A CASE STUDY WITH A DIFFERENCE

Resting and exercising heart rate before, during and after a 10-day space flight

Karen A Sharwood

The upright position at 1 G (earth's gravity) defines the normal operating conditions for the human cardiovascular system.[1] Gravity has important effects on cardiovascular mechanisms and their response to exercise, specifically in terms of filling pressures and intravascular fluid distribution. The removal of all hydrostatic gradients when entering space causes a headward shift of fluids,[2] which is believed to be the primary stimulus for many of the physiological effects of space flight,[2] including reductions in plasma volume and orthostatic intolerance on return to gravity.

Case report

Heart rate was measured before, during and after a 10-day space flight in Mark Shuttleworth, a 28-year-old man. A standard testing protocol was performed on 4 occasions, once a week preceding the flight, on 3 occasions during the flight and once a day for 5 days following the flight. This protocol included a 20-minute orthostatic test, comprised of 10 minutes of supine lying and 10 minutes of standing, followed by a cardiovascular exercise response test performed on a stationary recumbent cycle ergometer. The cardiovascular test included 4 exercise stages, each lasting 2 minutes and separated by 1 minute of rest. Exercise intensity began at 100 watts and increased by 25 watts for each stage thereafter, and was followed immediately by a 10-minute supine recovery period. Other measurements recorded during these testing sessions included lean thigh volume, percentage body fat, mid-thigh girth measurements and hamstring flexibility. During the space flight, Mark performed the same testing regimen, excluding the orthostatic test, body fat, lean thigh volume and hamstring flexibility measurements. After the flight, he was monitored every day for 5 days. Twenty-four hours after the flight and on days 3 and 5 he repeated the entire testing protocol, while on days 2 and 4 after the flight only the orthostatic test was performed.

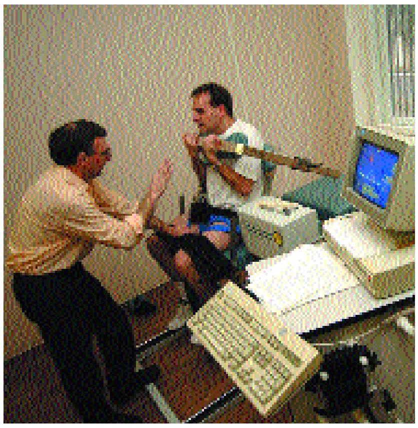
Karen Sharwood studied Human Movement Studies at Rhodes University followed by honours in Exercise Science (Biokinetics) at the University of Cape Town. She is currently completing her PhD at the MRC/Research Unit for Exercise Science and Sports Medicine at the University of Cape Town, where her primary research interests include changes in muscle characteristics and physiology associated with chronic endurance training, hydration status and the associated medical consequences of ultraendurance exercise and more recently, space physiology.

Table I. Descriptive characteristics

Variable	Average pre-flight	Average in-flight	Average post-flight
Age (yrs)	28.0	-	-
Height (cm)	176.0	-	-
Weight (kg)	76.5	-	73.2
Mid-thigh girth (cm)	51.4	49.7	50.2
Left hamstring flexibility (°)	73.8	-	72.0
Right hamstring flexibility (°)	94.0	-	93.0
Body fat (%)	13.6	-	12.1
Lean thigh volume (cm^3)	5329.0	-	2735.0

Table I lists Mark's descriptive characteristics before, during and after the flight. The body weight lost was due to a decrease in muscle mass, illustrated by a decrease in muscle girth size and lean thigh volume and a decrease in body fat, as well as possible body fluid losses experienced on re-entering the earth's atmosphere. Fig. 1(a) shows the orthostatic test results from before the flight (averaged) and each day following the flight, for 5 days. Orthostatic tolerance was clearly compromised immediately after landing, with resting supine and standing heart rate values 24 hours after landing approximately 20 beats / min higher than pre-flight values. Heart rate was still elevated above pre-flight values 48 hours after the flight, but had returned to baseline levels within 72 hours (day 3). Mark reported symptoms of dizziness and nausea on standing during the first orthostatic test performed 1 day after landing. Despite these symptoms, however, he was still able to complete the 10 minutes of standing. These symptoms were not reported on any other day during any of the testing.

