studied (Evans et al., 2015). Specifically, Evans et al. (2015) reported 2.62 ng/μg increase in u-P8 to be associated with smaller head circumference by 0.32 cm and each 3.38 ng/μg increase in perchlorate equivalent concentrations to be associated with larger head circumference by 0.48 cm. Mervish et al. (2015) studied the longitudinal association between the levels of u-P8, u-NO3, and u-SCN with selected anthropometric measures among girls 6–8 years old and reported slower growth in waist circumference and body mass index associated with higher levels of perchlorate, nitrate, and thiocyanate. Higher levels of u-P8, u-NO3, and u-SCN have been reported to be associated with hearing difficulties during conversation among those aged 20–69 years old (Shiue, 2015a). Elevated u-SCN levels were found to be associated with emphysema, cancer, chronic bronchitis, wheezing, coughing, and sleep complaints (Shiue, 2015b).

Perchlorates are colorless, have no odor, and are stable at normal temperatures and as such may last in the environment for several years but they react quickly at high temperatures (ATSDR, 2008). They are used in rocket fuels, and other uses of perchlorates include temporary adhesives, electrolysis baths, batteries, air bags, drying agents, etching agents, cleaning agents and bleach, and oxygen generating systems (ATSDR, 2008). Exposure to perchlorates may occur by ingestion of contaminated drinking water, milk, leafy green vegetables which contain elevated levels of perchlorate, by living near a rocket manufacturing or testing facility and by living near or working at a factory where they are made, or by living near a factory that makes fireworks, flares, or other explosive devices (ATSDR, 2008).

Thiocyanates are a group of compounds formed from combination of sulfur, carbon, and nitrogen and they are found in various foods and plants (ATSDR, 2006). People may be exposed to thiocyanates by eating foods like plants, dairy products, meat that contain thiocyanate and by working in cyanide-related industries, such as the manufacture of electronic computing equipment, commercial printing, photographic processes, hospitals, production of adhesives, and construction and furniture manufacture (ATSDR, 2006). However, active and passive smoking may be the primary source of exposure to thiocyanates for smokers because cyanide present in the cigarette smoke is metabolized to thiocyanate through sulfuration with thiosulfate by mitochondrial rhodanase (Zil-a-Rubab and Rahman, 2006). Plants that contain thiocyanates include cassava, cabbage, turnips, broccoli, Brussel sprouts, and cauliflower (EMPOWER, 2016).

Largest source of exposure to nitrates is via drinking water but vegetables like cauliflower, spinach, collard greens, broccoli, and other root vegetables also contain nitrates (ATSDR, 2013).

National Health and Nutrition Examination Survey (NHANES, CDC, 2016) has released data on u-SCN, u-P8, and u-NO3 since 2001–2002 in the public domain. However, for 2001–2002, data were released for surplus samples only and as such could not be used to develop estimated parameters for the general population. For 2003–2004, data were released for u-P8 only. Starting with the 2005–2006 cycle of NHANES, data on u-SCN, u-P8, and u-NO3 have continuously been released. The most recent available data are for 2011–2012 cycle of NHANES. While data from NHANES for u-SCN, u-P8, and u-NO3 have often been used (Ko et al., 2014, Steinmaus et al., 2013, 2015) in the context of studying their association with thyroid function, as far as it can be determined, they have not been used to estimate levels of these chemicals for the general population by age, gender, race/ethnicity, and active and passive smoking. In addition, since data are now available for four NHANES cycles or eight years, the time trends in their levels may also be studied. Consequently, this study was undertaken to study variability in the levels of u-SCN, u-P8, and u-NO3 by age, gender, race/ethnicity, and passive and active smoking and to study trends in their levels over 2005–2012. For the first time, impact of exposure to environmental tobacco smoke (ETS) at home on the levels of u-SCN, u-P8, and u-NO3 will be investigated. Since, it is not possible to distinguish between the exposures to second hand and third hand smoke, ETS for the purpose of this study includes exposure to both second hand and third hand smoke. While studying exposure to passive smoking, importance of exposure to third hand smoke as a component of passive smoking has been reported by Protano and Vitali (2011), Protano et al. (2012a) and Matt et al. (2011) among others.

In preliminary analyses, it was found that adjusted levels of u-SCN, u-P8, as well as u-NO3 were lower for males than females and higher for non-Hispanic whites than non-Hispanic blacks which was contradictory to what was reported by Ko et al. (2014) for the levels unadjusted for gender and racial/ethnic differences in urinary creatinine (u-creat) for NHANES 2005–2006 data. Consequently, a special analysis was performed for 2005–2006 to show how levels unadjusted for gender and racial/ethnic differences in u-creat may change when model based adjustments are made for the effect of u-creat as recommended by Barr et al. (2005).

Briefly, the objective of this study was to study the variability in the levels of u-SCN, u-P8, and u-NO3 by age, gender, race/ethnicity, and passive and active smoking over 2005–2012.

2. Materials and methods

2.1. Data source and data description

Data from NHANES for the years 2005–2012 from demographic, u-P8, u-NO3, and u-SCN files, recent tobacco use questionnaire, family smoking questionnaire for those aged ≥12 years were downloaded and match merged. NHANES uses a complex, stratified, multistage, probability sampling designed to be representative of the civilian, non-institutionalized U.S. population based on age, sex, and race/ethnicity. Sampling weights are created in NHANES to account for the probabilities of selection and response as well as total U.S. population for selected combinations of gender, age, and race/ethnicity.

Two different databases were generated, namely, for those aged 12–19 years and for those aged ≥20 years. Total number of participants aged 12–19 was 4034 and 13,186 for those aged ≥20 years. Details are given in Table 1.

2.2. Derived variables and definitions

For the purpose of this study, definition of active smoking status was based on self-reported use of one or more tobacco products during the last 5 days and observed levels of serum cotinine. Those who reported having used one or more tobacco products during the last five days or