

Gradient Compression Garments as a Countermeasure to Post-Space Flight Orthostatic Intolerance: Potential Interactions with the Maximum Absorbency Garment

S. M. C. Lee¹, S. S. Laurie¹, B. R. Macias¹, M. Willig², K. Johnson³, M. B. Stenger³
¹KBRwyle Science, Technology, and Engineering Group, Houston, TX; ²GeoControl Systems, Inc., Houston, TX;
³NASA Johnson Space Center, Houston, TX

BACKGROUND

- Astronauts and cosmonauts may experience symptoms of orthostatic intolerance during re-entry, landing, and for several days following landing from short- and long-duration spaceflight.
- Presyncopal symptoms have been documented in ~20% of short-duration and greater than 60% of long-duration flyers on landing day specifically during 5-10 min of stand tests or 80° head-up tilt tests (Meck et al. 2001; Lee et al. 2015). No countermeasures employed during these tests.
- Current operational countermeasures to orthostatic intolerance include fluid loading prior to and whole body cooling during re-entry as well as compression garments that are worn during and for up to several days after landing.
- Both NASA and the Russian space program have utilized compression garments to protect astronauts and cosmonauts traveling on their respective vehicles. A previous report from our laboratory demonstrated the efficacy of these garments in hypovolemic subjects (Platts et al. 2009; Figure 1).

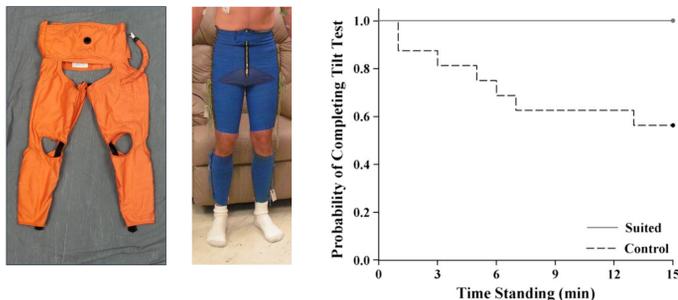


Figure 1. The NASA Anti-Gravity Suit (left) and the Russian Kentavr (center) are two lower body compression garments designed to protect against post-space flight orthostatic intolerance during and after re-entry and landing. The rate of presyncope during a 15-min 80° head-up tilt test was significantly greater in hypovolemic subjects not wearing one of these two compression garments (right panel). All subjects wearing compression garments completed the tilt test without signs or symptoms of orthostatic intolerance (Platts, 2009).

- A “next-generation” gradient compression garment (GCG) has been developed and tested in collaboration with a commercial partner to support future space flight missions.
- Unlike previous compression garments used operationally by NASA that provided a single level of compression across only the calves, thighs, and lower abdomen, the GCG provides continuous coverage from the feet to below the pectoral muscles in a gradient fashion (from ~55 mm Hg at the feet to ~16 mmHg across the abdomen; Figure 2).

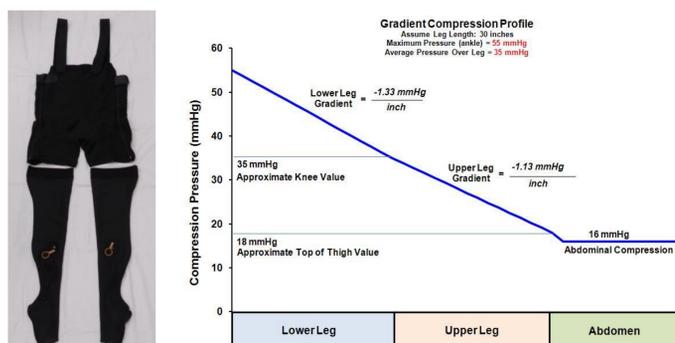


Figure 2. The custom-designed, three-piece GCG is constructed for each individual based upon circumferential measurements of the foot, legs, and torso. Compression provided by the GCG is directly related to the tension in the circumferential fibers; this tension is based on the length of the fibers and was verified by a HATRA lateral stretch measurement instrument that is identified in the British Standard for testing compression in elastic stockings (Stenger et al. 2014).

- The efficacy of the GCG (Figure 3) has been demonstrated previously after a 14-d bed rest study without other countermeasures (Stenger et al. 2014) and after short-duration Space Shuttle missions (Stenger et al. 2013).

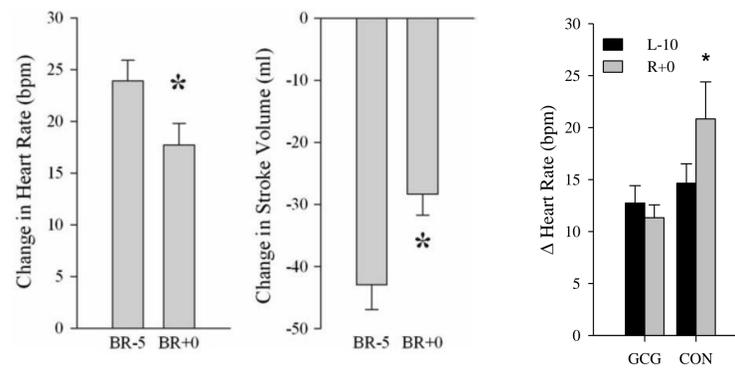


Figure 3. Fifteen subjects participated in 15-min 80° head-up tilt tests before (BR-5) and immediately after (BR+0) 14 days of bed rest (Stenger et al. 2014). Subjects wore the GCG during testing on BR+0 but not on BR-5. The rise in heart rate (left panel) and drop in stroke volume (center panel) from supine to head-up tilt were smaller on BR+0 than on BR-5 (*significantly less than BR-5). Similarly, in Space Shuttle astronauts (right panel) who did not wear the GCG (control subjects, CON) the increase in heart rate from prone to standing was significantly greater on landing day (R+0) than before space flight (L-10) during a 3.5-min stand test. The normal post-flight rise in heart rate was prevented by wearing the GCG on R+0 (Stenger et al. 2013). (*significantly greater than pre-flight and than GCG group on R+0)

- Currently the GCG is being tested during a stand test following long-duration missions (~6 months) to the International Space Station (Figure 4).

