Link between exercise intensity and risk of infection while training indoors

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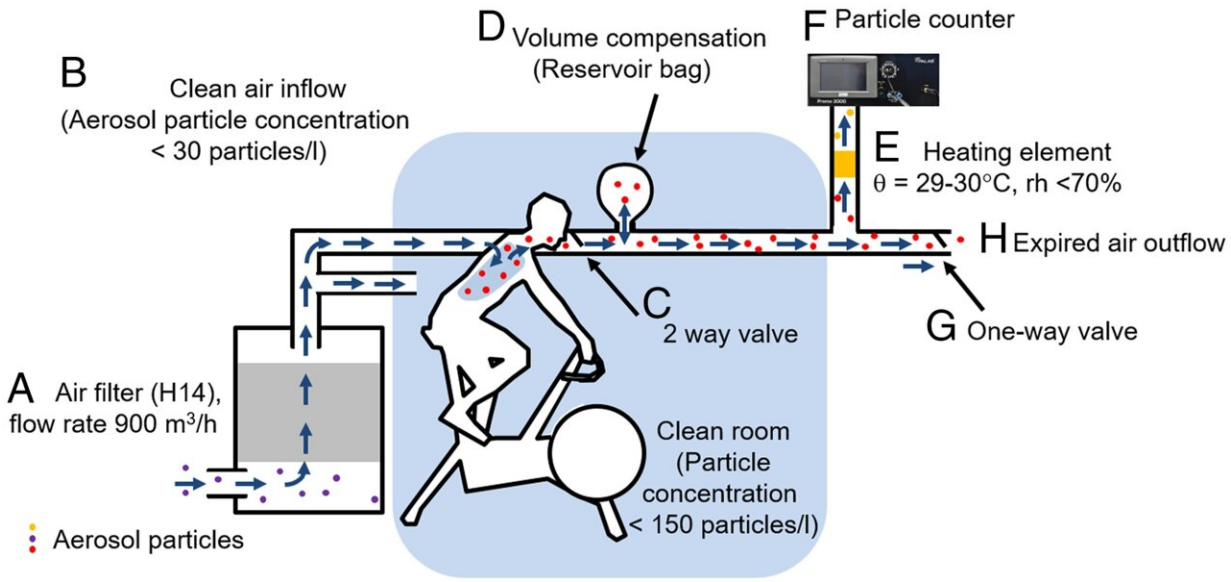

Schematic illustration of the experimental set up designed to measure ventilation, aerosol particle concentration, and aerosol particle emission at a wide range of ventilation from rest to maximal exercise. Ambient air was first filtered (A) to generate air that is nearly free of aerosol particles. The subject then inhaled the (B) filtered, clean air through a silicone face mask that covered mouth and nose (not shown). The silicone mask was (C) connected to a two-way valve so that only exhaled air entered the outflow. A plastic bag acted as a buffer/reservoir (D). A pump diverted ~5 liter/min of the exhaled air through first (E) a heated tube to eliminate condensation and then to the (F) Palas Promo 3000 particle counter. This counter uses a Welas 2300 sensor for particle detection. The remaining air was released into the environment through a separate tube and a one-way valve (G) so that ambient air could not enter the system. The experiment was conducted in a clean room to further reduce the risk of aerosol

particle contamination. Credit: *Proceedings of the National Academy of Sciences* (2022). DOI: 10.1073/pnas.2202521119

Until now, there has been no clarity on how exercise intensity affects the emission and concentration of aerosol particles in exhaled air. With a new experimental setup, a Munich research team has shown that aerosol emissions increase exponentially with intense physical exertion—so that indoor sporting activities result in a higher risk of infectious diseases such as COVID.

Before the study it was known that the respiratory volume for untrained people increases from around 5–15 liters per minute at rest to over 100 l/min when exercising. Highly trained athletes actually reach levels of 200 l/min. It was also known that many people have been infected with the SARS-CoV-2 virus when exercising indoors.

However, it was unclear how exercise intensity was linked to the concentration of aerosol particles in exhaled air and the actual quantity of aerosols exhaled by an individual per minute and thus on the potential risk of spreading infectious diseases such as SARS-CoV-2. This information is urgently needed, however, for example to design mitigation measures for school gyms and other indoor sports facilities, fitness studios or discos to avoid shutdowns in case of serious waves of infection.

New methodology delivers individually measurable aerosol values

A team lead by Henning Wackerhage, a Professor of Exercise Biology at the Technical University of Munich (TUM), and Prof. Christian J. Kähler, the Director of the Institute of Fluid Mechanics and

Aerodynamics at the Universität der Bundeswehr München, has developed a new investigative method for studying these questions.

Their experimental apparatus initially filtered out the aerosols already present in the ambient air. In the subsequent ergometer stress test, the test subjects inhaled the purified air through a special mask covering the mouth and nose. The exercise intensity was gradually increased from rest to the point of physical exhaustion. The mask was connected to a two-way valve through which only the exhaled air can escape. The quantity of aerosol particles emitted per minute was then measured and directly linked to the current performance of the healthy, 18- to 40-year-old test subjects.

Moderate aerosol emissions at medium exertion

The researchers were thus able to investigate for the first time how many aerosol particles are exhaled per minute by an individual at various levels of exercise intensity. The result: aerosol emissions during exercise initially increased only moderately up to an average workload of around 2 watts per kilogram of body weight. Above that point, however, they rose exponentially. That means that an individual who weighs 75 kilograms reaches that threshold at an ergometer reading of around 150 watts. This corresponds to moderate effort for a casual athlete, perhaps comparable to the exercise intensity of moderate jogging.

The aerosol emissions of well-trained athletes was significantly higher than those of untrained test subjects at maximum effort due to their much higher minute ventilation. The researchers did not find significant differences in particle emissions between genders.

Protective measures are important for high-intensity training

Although the aerosol experiments provide only indirect knowledge on the quantity of viruses in exhaled air, the study suggests useful starting points for managing indoor activities when a wave of infection combined with a poorly immunized population threatens to overwhelm the health care system.

"Based on our results, we distinguish between moderate endurance training with an intensity of up to 2 watts per kilogram of body weight and training at high to maximum intensity. Due to the sharp rise in aerosol emissions at high-intensity workloads above that initial benchmark, special protective measures are needed in case of a high risk of infections with serious consequences," says study leader Prof. Wackerhage.

"Ideally, that kind of training would be moved outdoors. If that is not possible, testing should be done to ensure that no infected individuals are in the room. The participants should also maintain a proper distance and a high-efficiency ventilation system should be running. In addition, infection risks are reduced by training at lower intensities and keeping sessions shorter. It might also be possible for fit, young athletes to wear masks while training." At low workloads such as easy to moderately intense endurance training, adds Prof. Wackerhage, less protection is needed and the infection risk can be controlled through distancing and ventilation systems.

The study is published in the *Proceedings of the National Academy of Sciences*, and the research team is currently conducting experiments to compare aerosol emissions in strength and endurance training and to correlate them with test subjects' ages and physical characteristics.

More information: Benedikt Mutsch et al, Aerosol particle emission increases exponentially above moderate exercise intensity resulting in superemission during maximal exercise, *Proceedings of the National*

Academy of Sciences (2022). DOI: 10.1073/pnas.2202521119