The Journal of Physiology

CLINICAL PERSPECTIVES

Wasting away in Mars-Aritaville

Michael J. Joyner
Department of Anesthesiology, Mayo Clinic, 200 First Street SW, Rochester, MN 55905, USA

Email: joyner.michael@mayo.edu

Humans encountered physiological challenges as soon we began to leave the ground, first with balloons, then with planes, and more recently via rockets. Early high-altitude balloon flight exposed the sojourners to extreme cold and potentially lethal hypoxia (West, 1982). As planes became more powerful and manoeuvrable, pilots experienced severe G-forces that could limit brain perfusion and cause loss of consciousness. The problems of temperature, hypoxia and G-forces have all been solved with relatively straightforward countermeasures including supplemental oxygen, pressurized environments, improved clothing, and G-suits along with straining manoeuvres.

The solutions to these problems have all also had significant translational implications with many finding a second home in clinical medicine. For example, the fundamental discoveries and engineering breakthroughs required to understand how humans respond to high G-forces, found second homes after the Second World War in the emerging fields of cardiac catheterization, cardiac surgery and critical care medicine. Many of the key advances were made by the legendary physician–scientist Earl Wood, who worked at my institution, the Mayo Clinic, during and after the Second World War (see the obituary of Earl Wood in the *New York Times*, 26 March 2009). Additionally, numerous advances in respiratory physiology with subsequent clinical applications owe their genesis to observations made at high altitude including those made during aviation.

In contrast to the high G-forces experienced by the pilots of high-performance planes, weightlessness during space flight creates major problems for astronauts. The adaptations (or perhaps maladaptations) to space flight include rapid cardiovascular deconditioning and loss of blood volume, skeletal muscle wasting, and reductions in bone density. Endurance exercise training and acute bouts of high-intensity exercise can ameliorate much of the cardiovascular deconditioning and changes in blood volume associated with both medium-term (weeks) and long-term weightlessness (months). Additionally, head-down tilt bedrest appears to be a useful analogue for the cardiovascular deconditioning that occurs with prolonged space flight, making ground based studies highly informative (Engelke *et al.* 1996; Guinet *et al.* 2009).

Along with cardiovascular deconditioning there are also losses of both skeletal muscle mass and bone density with space flight. In a recent issue of *The Journal of Physiology*, Fitts *et al.* (2010) reported that 180 days of space flight causes marked atrophy and force loss of skeletal muscle biopsy-derived fibres from space station crew members. In this context, the effects of space flight were especially evident in type 1 fibres of ‘anti-gravity’ muscles, like the soleus. Importantly, and in contrast to cardiovascular deconditioning, these effects were largely resistant to amelioration by concurrent exercise training in space. Along these lines there are a number of caveats and clinical observations that either inform or are informed by these findings.

First, modern orthopaedic surgery has abandoned, when possible, extreme immobilization and this practice appears to have improved both the speed and efficacy of reconstructive surgery in a variety of settings. This trend includes rehabilitation from conditions like total joint replacement in older patients, and also knee reconstruction in elite athletes. Orthopaedic surgeons and physical therapists have learned the hard way that extreme skeletal muscle inactivity is devastating, slows recovery, and can lead even young healthy patients to a state where full recovery is limited.

Second, crew members on the international space station could be generically described as middle-aged. If 6 months of minimal gravitational stress and physical activity can be associated with severe loss of muscle function, what does 20 or 30 years of physical inactivity do? There is already evidence that extreme physical inactivity for only 10 days can evoke a variety of metabolic changes that predispose the physically inactive to conditions like diabetes and obesity (Olsen *et al.* 2008).

Third, frailty independent of other risk factors is a major contributor to premature death and disability in older humans (Schatz, 2002). This becomes even more apparent in individuals in their 70s and 80s. If effective countermeasures are developed for prolonged space flight, will they have implications for preventing, reducing, or reversing frailty in the elderly?

Fourth, what about prolonged space flight? Exploration of Mars will require a mission of 3–4 years. Will muscle (and bone) loss be the scurvy of modern-day exploration, or will space flight make new contributions to medicine similar to those made by previous explorers in the areas of nutrition and hygiene? Along these lines, the discovery by Lind in the 1700s that citrus fruit (vitamin C) could treat scurvy is generally considered the first clinical trial. It is also an excellent example of how exploration, pathophysiology and medicine sometimes intersect for extremely applied reasons (Thomas, 1997).

In summary, the paper by Fitts and colleagues shows that new and innovative countermeasures will be required as human exploration of space continues. If the history of these countermeasures from earlier aviation- and exploration-based experiences is any guide, the spinoffs for clinical medicine are likely to be large.

References

Engelke KA, Doerr DF, Crandall CG & Convertino VA (1996). *Am J Physiol Regul Integr Comp Physiol* **271**, R837–R847.

Fitts RH, Trappe SW, Costill DL, Gallagher PM, Creer AC, Colloton PA, Peters JR, Romatowski JG, Bain JL & Riley DA (2010). *J Physiol* **588**, 3567–3592.

Guinet P, Schneider SM, Macias BR, Watenpaugh DE, Hughson RL, Le Traon AP, Bansard JY & Hargens AR (2009). *Eur J Appl Physiol* **106**, 217–227.

Olsen RH, Krogh-Madsen R, Thomsen C, Booth FW & Pedersen BK (2008). *JAMA* **299**, 1261–1263.

Schatz IJ (2002). *Clin Auton Res* **12**, 223–224.

Thomas DP (1997). *J R Soc Med* **90**, 50–54.

West JB (1982). *J Appl Physiol* **52**, 1393–1399.

DOI: 10.1113/jphysiol.2010.198861