Environmental Pollution 240 (2018) 209–218

Contents lists available at ScienceDirect

Environmental Pollution

journal homepage: www.elsevier.com/locate/envpol

Associations of urinary polycyclic aromatic hydrocarbons with bone mass density and osteoporosis in U.S. adults, NHANES 2005–2010☆

Jing Guo [a], Yun Huang [b], Suchen Bian [c], Chuning Zhao [a], Yumin Jin [a], Dongdong Yu [a], Xinkai Wu [c], Dan Zhang [b], Weiming Cao [d], Fangyuan Jing [e, *], Guangdi Chen [a, **]

[a] Institute of Environmental Health, Department of Public Health, Zhejiang University School of Medicine, Hangzhou, China
[b] Key Laboratory of Reproductive Genetics (Ministry of Education), Women's Hospital, Zhejiang University School of Medicine, Hangzhou, China
[c] Department of Clinical Medicine, Undergraduate School, Zhejiang University School of Medicine, Hangzhou, China
[d] School of Humanities and Social Sciences, Zhejiang Chinese Medical University, Hangzhou, China
[e] Department of Epidemiology and Biostatistics, School of Public Health, Hangzhou Medical College, Hangzhou, China

ARTICLE INFO

Article history:
Received 10 October 2017
Received in revised form
23 April 2018
Accepted 23 April 2018

Keywords:
Polycyclic aromatic hydrocarbons
Bone mass density
Osteoporosis
General population
NHANES

ABSTRACT

Polycyclic aromatic hydrocarbons (PAHs) are environmental endocrine disruptors, which may modify the bone mineralization. However, epidemiological evidences on this issue were scant. We aimed to investigate the associations of PAHs with bone mass density (BMD) and osteoporosis based on a nationally-representative sample from general U.S. population. Data utilized were extracted from the 2005–2010 National Health and Nutrition Examination Survey (NHANES). Nine urinary PAHs (U-PAHs) metabolites were measured as exposure biomarkers. Associations of specific U-PAHs with BMD and osteoporosis were estimated by multivariable adjusted linear regression models and logistic regression models, respectively. Compared with women at the first tertiles, those at the third tertiles of 1-Hydroxynapthalene, 2-Hydroxyfluorene, 3-Hydroxyphenanthrene, 2-Hydroxyphenanthrene and 9-Hydroxyfluorene had significantly decreased BMD levels [coefficient (β) = −0.023 to −0.014, $p < 0.05$] or increased likelihoods of osteoporosis [odds ratios (ORs) = 1.86 to 3.36, $p < 0.05$] at different bone sites. Whereas, elevated BMD levels ($\beta = 0.021$, $p < 0.05$) at trochanter and decreased likelihoods of osteoporosis (OR = 0.33, $p < 0.05$) at intertrochanter were observed among women at the second tertiles of 1-Hydroxypyrene and 2-Hydroxynapthalene, respectively. Similar results were found for all the population, i.e., combination of men and women. Most of the significant associations disappeared among adult men only. Furthermore, Associations between U-PAHs and BMD were stronger for postmenopausal women when compared with premenopausal group. In conclusion, associations of U-PAHs with BMD and osteoporosis varied by specific U-PAHs and bone sites, as well as menopausal status and genders in U.S. adults.

1. Introduction

Osteoporosis is a skeletal disorder characterized by a decrease in bone mass and combined with deterioration of bone micro-architecture (Hendrickx et al., 2015). It was estimated that about 53.6 million U.S. adults aged 50 years and above had osteoporosis and low bone mass in femoral neck or lumbar spine in year 2010 (Wright et al., 2014). As a worldwide epidemiologic health issue, one in three women aged over 50 years old will be suffered from an osteoporotic fracture (Melton, 1995; Randell et al., 1995). The etiology of reduction in bone mass and development of osteoporosis is complex, including endogenous, environmental and genetic factors (Hendrickx et al., 2015).

Polycyclic aromatic hydrocarbons (PAHs) are a series of organic compounds that possess two or more fused aromatic rings arranged in different configurations (Mumtaz et al., 1996). Environmental PAHs are mainly generated from incomplete combustion of carbon-containing materials (Wild and Jones, 1995). More than one hundred

☆ This paper has been recommended for acceptance by Payam Dadvand

* Corresponding author. 481 Binwen Road, Binjiang District, Hangzhou, 310053, China.
** Corresponding author. 866 Yuhangtang Road, Xihu District, Hangzhou, 310058, China.
E-mail addresses: jingfy@hmc.edu.cn (F. Jing), chenguangdi@zju.edu.cn (G. Chen).

https://doi.org/10.1016/j.envpol.2018.04.108
0269-7491/

PAHs exist in the environment and usually occur as complex mixtures (Mumtaz et al., 1996). The primary routes of exposure to PAHs in the general population consist of air inhalation, food consumption, cigarette smoking and dermal contact (Kim et al., 2013). Due to the lipophilic property, PAHs tend to deposit and accumulate in the biosystems and food chain (Bansal and Kim, 2015).

