Next-Generation Anti-Gravity Suits

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Orthostatic intolerance after space flight is still an issue for astronaut health. No in-flight countermeasure has been 100% effective, to date. NASA currently uses an inflatable anti-gravity suit during reentry; however, this device can be uncomfortable when inflated, and loses effectiveness upon egress from the shuttle. The Russian Space Agency currently uses a mechanical counterpressure garment (Kentavr) that is difficult to adjust without the aid of a medical specialist, and prolonged use may result in painful swelling at points where the garment coverage is not continuous (i.e., feet, knees, and groin). To improve comfort, reduce upmass and stowage requirements, and control fabrication and maintenance costs, the Johnson Space Center research team has been evaluating a variety of gradient-compression, mechanical counterpressure garments, constructed from spandex and nylon, as a possible replacement for the current anti-gravity suit. Researchers examined comfort and cardiovascular responses to knee-high garments in normovolemic (normal volume of blood) subjects; thigh-high garments in hypovolemic (low volume of blood) subjects (a basic model for plasma volume losses in space) and in astronauts after space flight; and one-piece breast-high garments in hypovolemic subjects. These gradient compression garments provide 55 mmHg of compression over the ankle, decreasing linearly to approximately 35 mmHg at the knee. In thigh-high versions, the compression continues to decrease to approximately 20 mmHg at the top of the leg, and for breast-high versions, to approximately 15 mmHg over the abdomen. Measures of efficacy include increased tilt survival time, elevated blood pressure and stroke volume, and lower heart-rate response to orthostatic stress compared to control subjects without a countermeasure. Results from these studies suggest that the greater the magnitude of compression and the greater the area of coverage, the more effective the compression garment becomes. Researchers are currently testing a three-piece breast-high compression garment on astronauts after space shuttle missions. The team chose a three-piece garment consisting of thigh-high stockings and shorts because it is easy to don and comfortable to wear, and the garment should provide the same level of protection as the one-piece breast-high garments evaluated in hypovolemic test subjects.

Fig. 1. *Compression garments consist of thigh-high stockings with overlapping shorts that provide continuous, gradient compression from the feet to the bottom of the ribcage.*

Methods

Eight astronauts have enrolled in this study to determine the comfort and effectiveness of breast-high gradient-compression garments to prevent post-space flight orthostatic intolerance. These garments have a compression gradient similar to previous designs, with maximum (55 mmHg) compression at the ankles, decreasing to approximately 15 mmHg over the abdomen. To date, three astronauts completed all test sessions, which included testing 60 (L-60) and 30 (L-30) days preflight, followed by testing on landing day (R+0) and 1 day after landing (R+1). Sixty days before flight, subjects were measured for the custom-fit garments depicted in figure 1. Baseline orthostatic tolerance was assessed during a stand test without garments on L-30, and garment effectiveness was tested with a similar stand test after space flight on R+0 and R+1. Orthostatic tolerance was determined by upright responses of continuous heart rate, blood pressure, and stroke volume. Cardiac output, total peripheral resistance, and measures of autonomic function were calculated offline. These treatment subjects were compared to a control cohort who underwent an identical orthostatic challenge before and after space flight, although without stroke volume measurements.

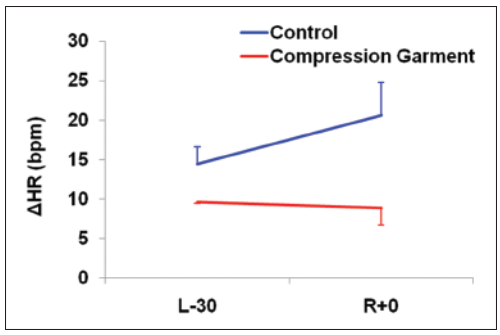

Fig. 2. *Control subjects (n=6) exhibit an elevated heart rate response to standing after space flight compared to compression garment subjects (n=3).*

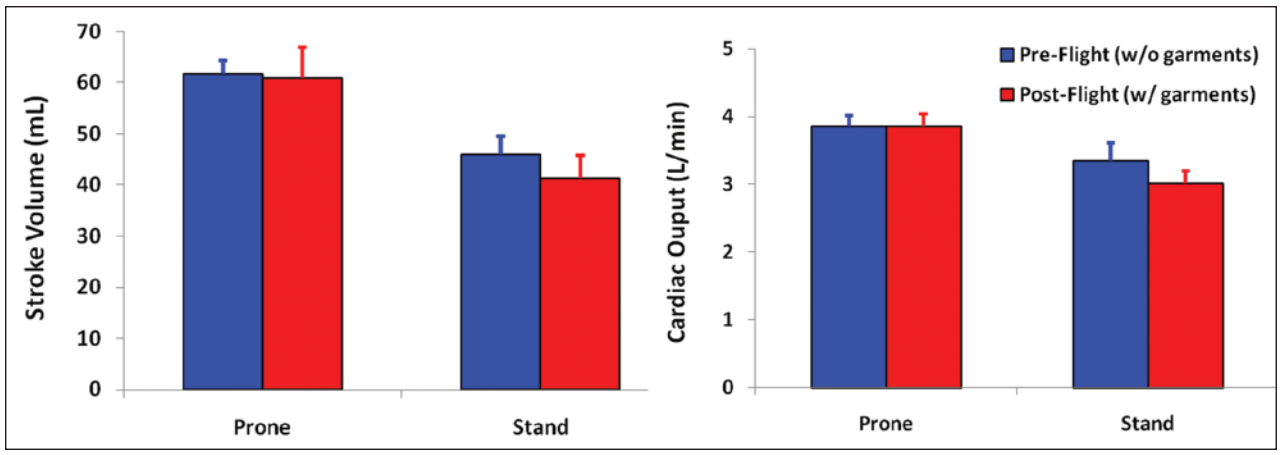

Fig. 3. *Prone and upright stroke volume (left) and cardiac output (right) before (blue) and after (red) a space shuttle mission (n=3).*

Results

Preliminary results (n=3 treatment, n=6 control) suggest that this new compression garment prevented the increase in heart rate that is commonly observed on R+0 in control subjects after space flight (figure 2).

Furthermore, in this small group of subjects, the expected decrease in post-flight stroke volume and cardiac output appears to have been prevented (figure 3).

Summary

This study is in progress, and final results are not yet available from which to make specific recommendations. However, preliminary data suggest that these garments are comfortable to wear and may be a viable replacement for the current anti-gravity suits used during reentry, landing, and immediately post-flight. If these garments are shown to be effective and comfortable in astronauts following these space shuttle missions, they may be appropriate for use by pilots and passengers participating in commercial space flight ventures and in astronauts following long-duration space flight.