

## Using Astronaut Case Studies to Teach the Physiological Effects of Elevated Carbon Dioxide Concentrations

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The microgravity environment of space encompasses numerous hazards requiring the human body to adapt with interesting and entertaining results that can help educate students grasp core physiology concepts. Living and surviving in microgravity daily can test the limits of the human body and the closed system environment of a space ship can offer some unique ability to learn more on how the atmospheric contents also influence crew physiology, memory, information processing. Thus, astronauts are often the first people to provide anecdotal evidence for new areas of research while in microgravity environments. One of the many challenges astronauts encounter in the space environment is air quality, or more specifically the presence of carbon dioxide within the atmosphere. Two books, *Apollo 13* by Jim Lovell and Jeffery Kluger and *Endurance* by Scott Kelly, provide both mention and explain anecdotal accounts of physiological effects of breathing elevated levels of carbon dioxide (CO<sub>2</sub>). These accounts provide interesting potential research opportunities for the future as it is expected for humans to venture to Mars which could take 6 - 8 months of transit time for astronauts in a closed-loop spacecraft plus in the classroom, it provides a realistic and unique case study to challenge students to understand the physiological mechanisms of respiratory and potentially cardiovascular physiology.

In Scott Kelly's memoir *Endurance* (2017) [1], while aboard the International Space Station (ISS) for 340 days, he began to notice the negative effects of carbon dioxide once atmospheric concentrations reached 0.4 percent, approximately ten times the average CO<sub>2</sub> concentration on Earth. At 0.4 percent, Kelly experienced chronic headaches and sinus congestion. As the CO<sub>2</sub> concentrations rose above 0.5 percent, Kelly began feeling degraded cognitive abilities and a burning sensation in his eyes. Kelly also experienced irritability that appeared to increase as the CO<sub>2</sub> concentrations in the ISS increased. Amiko, Kelly's girlfriend at the time and now his wife, was able to fairly accurately predict the ISS' CO<sub>2</sub> concentration by judging Kelly's level of irritability during video calls. These accounts show that both Kelly and Amiko were sensitive to physiological symptoms to high CO<sub>2</sub> and that with some consistency, symptoms experienced were perceived and correlated to a specific level of CO<sub>2</sub> within the ISS atmosphere.

Despite the ISS allowing a maximum CO<sub>2</sub> level of 0.8 percent, the Apollo program's maximum allowable CO<sub>2</sub> concentration was 0.25 percent, the same value used by United States Navy submarines in that same era [2]. When Apollo 13's oxygen tank exploded in the year 1970, the CO<sub>2</sub> began to steadily rise during the crew's emergency return back to Earth. The Apollo team used creative engineering solutions to reabsorb ambient CO<sub>2</sub>, but the gas levels still managed to reach two percent of total atmospheric levels before it started to decrease. The Apollo crew was concerned that without a functional scrubber, CO<sub>2</sub> levels would rise uncontrollably until the astronauts experienced debilitating hypercapnia.

These Apollo 13 and *Endurance* examples provides an interesting and entertaining method to discuss the physiological effects of blood CO<sub>2</sub> concentrations and how the central chemoreceptor will respond by altering respiratory rate plus the effects of continual rise in blood

CO<sub>2</sub> levels that can potentially lead to respiratory failure levels that the Apollo crew was for a period of time potentially exposed. Kelly's example shows potentially how sensitive the human body is to increasing levels of CO<sub>2</sub> below concentrations of 0.8 percent. Kelly's ISS case study can be used to teach current research regarding elevated CO<sub>2</sub> levels and the more subtle changes and the effects on the nervous system giving insight to potential global atmospheric changes associated with climate change.

### Bibliography

1. Kelly S. "Endurance: A Year in Space, A Lifetime of Discovery". New York (NY): Alfred A. Knopf (2017).
2. Kluger J and Lovell J. "Apollo 13". New York (NY): Houghton Mifflin (1994).

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