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Secondhand smoke in waterpipe tobacco venues in Istanbul, Moscow, and Cairo

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ABSTRACT

Objective: The prevalence of waterpipe tobacco smoking has risen in recent decades. Controlled studies suggest that waterpipe secondhand smoke (SHS) contains similar or greater quantities of toxicants than cigarette SHS, which causes significant morbidity and mortality. Few studies have examined SHS from waterpipe tobacco in real-world settings. The purpose of this study was to quantify SHS exposure levels and describe the characteristics of waterpipe tobacco venues.

Methods: In 2012–2014, we conducted cross-sectional surveys of 46 waterpipe tobacco venues (9 in Istanbul, 17 in Moscow, and 20 in Cairo). We administered venue questionnaires, conducted venue observations, and sampled indoor air particulate matter ($PM_{2.5}$) ($N=35$), carbon monoxide (CO) ($N=23$), particle-bound polycyclic aromatic hydrocarbons (p-PAHs) ($N=31$), 4-methylnitrosamino)-1-(3-pyridyl)-1-butanone (NNK) ($N=43$), and air nicotine ($N=46$).

Results: Venue characteristics and SHS concentrations were highly variable within and between cities. Overall, we observed a mean (standard deviation (SD)) of 5 (5) waterpipe smokers and 5 (3) cigarette smokers per venue. The overall median (25th percentile, 75th percentile) of venue mean air concentrations was 136 (82, 213) $\mu g/m^3$ for $PM_{2.5}$, 3.9 (1.7, 22) ppm for CO, 68 (33, 121) ng/m^3 for p-PAHs, 1.0 (0.5, 1.9) ng/m^3 for NNK, and 5.3 (0.7, 14) $\mu g/m^3$ for nicotine. $PM_{2.5}$, CO, and p-PAHs concentrations were generally higher in venues with more waterpipe smokers and cigarette smokers, although associations were not statistically significant.

Conclusion: High concentrations of SHS constituents known to cause health effects indicate that indoor air quality in waterpipe tobacco venues may adversely affect the health of employees and customers.

1. Introduction

Waterpipes (also known as hookah, nargile, calean, goza, or shisha) have been traditionally used to smoke tobacco in the Eastern Mediterranean region and parts of Asia and Africa for centuries (World Health Organization, 2005). The prevalence of waterpipe smoking has been rising in recent decades, particularly among youth in Europe, the Middle East, and the United States (US) (Maziak et al., 2015). This increase in prevalence and geographic expansion has been related to several factors, including the perception that waterpipe smoking is less harmful than cigarettes, the distribution of flavored tobacco products, the social culture of waterpipes in cafés and restaurants, and aggressive commercial marketing (Maziak et al., 2015). Despite successful legislative bans on indoor smoking in many countries, most indoor smoking legislation exempts waterpipe smoking establishments (Jawad et al., 2015).

A complex mixture of exhaled mainstream smoke and sidestream smoke emitted directly from the burning source (Apelberg et al., 2013), SHS is well known to cause significant morbidity and

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mortality (Centers for Disease Control and Prevention, 2014). SHS is commonly measured using both tobacco-specific markers (e.g., nicotine) and non-specific markers of combustion (e.g., respirable particulate matter [PM]). Smoking machine studies and controlled human experiments suggest waterpipe SHS contains similar toxicants compared to cigarettes, may have higher levels of nicotine, ultrafine PM, carbon monoxide (CO), polycyclic aromatic hydrocarbons (PAH), volatile aldehydes (e.g., formaldehyde), phenols, benzene, and metals, and lower levels of tobacco-specific nitrosamines (Al Rashidi et al., 2008; Daher et al., 2010; Schubert et al., 2011, 2014; Sepetdjian et al., 2013, 2008; Shihadeh and Saleh, 2005; Shihadeh et al., 2015). In contrast to cigarettes, waterpipe SHS includes combustion products both from the tobacco and from the burning source (usually charcoal) (Schubert et al., 2014; World Health Organization, 2005). Other differences in emissions may be related to the lower burning temperature of waterpipe tobacco (Shihadeh, 2003) or the longer length of an average waterpipe smoking session, which usually lasts 20–80 min (World Health Organization, 2005).

Compared to controlled experiments, real-world studies of waterpipe SHS are more likely to capture the expected variability in waterpipe tobacco composition, smoking behaviors, and environmental factors. Recently, several observational studies measuring SHS in waterpipe venues have found elevated concentrations of particulate matter with an aerodynamic size of 2.5 μm or less ($PM_{2.5}$), CO, nicotine, and carbon (Al Mulla et al., 2014; Cobb et al., 2013; Fiala et al., 2012; Hammal et al., 2015; Saade et al., 2010; Zaidi et al., 2011; Zhang et al., 2015; Zhou et al., 2014). However, most existing studies have been conducted with small samples, limited air markers of SHS (i.e., only PM), and relatively short sampling times (less than 2 h). The purpose of this study was to quantify SHS levels and describe the characteristics of waterpipe tobacco venues in Turkey, Russia, and Egypt.