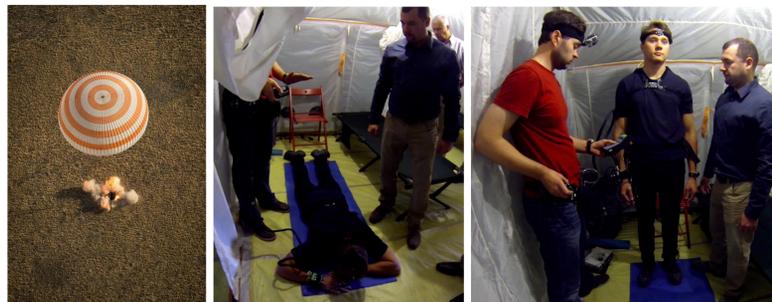


Figure 4. As part of the joint NASA-Institute of Biomedical Problems Field Test, soon after landing (left panel) astronauts doff the Kentavr in the tent at the landing zone and don the GCG. Depending on conditions in Kazakhstan, testing is completed either in the medical tent at the Soyuz landing site (~1 hr post-landing) or at the airport (~4 hrs post-landing) in transit to Johnson Space Center. The recovery-from-fall stand test starts with astronaut in the prone position for 2 min, after which they stand for 3.5 min while continuous ECG (Holter) and finger blood pressure (Finapres) are recorded.

- While results to date have been promising, interactions of the GCG with other space suit components have not been examined. Specifically, it is unknown whether wearing the GCG over NASA's Maximum Absorbency Garment (MAG; absorbent briefs worn for the collection of urine and feces while suited during re-entry and landing) will interfere with the effectiveness of the GCG or conversely whether the GCG will reduce the fluid absorption capabilities of the MAG.

REFERENCES

- Lee SMC, Feiveson AH, Stein S, Stenger MB, Platts SH. Orthostatic intolerance after ISS and Space Shuttle missions. *Aerosp Med Hum Perform* 86: A54-67, 2015.
- Meck JV, Reyes CJ, Perez SA, Goldberger AL, Ziegler MG. Marked exacerbation of orthostatic intolerance after long- vs. short-duration spaceflight in veteran astronauts. *Psychosom Med* 63: 865-873, 2001.
- Platts SH, Tuxhorn JA, Ribeiro LC, Stenger MB, Lee SMC, Meck JV. Compression garments as countermeasures to orthostatic intolerance. *Aviat Space Environ Med* 80: 437-442, 2009.
- Stenger MB, Lee SMC, Ribeiro LC, Phillips TR, Ploutz-Snyder RJ, Willig MC, Westby CM, Platts SH. Gradient compression garments protect against orthostatic intolerance during recovery from bed rest. *Eur J Appl Physiol* 114: 597-608, 2014.
- Stenger MB, Lee SMC, Westby CM, Ribeiro LC, Phillips TR, Martin DS, Platts SH. Abdomen-high elastic gradient compression garments during post-spaceflight stand tests. *Aviat Space Environ Med* 84: 459-466, 2013.

SPECIFIC AIMS

This operational, directed study will:

- Determine whether the effectiveness of the GCG is affected by the MAG with regard to cardiovascular responses to head-up tilt, the standard orthostatic intolerance test employed for astronauts and bed rest subjects;
- Determine whether the effectiveness of the MAG is compromised by the GCG tested by injecting a standard fluid volume (950 ml in 3 separate simulated “urine voids”) at a standardized rate (30 ml/sec); and
- Determine whether comfort is affected by wearing the MAG under the GCG using a standardized questionnaire.

METHODS

- Ten subjects will be recruited to participate. Subjects will be selected to span the range 5th to 95th percentile in body size so as to represent the range of astronauts who might participate in space flight.
- A trained technician will measure the circumference of each subject's legs every 1.5 in from the feet to the top of the thigh (Figure 5). Additional measurements will be taken along the torso ending just below the breast-line. From these, custom garments will be constructed.



Figure 5. Circumferential measurements of the leg used in the construction of the custom-fitted GCG (left). Example of MAG (right) worn by astronauts under the space suit for collection of urine and feces.

- Subjects will participate in two separate 80° 15-min head-up tilt tests, one with and one without the MAG worn under the GCG. Testing will be conducted on the same day, with at least 15 min of rest between tilts, in random order.
- Heart rate, blood pressure, and stroke volume will be measured. Tolerance to head-up tilt (time) will be assessed using survival analysis. Subjects also will report their level of comfort using the scale used in our previous investigations.
- Separately, subjects will wear the MAG with and without the GCG. A known volume of normal saline (300 ml, representing a single void) will be injected into the MAG at a controlled rate. Subjective ratings of wetness and location will be recorded after 10 minutes.
- Results from this study will guide future development and operational use of the GCG and MAG to maximize crew health, safety, and comfort.