Reducing Bioaerosol Emissions and Exposures in the Performing Arts: A Scientific Roadmap for a Safe Return from COVID19

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Background:
Humans are known to emit aerosols (airborne particles of various sizes) from their respiratory tract through actions such as regular breathing, forced-air breathing (i.e., playing musical instruments or exercising), vocalizing, sneezing, and coughing [1-3]. Recent and past scientific literature suggests that these particles are of biologic origin (i.e., they are released from the respiratory epithelium). Further, the belief exists that such particles may be infectious in nature if they originate from a person who has contracted an infectious disease (i.e., SARS-COV-2) [3-5]. Unfortunately, many infected individuals are asymptomatic (they do not realize they are infected) and during such time, human exposure to infectious aerosol is likely to occur if the infected individual participates in group activities such as choir, dance, acting, or instrument ensembles [6, 7]. Only scant evidence exists to document the rate of aerosol release during performing arts activities [8, 9] and whether there are effective means to control such releases (and reduce the risk for human exposure). This proposal seeks to enact a rigorous, data-driven approach to inform a safe return to activities for the performing arts community.

Specifically, we propose to answer the following questions:

1. What is the rate (and size) of bioaerosol emitted by performers of varying age and gender when engaging in music, voice, and dance?
2. How effective are active and passive control measures at reducing bioaerosol emissions and exposures? These measures include isolation and distancing, room ventilation and filtration, respirator and homemade mask use, and use of personal protective equipment (N95 respirators, homemade masks, face shields, and an air-filtering mouthpiece).
3. Can the risks of co-exposure be reduced to acceptable levels using these active and passive controls?

Project Objective:
The goal of this project is to reduce the risk of human exposure and co-infection to SARS-COV-2 aerosol during performing arts activities. Our research aims to:

1. Establish the magnitude and variability of aerosol release rates, as a function of particle size, from: regular breathing during percussion and string instrumentation, heavy breathing under exertion (dance), and vocalizing across a range of volume and pitch during singing and speaking. These data will be collected for n = 100 performers of varying age and gender to represent a more valid statistical sample of the performing arts population.
2. Establish the magnitude and variability of aerosol release rates, as a function of particle size, from wind instruments, including flute, clarinet, oboe, bassoon, saxophone, recorder, trumpet, trombone, tuba, euphonium, horn. These data will be collected for n = 100 performers of varying age and gender to represent a more valid statistical sample of the performing arts population.

3. Determine the efficacy of active control techniques to prevent human aerosol release (in relation to Objectives 1 and 2) to include: wearing surgical/homemade masks, wearing N95-certified respirators, wearing face shields, utilizing low-resistance filtering mouthpieces.
4. Model the efficacy of passive control techniques to prevent exposure to infectious aerosol, to include social distancing and isolation, room ventilation and filtration, and use of personal protective equipment.

Impact:
The project will develop two primary outputs. The first output is a robust and scientifically rigorous dataset on endogenous particle release rates (stratified by gender, age, and activity type). This dataset will be published in the open science literature and in a manner that is accessible and understandable by stakeholders in the performing arts community. The second output will be a guidelines document that outlines the efficacy of various strategies to control emissions and reduce exposures to infectious bioaerosols. This guidelines document is envisioned to provide the scientific basis for a "safe to perform" position statement to be developed in collaboration with national/international governance bodies in the performing arts.

Project Timeline:

Week 1	Week 4	Week 7	Week 10	Week 12	Week 15
Project initiation	Data collection begins	Preliminary results report	Data collection ends	Data analysis	Final report

The Facilities at Colorado State University:

The Powerhouse Energy Campus at Colorado State University contains a unique, simulated environmental testing (SET) facility that was constructed to study human aerosol emissions and exposures in a clean, versatile environment. The SET is temperature- and humidity-controlled chamber; it measures 10 x 10 x 8 ft on the interior, and operates under a computer-controlled, HEPA-filtered air delivery system. The SET facility, one of only a handful like it across the planet, can be sterilized, purged with clean air in a matter of minutes, and operated with sophisticated equipment to monitor aerosol size and concentration, human respiration and activity rate, and environmental variables (temperature, pressure, relative humidity) - all of which are automatically recorded by a custom-built computer control and data acquisition system. It is large enough to allow a wide range of human movements and activities and has been approved for human subjects research by the Colorado State Institutional Review Board. In addition to this unique facility, the Volckens research group at CSU houses over $2M in sophisticated aerosol research equipment for the determination of aerosol size, concentration, and chemical composition.

