Observation of aerosol generation by human subjects during cardiopulmonary exercise testing using a high-powered laser technique: A pilot project

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Objectives

Human respiratory aerosols may have important implications for transmission of pathogens such as COVID-19. Most studies of human aerosols have been performed at rest and study results may not apply to the clinical environment. The study of aerosol production during vigorous breathing activities such as exercise is limited. In particular, data on aerosol production during cardiopulmonary exercise testing (CPET) are lacking.

Study methods

The authors used a high-powered, pulsed Nd:YAG laser to illuminate a region of interest in front of two healthy adult subjects during CPET. Subjects exercised to the point of respiratory compensation (fatigue) using two different cycle-based CPET systems: Vyntus™ CPX Metabolic Cart and Vmax™ Metabolic Cart. CPET with breath-by-breath aerosol particle counting was performed and images were captured with a high-speed, high-resolution camera to determine net exhaled particle (NEP) counts at different phases of CPET, including resting breathing, submaximal exercise, peak exercise, and active recovery. Image acquisition was synchronized with the laser pulses. Particle-image velocimetry (PIV) was used to measure particle velocities. Experiments were performed with the room ventilation activated.

Results

For both CPET carts and both subjects, the NEP per ml reached a minimum value at peak exercise and subsequently increased into recovery. (See Figure) NEP per ml was two to three times higher at resting breathing than at peak exercise. On a per minute basis, NEP production initially rose with exercise but declined in late and peak exercise, then rebounded in early recovery to values approximately three to four times higher than measured during resting breathing.

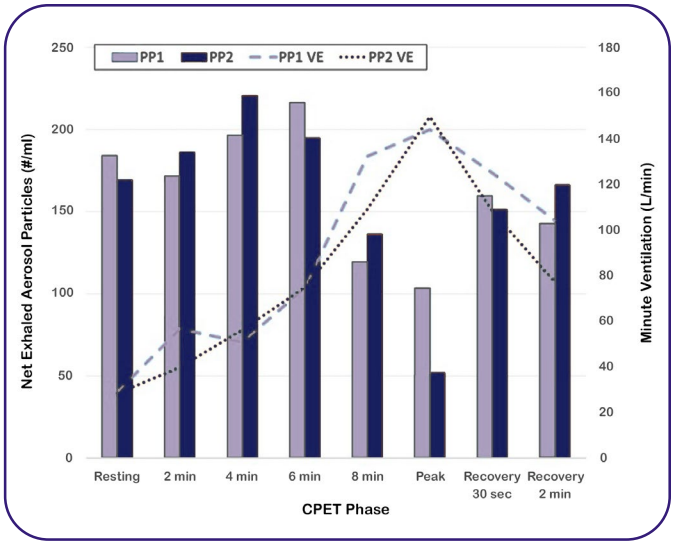

Figure 1 Aerosols vs. minute ventilation (VE) by exercise phase. PP1: subject 1; PP2: subject 2.

What is CPET?

Cardiopulmonary exercise testing (CPET) provides assessment of pulmonary and cardiovascular system functionality by measuring the response of these systems to both submaximal and peak effort during exercise. Often using either a cycle ergometer or a treadmill, the subject breathes into the CPET device which measures oxygen consumption and car-bon dioxide production, along with highly accurate standard spirometric function such as minute ventilation and tidal volume. CPET and numerous other medical procedures that produce aerosols and are deemed non-emergent have been postponed or suspended during the current pandemic. However, measurement and analysis of aerosols produced during CPET are lacking, and applicability of aerosol data from resting breathing and spirometry maneuvers to CPET have not been adequately established.

Figure 2 Vyntus™ CPX (technician not wearing mask for clarity)

Take home message

- Human activities produce aerosols that may be infective.
- Measurement of aerosols during cardiopulmonary exercise testing has not been previously explored.
- Technique used Nd:YAG laser to illuminate region of interest in front of subject; particle images obtained by high-definition gated CMOS camera and counted.
- Number of aerosols produced actually decreased at peak exercise, then returned to baseline during recovery.
- The study identified higher numbers of aerosol particles than seen with other methods.

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