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Effects on heart rate variability by artificially generated indoor nano-sized particles in a chamber study

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HIGHLIGHTS

- Exposure to studied particles results in different patterns of HRV.
- HRV may be used for information on physiological responses of particle exposures.
- Particle characteristics may identify their properties for potential health effects.

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ABSTRACT

Background: Airborne particles are associated with increased morbidity and mortality due to respiratory and cardiovascular diseases in polluted areas. There is a growing interest in nano-sized particles with diameter <100 nm and their potential health effects. Heart rate variability (HRV) is a noninvasive method for cardiovascular risk prediction in high prevalent groups.
Aim of study: The aim was to evaluate the impact of nano-sized indoor air particles on HRV for healthy and adult females.
Methods: All exposures were performed as controlled chamber experiments with particle exposure from burning candles, terpene + ozone reactions or filtered air in a double-blind cross over design. Twenty-two healthy females were investigated during 10 min periods at different exposures and the reactivity in high frequency (HF) spectral band of HRV were computed.
Results: Heart rate was unchanged from baseline values in all groups during all experimental settings. HF power of HRV tended to increase during exposure to particles from burning candle while particles from terpene + ozone reactions tended to decrease HF power.
Conclusions: Exposure to nano-sized particles of burning candles or terpene + ozone reactions results in different patterns of heart rate variability, with signs of altered autonomic cardiovascular control.
Practical implications: This study indicates that the HRV method may be used for information on physiological responses of exposure to different nano-sized particles and contribute to the understanding of mechanisms behind health effects of particle exposures.

1. Introduction

An increasing number of studies show correlation between chronic exposure to airborne particles and health problems, for instance from the cardiovascular system, by promoting inflammation and atherosclerosis (Ezzati et al., 2002; Brook et al., 2010; Nawrot et al., 2011; Weichenthal, 2012). Since humans, at least in the industrialized parts of the world, tend to spend more than 85% of their life indoors (Klepeis et al., 2001) particles in these environments are of special interest from a health perspective. As the development of new measurement instruments is progressing, the understanding for which particle properties affect our health is

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increasing, and more extensive studies of aerosols and their health influence are motivated and needed.

Particularly the health impact of airborne nano-sized particles with a dimension <100 nm is of increasing concern, not least as a consequence of the growing industry of engineered nano materials. However, humans are already today frequently exposed to high concentrations of nano-sized particles, in general indoor environments as well as in workplaces. Several indoor activities generate particles in the nano-size range. Recent studies indicate that about 60% of integrated daily residential exposure to nano-size particles by number can be attributed to indoor sources (Bekö et al., 2013; Bhangar et al., 2011; Mullen et al., 2011; Wallace and Ott, 2011). Burning candles have previously been identified as a significant source of nano-sized particles (Stabile et al., 2012; Hussein et al., 2006; Pagels et al., 2009) and other examples of nano-size particle generating sources are heat related activities such as cooking, frying, toasting and laser printing but also cleaning products and furniture polish containing terpenes, which in presence of ozone form particles (Brook et al., 2010).

The mechanisms behind the health impact of fine and nano-sized particles are not fully understood, although some studies in recent years provide a basis for better theoretical understanding of exposure, uptake and kinetics (Brown et al., 2000; Koch and Stöber, 2001; Kreyling et al., 2002; Oberdorster et al., 2004). Most of today's knowledge about airborne particle's health impact is the result of epidemiological studies based on measurements of outdoor particles. Sun et al. (2010) pointed out the need to acquire knowledge about the specific combination of airborne particles which can be blamed for health concerns. A need for toxicological studies exists, as well as means to assess health effects of exposure to indoor particles in humans (Morawska et al., 2013).

Heart rate variability (HRV) is, since long a well-recognized, noninvasive, independent method, for cardiovascular risk prediction in high prevalent groups (Malik, 1996). Influence of the sympathetic and parasympathetic branches of autonomic nervous system regulates heart rate and its variability. The major part of this variability is constituted by alterations in respiratory mediated influence on the parasympathetic load. Further, a link between inflammatory mediators and autonomic cardiac control has been shown (Czura and Traycey, 2005; Sloan et al., 2007; Luttman-Gibson et al., 2010) and an association between low grade inflammation and cardiovascular disease has been reported (Ridker and Morrow, 2003; Celik et al., 2011). In this work, a methodology has been developed with the purpose of exploring the effects on heart rate variability in healthy humans exposed to indoor generated candle particles and particles from terpene–ozone reactions.