Steroid sex hormones play critical roles in promoting bone growth and maintaining bone density (Manolagas, 2013; Manolagas et al., 2002). Estrogen has the capacities to stimulate bone growth and maturation, and to inhibit bone resorption (Karsenty, 2012; Riggs, 2000). PAHs are characterized as endocrine disruptor chemicals (EDCs) which interfere with the homeostasis of organisms by mimicking endogenous hormones, exhibiting estrogenic or anti-estrogenic activities (Zhang et al., 2016). Emerging epidemiological evidences suggest that EDCs are significantly related to the levels of bone mass density (BMD) (Glynn et al., 2000; Hodgson et al., 2008; Khalil et al., 2016; Min and Min, 2014). Besides, laboratory studies demonstrated suppressed osteoblastic activity and decreased mRNA expressions of osteoblastic markers in goldfishes treated with seawater polluted with highly concentrated PAHs (Suzuki et al., 2016). Monohydroxylated PAHs showed propensities to inhibit both osteoclasts and osteoblasts, and to disrupt the bone metabolism in teleosts (Suzuki et al., 2009). Vertebral bone mineralization was suggested as an indicator of PAHs pollution in sea bass (Danion et al., 2011). According to these findings, we hypothesized that through the endocrine-disrupting properties, PAHs may modify the skeletal homeostasis and mineralization.

However, relationships between PAHs and bone health have not been explored in humans until now. The purpose of the present study was to investigate the associations of PAHs with BMD and osteoporosis based on a nationally-representative sample from general U.S. population.

2. Methods

2.1. Study design and participants

Data analyzed in this study was extracted from the National Health and Nutrition Examination Survey (NHANES), which is an ongoing study to assess the heath and nutritional status of the non-institutionalized U.S. population [Centers for Disease Control and Prevention (CDC), 2014]. Subjects who accepted an in-home interview were then invited to participate in the physical examination, including urine and blood collection, in specially-designed and equipped mobile centers. The protocol of NHANES was approved by the National Center for Health Statistics (NCHS) Research Ethics Review Board. Written consent was obtained from each participant.

The NHANES interview consisted of demographic, dietary and health-related factors; the examination component included medical and physical measurements, as well as laboratory tests administered by highly trained medical personnel (CDC, 2014). Data of NHANES 2005–2010, where nine urinary PAHs (U-PAHs) metabolites and BMD levels in proximal femur and lumbar spine have been continuously measured, were combined to increase the sample size.

2.2. Measurement of U-PAHs

Measurement of U-PAHs was performed by the National Center for Environmental Health (NCEH) (CDC, 2013). Briefly, Spot urine specimens were collected during physical examination, stored at below −20 °C and then shipped on dry ice to NCEH (CDC, 2013). All samples in long-term storage were kept at −70 °C until analysis (CDC, 2013).

The method of isotope dilution gas chromatography/tandem mass spectrometry (GC-MS/MS) was applied to test the levels of nine monohydroxy-PAHs (OH-PAHs), including 2-Hydroxyfluorene, 3-Hydroxyfluorene, 9-Hydroxyfluorene, 1-Hydroxyphenanthrene, 2-Hydroxyphenanthrene, 3-Hydroxyphenanthrene, 1-Hydroxypyrene, 1-Hydroxynapthalene and 2-Hydroxynapthalene (CDC, 2013). Samples below the limit of detection (LOD) for each U-PAHs were assigned a level of LOD divided by the square root of 2. The creatinine-corrected U-PAHs values (ng/g creatinine) were analyzed to adjust for the between-subject variations of dilution in spot urine samples. Levels of urine creatinine were measured using modified kinetic Jaffé method (NCHS, 2011).

2.3. Assessment of BMD and osteoporosis

The NHANES team separately examined BMD levels in lumbar spine and femoral regions of total femur, femur neck, trochanter and intertrochanter. BMD (gm/cm^2) was measured by the method of dual-energy x-ray absorptiometry (DXA) with Hologic QDR 4500A fan-beam densitometers (Hologic Inc., Bedford, MA, USA) (CDC, 2007). BMD of lumbar spine was calculated as mean of first through fourth lumbar vertebra (Khalil et al., 2016). For regions of proximal femur, the left hip was routinely scanned. The right hip was scanned when the participant self-reported a fractured left hip, a left hip replacement, or a pin in the left hip. Participants were excluded from the DXA scan if they had fractures, replacements or pins in both hips. Besides, subjects were ineligible for DXA examination if they were pregnant, self-reported use of radiographic contrast material in the past 7 days, weighted over 300 pounds, or participated in nuclear medicine studies in the past 3 days (CDC, 2012).

Osteoporosis was defined according to the diagnostic criteria recommended by the World Health Organization (WHO) that BMD values surpass 2.5 standard deviation (SD) below mean of young adult reference group (Looker et al., 1997). Mean femoral BMD of 20–29-year-old non-Hispanic white women from NHANES III was selected as the reference value (Looker et al., 1997). Osteoporosis was separately assessed in total femur, femur neck, trochanter and intertrochanter. Overall osteoporosis was regarded as an osteoporosis in any femoral regions of interest.

2.4. Covariates

Information on demographics and lifestyle factors were obtained by the questionnaires. Demographic characteristics contained age (years), race/ethnicity (non-Hispanic white, non-Hispanic black, Mexican American, others), educational level (under high school, high school or equivalent, above high school) and marital status (married/cohabiting, widowed/devoiced/separated, never married). Individuals were identified as never-, current- and ever-smokers. Recreational physical activity was classified into sedentary (no regular physical activity), insufficient [regular activity, but less than 500 metabolic equivalent (MET)-minutes per week], moderate (500–1000 MET-minutes per week) and high (more than 1000 MET-minutes per week) grades according to the 2008 Physical Activity Guidelines for Americans (Tucker, 2017). Regular milk consumption was ascertained if subjects reported that they drink milk for at least five times per week for most of their life including childhood (Khalil et al., 2016).

Health examination was performed in the mobile centers. Body mass index (BMI, kg/m^2) was categorized into normal weight of <25, overweight of 25 to <30 and obesity of ≥ 30. Hypertension was defined as having an average systolic blood pressure of ≥ 90 mm Hg or diastolic blood pressure of ≥ 140 mm Hg, a