Our team has published extensively on aerosols and the human respiratory system [10-14], aerosol exposure research with human subjects [15-18], clinical exposure research in controlled environments [14, 19-21], and bioaerosol emissions/characterization [22-24].

The Team:

John Volckens is a professor of Mechanical Engineering and the Director of the Center for Energy Development and Health at CSU. He has appointments in Environmental Health, Biomedical Engineering, the Colorado School of Public Health, and the CSU Energy Institute. His research interests involve air quality, low-cost sensors, exposure science, and air pollution-related disease. He received clinical research training in controlled human exposure at the U.S. EPA's National Health Effects and Exposure Research Laboratory in Research Triangle Park, NC. He holds 4 patents and has published over 100 scientific manuscripts related to human exposure science, aerosol technology, and air pollution-related disease. He has been the PI of over $20M in funded research from the National Institutes of Health, the Centers for Disease Control, EPA, and NASA.

Heather Pidcoke is the Chief Medical Research Officer and Associate Director of Research at the Translational Medicine Institute at Colorado State University. She received her Doctor of Medicine from the University of Southern California Keck School of Medicine, has a Master of Science in Clinical Investigation, and a PhD in Physiology from the University of Texas, Health Science Center, San Antonio. Pidcoke has industry experience with clinical development projects and has been recognized on a national level for her contributions in advancing medical research for military personnel. She received the Presidential Early Career Award for Scientists and Engineers from the White House Office of Science and Technology Policy in May 2016.

Dan Goble is the director of the School of Music, Theatre and Dance at Colorado State University. Dr. Goble served as the dean of the School of Visual and Performing Arts at Western Connecticut State University in Danbury, Conn., where for 21 years his leadership roles also included chair of the Department of Music and coordinator of Jazz Studies. During his tenure at Western Connecticut State University (WCSU), Dr. Goble provided leadership for curricular and programmatic changes that affected positively the School of Visual and Performing Arts (SVPA) and the university, most notably the planning and construction of an award-winning $97 million instructional and performance facility, which opened in 2014.

Rebecca Phillips is professor of music and director of bands at Colorado State University where she conducts the CSU Wind Symphony and guides all aspects of the band and graduate wind conducting program. She has served as a guest-conductor and clinician, throughout North America, Europe, and Asia. Dr. Phillips regularly conducts collegiate honor bands, all-state bands, and festival bands across the United States, Canada, and Europe and she has been a rehearsal clinician at the Midwest Clinic: *An International Band and Orchestra Conference.* In June 2020, she will be President of the National Band Association and is currently the Music Education chair of the College Band Directors National Association. She was selected for membership in the prestigious American Bandmasters Association in 2014.

Charles Henry is a Professor of Chemistry and Chemical & Biological Engineering. Dr. Henry's research interests lie broadly in the development of lab-on-a-chip technologies, to study environmental and biological phenomena. Major techniques used include microfabrication, chromatography, electrochemistry, electrophoresis, microfluidics, microscopy, and 3D printing. Dr. Henry has published over 180 peer-reviewed publications, generated 8 patents, and is an Associate Editor for Analytica Chimica Acta. In addition, Dr. Henry has been involved in five spin-out companies from Colorado State University with products ranging from industrial water quality sensors to low-cost environmental diagnostics.

Project Budget:

Name	Effort	Salary Cost	Fringe Cost
John Volckens	6%	$4,333.25	$1,243.64
Chuck Henry	6%	$4,333.25	$1,243.64
Clinical Coordinator	100%	$22,000.00	$6,314.00
Research Engineer	100%	$30,000.00	$8,610.00
Graduate Student	100%	$6,450.00	$541.80

Total Personnel + Fringe costs: $85,069.59

SET Facility setup	$2,500.00
Prototype controls and PPE (masks, shields, etc.)	$7,500.00
Open access publication fees	$1,500.00
Cleaning supplies and consumables	$400.00
Participant stipends	$2,000.00

Total Other costs: $13,900

Administrative charges: $4,453.63

Total Project Costs: $103,423.22

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