Fig. 1(b) shows the heart rate response to the graded interval exercise test performed before, during and after the flight. At rest, there were no differences in heart rate between earth and microgravity conditions. During the first 3 exercise intervals, performed at low intensities, heart rate was relatively similar between gravity and microgravity conditions, but at a higher intensity of 175 watts (stage 4) heart rate was markedly



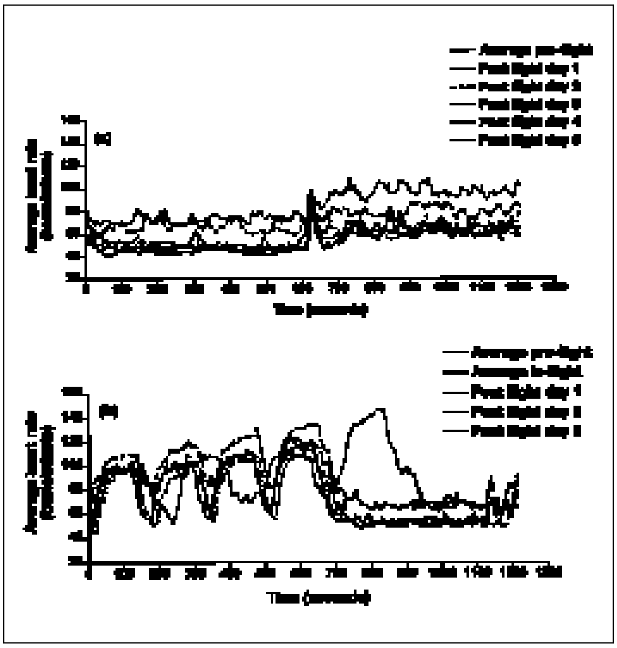


Fig. 1 (a) Orthostatic tolerance test performed before a 10-day space flight and repeated every day for 5 days following the flight. (b) Cardiovascular response test performed before and during a 10-day space flight and repeated on days 1, 3 and 5 following the flight.

elevated under the microgravity conditions. Mark also reported that at this intensity, a greater effort was required to complete the stage compared to the same intensity under gravity conditions. Even though exercising heart rate remained similar during each of the first 3 stages, Fig. 1(b) also illustrates that the heart rate during each recovery interval did not return to the same recovery levels observed under gravity conditions, nor did heart rate return to resting values within 10 minutes of completing the test. It is also clear from Fig. 1(b) that the amount of time taken to perform the test was longer in space than on earth. This could be because Mark had to monitor the time of each interval himself, whereas on earth this was done by the investigator. As discussed above and illustrated in Fig. 1(a), resting heart rate 24 hours after landing was clearly elevated. Similarly, heart rate during the exercise test was consistently elevated above all other data sets in all 4 stages of the test, excluding stage 4 of the in-flight test by approximately 20 beats / min. Again, cardiovascular response returned to baseline, pre-flight values approximately 72 hours after landing.

Discussion

The cardiovascular system seems to adapt well to 10 days' exposure to microgravity, but is significantly compromised on re-establishment of gravitational forces, resulting in orthostatic intolerance. Microgravity has a direct effect on the cardiovascular system during exercise, which seems to be more evident during exercise at higher intensities. Many of the physiological consequences of weightlessness and the cardiovascular abnormalities on return from space could be due, at least in part, to alterations in the regulation of the autonomic nervous system. Previous studies investigating the effects of microgravity on the autonomic system have revealed conflicting results and have been unable to conclude whether autonomic control differs between earth and a microgravity environment.[3-5] Accordingly, it could be suggested that microgravity itself does not act as a stressor to the cardiovascular system, but it is rather the adaptive changes that occur in response to the in-flight environment that result in the adverse effects on the cardiovascular system discussed above.

Photos: **www.africaninspace.com**

1. Buckey JC jun, Gaffney FA, Lane LD, *et al.* Central venous pressure in space. *J Appl Physiol* 1996; **81:** 19-25.
2. West JB. Historical perspectives: Physiology in microgravity. *J Appl Physiol* 2000; **89:** 379-384.
3. Eckberg DL, Convertino VA, Fritsch JM, Doerr DF. Reproducibility of human carotid baroreceptor-cardiac reflex responses. *Am J Physiol* 263 (*Regulatory Integrative Comp Physiol 32*): 1992; R215-R220.
4. Fritsch-Yelle JM, Charles J, Jones MM, Wood ML. Microgravity decreases heart rate and arterial pressure in humans. *J Appl Physiol* 1996; **80:** 910-914.
5. Goldstein DS, Horwitz D, Keiser HR. Comparison of techniques for measuring baroreflex sensitivity in man. *Circulation* 1982; **66:** 432-439.