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Characterization of phthalates exposure and risk for cosmetics and perfume sales clerks☆

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ABSTRACT

High levels of phthalates in name-brand cosmetics products have raised concerns about phthalate exposure and the associated risk for cosmetics sales clerks. We assessed the exposure and risk of phthalates in 23 cosmetics, 4 perfume, and 9 clothing department store sales clerks. We collected 108 urine samples pre- and post-shift and analyzed for phthalate monoesters through liquid chromatography–electrospray ionization–tandem mass spectrometry. Phthalates in 32 air samples were collected and analyzed through gas chromatography–mass spectrometry. Demographic characteristics and information on the exposure scenarios were obtained through questionnaires. Principal component analysis, cluster and risk analysis were applied to identify the exposure profile and risk of phthalate.

Median post-shift levels of urinary mono-2-ethylhexyl phthalate (MEHP) and monomethyl phthalate (MMP) were significantly higher than the corresponding pre-shift levels in cosmetics group (53.3 vs. 30.9 μg/g-c for MEHP; 34.4 vs. 22.5 μg/g-c for MMP; both $P < 0.05$) and the post-shift levels of urinary MMP was significantly higher than the corresponding pre-shift levels in perfume group (26.6 vs. 14.9 μg/g-c, $P < 0.05$). Median levels of air diethyl phthalate (DEP) in cosmetics (1.77 μg/m^3) and perfume (1.75 μg/m^3) groups and di-(2-ethylhexyl) phthalate (DEHP) in perfume group (6.98 μg/m^3) were higher than those in clothing group (DEP: 0.89; DEHP: 2.16 μg/m^3). Over half of cosmetic (70%) and perfume sale clerks had exceeded cumulative risk of phthalate exposure for anti-androgenic effect. We concluded that cosmetic and perfume workers had increased risks of reproductive or hepatic effects for DBP and DEHP exposure. We suggest that not only inhalation but dermal exposure is important route of phthalate exposure for cosmetics and perfume workers.

1. Introduction

Phthalates are additives used in plastics for softness and flexibility, in cosmetics as a vehicle for fragrances, and additive in many other daily products such as polyvinyl chloride (PVC), toys, and medical products (Koch and Calafat, 2009). Because phthalates are widely used, the potential consequences of the general and susceptible population exposure to phthalates have raised concerns (Chen et al., 2017; Huang et al., 2015, 2016; Kim et al., 2017; Wu et al., 2017; Yao et al., 2016; Zota et al., 2014). Considerable amounts of phthalates (up to 5%) are added to a wide range of cosmetics and personal care products and urinary phthalate monoester levels rise rapidly when such products are used daily (DiGangi and Norin, 2002; Duty et al., 2005; Houlihan et al., 2002; Houlihan and Wiles, 2000; Table S1). Moreover, higher levels of monobutyl phthalate (MBP), monoethyl phthalate (MEP), and mono-2-ethylhexyl phthalate (MEHP) can be found in women than in men, revealing an aggregate exposure of dibutyl phthalate (DBP), diethyl phthalate (DEP), and di-(2-ethylhexyl) phthalate (DEHP), all

Abbreviations: BBP, butyl benzyl phthalate; DBP, di-*n*-butyl phthalate; DEHP, di-(2-ethylhexyl) phthalate; DEP, di-ethyl phthalate; DMP, dimethyl phthalate; ED, exposure dose; MBP, mono-*n*-butyl phthalate; MBzP, monobenzyl phthalate; MDL, minimum detectable limit; MEHP, mono-2-ethylhexyl phthalate; MEP, monoethyl phthalate; MMP, monomethyl phthalate; ND, not detectable; RSD, relative standard deviation; μg/g-c, μg/g creatinine.

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of which are extensively used in cosmetic products such as perfume and nail polish (Al-Saleh and Elkhatib, 2016; DiGangi and Norin, 2002; Houlihan and Wiles, 2000; Koniecki et al., 2011; Silva et al., 2004; Just et al., 2010). Phthalates are estrogenic, anti-androgenic, and anti-thyroid endocrine disruptors in animals (Ema and Miyawaki, 2001a, b; Gray et al., 2000; Harris et al., 1997; Talsness et al., 2009). Previous study has indicated that DBP, butyl benzyl phthalate (BBP), and DEHP has a reproductively toxic effect on sexual differentiation among rodents when prenatal periods and causes decreased fertility in their offspring (Grande et al., 2007; Lee et al., 2004; Mylchreest et al., 1998, 1999, 2002). According to some studies, phthalates are associated with decreased thyroid function and reproductive hormone in general population and pregnant women (Araki et al., 2017; Chen et al., 2017; Huang et al., 2016, 2017a,b; Park et al., 2017; Johns et al., 2017).

