Supplementary response detailing dead space and CO_2 topic - MS#22-302

The following information has further background on human subject tests conducted on the tubular face mask in the paper, *Demonstration of a Reusable Mask in a Tubular Design that Provides Universal Fit and Protection from Respiratory Hazards*. It is provided to explain in part the research team's understanding of dead space and potential CO_2 build-up and how inhouse testing of prototypes addressed it. Ethics approval was secured for the tests. Results as described in this document are not generalizable. In this document, prototypes are alternately referred to as facegaiter and "Face Gaiter." The benchmark, a filtering facepiece respirator, was an FFP2 with a minimum 94% filtration efficiency certified to EN 149 and thereby close in grade to N95 filtering face piece respirators (95% minimum filtration efficiency) used elsewhere.

The facegaiter prototypes had a plenum for circulating and slowing airflow inside the mask and the space inside is larger than that of filtering facepiece respirators. Added space may permit CO_2 to accumulate, so the research team investigated its physiological impact by comparing it to a 3M Aura respirator (Minnesota, USA) widely used for extended periods in occupational settings with, at most, limited adverse impacts.

Each mask was fitted with a bespoke attachment of narrow plastic tubing (see Figure A) to enable the composition of gas inside of the masks to be collected during the trial. A length of narrow plastic tubing was attached to the bespoke fitting on each mask to enable regular measurements of the proportion of oxygen and carbon dioxide via a servomex analyser. At each measurement point, the concentration of oxygen and carbon dioxide inside the mask was continually sampled for 30 seconds. The mean values (across the 30 seconds) were used for subsequent analysis.

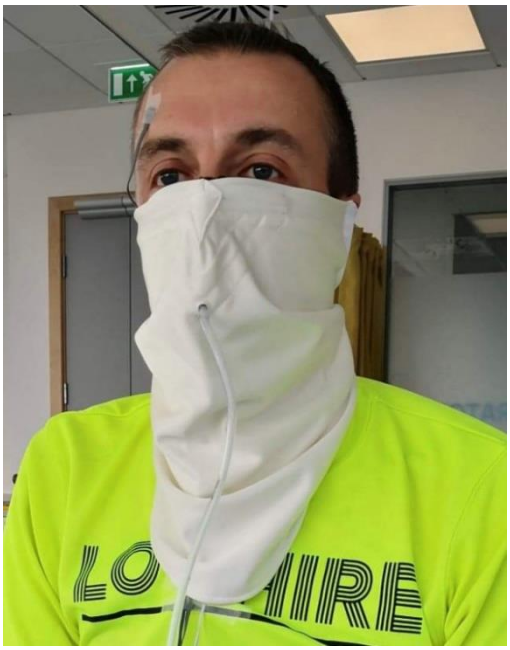

Figure A: Participant wearing a then-prototype cloth mask, a facegaiter™ (tensARC, Stirling, UK) mask with bespoke attachment (A) to sample gas composition inside the mask and visible skin thermistor on the forehead (B). *Photograph used with participant's permission.*

The research team's measurement was a 30 second average of air inside the dead space rather than an absolute measurement. As is well-known, the composition of gas is highly transient as a subject breathes in and out. The research team did not ask the subjects to hold their breath during the measurement, as this would not have been possible during exercise; thus, the data reported is largely a result of the local CO_2 from the immediately expired air. Had the research team measured during breath hold, observed values would likely have been like room air, as the air rapidly exchanges. The actual composition of air that the subject breathed in is not known (with any degree of precision).

Data do not show that there is "progressive build up" of CO_2 (see below). Rather, it increases immediately upon wearing the mask and remains fairly constant. Exercise increases the CO_2 percentage, which reflects the increased in VCO_2 during exercise. There are short- and long-term exposure recommendations for CO_2 (e.g. https://bmcinfectdis.biomedcentral.com/articles/10.1186/s12879-021-06056-0). The research team's values suggest the CO_2 in the masks exceeds those limits – but it must be reinforced that the data represent the average of the transient change rather than an absolute measure of what was breathed in.