2. Methods

2.1. Venue selection and recruitment

This study was conducted in Istanbul, Turkey, Moscow, Russia, and Cairo, Egypt, major cities in countries with a high prevalence of waterpipe smoking (Morton et al., 2014). Within each city, we identified neighborhoods with a high concentration of waterpipe tobacco venues. Although we initially planned a stratified random sample, we switched to a convenience sample strategy due to a low venue response rate. Venues were selected in neighborhoods of low, middle, and high socioeconomic status. The final venue response rate ranged from 32–34% in each city.

Eligible venues provided oral informed consent and had at least one non-smoking adult employee ($\geq$ 18 years of age) willing to provide hair, saliva, urine, and/or exhaled breath samples. Data collection was conducted between January and May 2013 in Istanbul, from December 2013 to May 2014 in Moscow, and November 2013 to April 2014 in Cairo. Field staff fluent in the local language conducted all communications with venues and participants in the native language. The Johns Hopkins Bloomberg School of Public Health Institutional Review Board and the ethics committee at each co-investigator's institution approved the study protocol.

2.2. Venue questionnaires and observations

Field staff administered a questionnaire to the owner or manager regarding venue characteristics (waterpipe availability, preparation practices, customer characteristics and behaviors, and smoking policies) and conducted observations of customer smoking behaviors during two 15 min periods, 45 min apart during peak business hours. Other sources of combustion, including cooking and burning candles or incense, were documented.

2.3. Indoor air sampling

We measured $PM_{2.5}$, CO, particle-bound PAHs (p-PAHs), 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanone (NNK, a tobacco specific nitrosamine), and nicotine in indoor air. Trained field staff placed a backpack containing air-sampling equipment for $PM_{2.5}$, CO, and NNK in a convenient, central location of the venue. $PM_{2.5}$, NNK, and CO samplers were in place for 24–36 h (the pump for $PM_{2.5}$ and NNK automatically turned off after 23 h). Passive air nicotine monitors were hung for several days in an unobtrusive central location. P-PAHs were measured for 1–2 h during peak business hours.

2.3.1. Particulate matter $<$ 2.5 micrometers ($PM_{2.5}$)

We collected real-time and integrated $PM_{2.5}$ at one-minute intervals using the 1200 personal DataRAM (pDR) aerosol monitor (Thermo Scientific, Franklin, MA), a light scattering photometer with a size-selective cyclone inlet. The pDR was connected to a calibrated air sampling pump (XR5000, SKC Inc., Eighty Four, PA, USA) running at 4 L/m. Integrated $PM_{2.5}$ was collected on a filter (Teflo R2PJ037, Pall Corp. NY) that was pre- and post-weighed using a microbalance (XP6, Mettler, Columbus, OH) according to standard methods (U.S. Environmental Protection Agency, 2011). $PM_{2.5}$ concentrations below the limit of detection (LOD) of 5 $\mu g/m^3$ (2%) were replaced with half the LOD.

We collected temperature and percent relative humidity at one-minute intervals using a temperature and relative humidity logger (HOBO U10-003, Onset Computer Corporation, Bourne, MA, USA). We adjusted continuous $PM_{2.5}$ measurements when the relative humidity exceeded 60%, as described previously (Laulainen, 1993; Morabia et al., 2009), to account for bias because of increases in particle size at high humidity. We also applied a waterpipe-specific gravimetric correction factor of 0.60, developed and applied previously (Torrey et al., 2015), to account for the differences between waterpipe SHS aerosol compared to the aerosol source used to calibrate the pDR by the manufacturer.

2.3.2. Carbon monoxide (CO)

We measured CO at one-minute intervals using a data-logging EL-USB-CO300 sampler (Lascar Electronics, Erie, PA, USA). Prior to fieldwork, each monitor was challenged with 5, 10, 30, 40, and 50 ppm CO using a 146C Dynamic Gas Calibrator (Thermo Environmental Instruments, Franklin, MA) connected to a regulator, tank (Matheson TRI*GAS, Twinsburg, OH, USA), and a zero-air source. Only monitors found to be within 5% of the known concentrations were used in the field. CO concentrations below the LOD of 0.5 ppm (3%) were replaced with half the LOD.

2.3.3. Particle-bound polycyclic aromatic hydrocarbons (p-PAHs)

We measured p-PAHs at one-minute intervals using a Photoelectric Aerosol Sensor (PAS2000, EcoChem Inc., League City, TX, USA), which photoionizes p-PAHs (three or more ringed PAHs) by exposing the aerosol to 220 nm ultraviolet light with a pre-set flow rate of 2 L/m. The PAS2000 was manufacturer-calibrated prior to use. Lamp intensity, flow rate, data readings, and operations were checked before sampling. P-PAH concentrations below the LOD of 1 $\mu g/m^3$ (5%) were replaced with half the LOD.

2.3.4. 4-(Methylnitrosamino)-1-(3-pyridyl)-1-butanone (NNK)

We measured NNK, a nicotine-derived nitrosamine ketone, on $PM_{2.5}$ filters (Wu et al., 2011). Samples were extracted with dichloromethane solution of internal standard (d4-NNK, Toronto