Plastic-related factories are a source of occupational exposure to phthalates (Dirven et al., 1993; Nielsen et al., 1985; Rustagi et al., 2011). Although the causality between occupational exposure to phthalates and the potential health effects for workers is debatable, studies have reported high levels of DEHP in air samples and MEHP in urine samples in the PVC processing industry (Dirven et al., 1993; Hsu et al., 2017; Milkov et al., 1973; Nielsen et al., 1985; Pan et al., 2006; Westberg et al., 2005). Using personal care products can immediately increase exposure to phthalates in adult men (Duty et al., 2005) and inhalation may be a crucial cause of phthalate exposure in women (Braun et al., 2014; Ferguson et al., 2017; Just et al., 2010; Miao et al., 2017). Because cosmetics are considered essential by most women and phthalates are probable reproductive toxicants in humans, questions pertaining to occupational exposure to phthalates in women who sell cosmetics and perfumes must be answered. In the present study, we studied airborne phthalates and urinary phthalate monoesters to evaluate phthalate exposure in sales clerks working in cosmetics and clothing department stores and assess their phthalate exposure dose (ED) and cumulative risk.

2. Materials and methods

2.1. Participants

We issued a preliminary questionnaire to full-time sales clerks from an iconic brand and serial department store in southern Taiwan. The participants were recruited from cosmetics, perfume, and clothing departments to represent three scenarios of phthalate exposure. Pregnant women were excluded to avoid selection bias. Human Ethics Committee of National Cheng Kung University Hospital approved the study protocol (No. ER-95-149). Written informed consent was obtained from all participants.

2.2. Sample collection

All glassware were washed with organic solvents and packed with aluminum foil before sample collection. From March 29 to April 12, 2007, urine samples were collected from each participant on four separate occasions. On each occasion, two urine samples (20–30 mL), one pre-shift (first morning spot urine) and one post-shift were collected. In addition, according to the distribution of our participants, 10 air sampling sites (four sampling sites each in the cosmetics and clothing departments and two sampling sites in the perfume department) were set for air sampling (Fig. S1). We used a sampling pump (Gillian BDX II; Lab Safety Supply Inc., Janesville, WI, USA) coupled with a sorbent tube (polyurethane foam/glass fiber filter, 22 × 100 mm, 76 mm, Cat No.: 226-126, SKC Inc., Eighty Four, PA, USA) to collect ambient air samples. The flow rate was set at 3 L/min for 8 h of stationary sampling. All air and urine samples were stored at −20 °C until the analysis.

2.3. Phthalates and urinary metabolites analysis

We used a published method with minor modifications for the phthalate air sampling and analysis (Adibi et al., 2003) using Soxhlet extraction and gas chromatography–mass spectrometry instrument (Agilent HP5890 Series II/5972A MS; Agilent Technologies, Santa Clara, CA, USA). Dimethyl phthalate (DMP), DEP, DBP, BBP, and DEHP were measured in air samples. We measured one blank PUF cartridges per area to assess the contamiation during the sampling preparation and analysis process. We assessed the breakthrough status of our air sampling by calculating the sampler contains a <5% of the upstream concentration according to OSHA 104 method (OSHA, 1994). Besides, we used a urinary analytical method (Huang et al., 2007) for phthalate metabolites analysis using off-line solid-phase extraction cartridge and liquid chromatography–electrospray ionization–tandem mass spectrometry instrument (API 3000; Applied Biosystems, Foster City, CA, USA). Five phthalate metabolites Mono-methyl phthalate (MMP), MEP, MBP, mono-benzyl phthalate (MBzP), and MEHP were measured in urine samples. Urinary creatinine levels were measured by spectrophotometric methods, and phthalate metabolite levels were divided by urinary creatinine levels and expressed as "μg/g creatinine" to account for urinary volume correction. The detailed description of analysis and performance of quality control were described in supplementary materials.

2.4. Questionnaire

Interviews and questionnaires were conducted to obtain demographic characteristics and determine exposure scenarios. The questionnaire obtained each participant's age, height, weight, educational attainment, marriage status, monthly salary, employment status (e.g., working days per month), food consumption, and frequency of cosmetics use on a regular workday.

2.5. Daily exposure dose and cumulative risk calculation

We applied a pharmacokinetic model, proposed by David (2000) that uses urinary phthalate monoester levels to evaluate the daily ED of phthalates in humans (David, 2000; Koch et al., 2003). The equation is as follows:

$$ED(\mu g/kg/d) = \frac{ME \times CE}{f \times 1000} \times \frac{MW_d}{MW_m} \quad (1)$$

where *ME* (μg/g-creatinine, μg/g-c) is the creatinine-adjusted level of urinary phthalate monoesters, CE (mg/kg/d) is the daily excretion amount of creatinine in women, *f* is the daily excretion rate of phthalates in urine (0.69 for MMP, MEP; 0.84 for MBP; 0.73 for MBzP; and 0.059 for MEHP) (Koch et al., 2004, 2012; Kohn et al., 2000), MWd is the molecular weight of phthalates, and MWm is the molecular weight of phthalate monoesters.

The smoothed creatinine excretion (CE) rates $CE_{smoothed}$ are age, body weight (BW) and height (ht), and gender-based values for urinary CE (Mage et al., 2004, 2008). The formulae of $CE_{smoothed}$ estimates for women in this study are listed below:

Women (≥18 years old) (2)

$$CE = 1.64 \times (140 - Age) \times BW^{1.5} \times ht^{0.5} \times 10^{-6} \ldots \text{(female adults)}$$

where Age (years old) and ht (cm) are the participant's age and height, which were obtained from the questionnaire; All of the parameters we used for calculating DIs are listed in Supplemental Table 2.