2. Aim

The aim of this study was to design a feasible chamber study with laboratory generated common indoor air particles and to evaluate the impact of these nano-sized particles on noninvasive markers of cardiovascular reactivity such as heart rate and its variability. The hypothesis (H0) was defined as no observed changes in the high frequency band (HF) of HRV during exposure and if changes proven, resulting in rejection of H0.

3. Methods

3.1. The experimental chamber

The exposure chamber is a 22 m^3 room where all interior surfaces (except for a window 0.8 m^2) are covered with a layer of stainless steel, see Fig. 1. No air can enter or leave the chamber except through a well-controlled ventilation system. The chamber

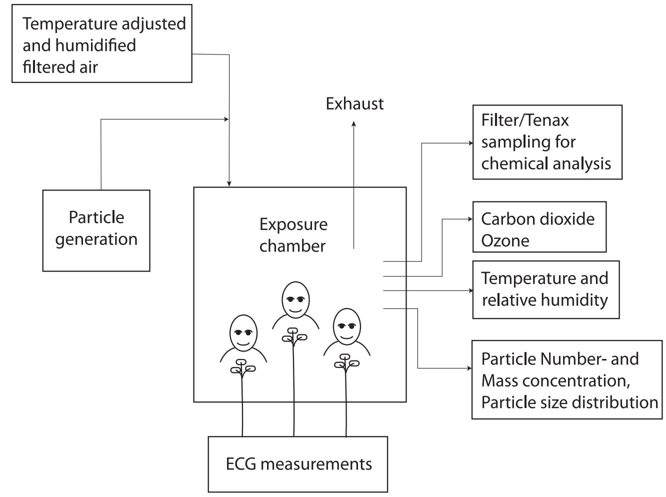

Fig. 1. The experimental set-up for the chamber exposure studies.

is supplied with air through a separate conditioning system by which air flow, temperature and relative humidity can be controlled and adjusted. The air passes through an activated carbon filter and an Ultra-Low Penetration Air (ULPA) filter before entering the chamber at roof level. An over-pressure in the chamber is typically maintained at 10 Pa or just below, to avoid undesired penetration of particles from the surrounding laboratory. The chamber can be used for human exposure as well as for source characterization and aerosol transformation studies and is previously described in detail (Isaxon et al., 2013).

4. Particle generation system

The generation system for candle smoke consisted of a glass and stainless steel chamber with a total volume of 1.3 m^3. An inlet for filtered and pressurized air was placed in the bottom of the chamber to provide a steady controlled flow through the generation volume. Ten blue paraffin/stearine candles of a common commercial brand were lit inside the generation volume. A mobile fan was used to make the flames flicker and hence produce soot particles in a way similar to the air streams which are created when there is movement in the vicinity of a candle in a normal indoor setting. The generation chamber was protected from contamination from the surrounding air by a hatch in front of the chamber opening. This hatch was kept closed at all times except for when the generation was initiated (Pagels et al., 2009).

Terpene vapor was generated continuously by passing pure nitrogen through a glass bottle of commercial essential oil (lemon oil, oleum citri, Interlam AB), consisting of 60–95% *d*-limonene. Ozone was generated by a spark discharge generator (Ozone Technology AB, model AM 3000-2) using filtered dry air, and was added to the ventilation air flow before this flow entered the exposure chamber, just downstream the inlet for addition of terpene vapors. The terpene vapor reacts with ozone in the gas phase before entering the exposure chamber which initiates a cascade of chemical reactions generating reaction products distributed between the gas and particle phase.

During the exposures, particle mass concentration was monitored with a Tapered Element Oscillating Microbalance (TEOM, Rupprecht & Patashnic Co Inc.) and particle number concentration and size distribution by a Scanning Mobility Particle Sizer system (consisting of a CPC 3010, TSI Inc and a long column Hauke DMA), all on-line techniques with a time-resolution of minutes. The